Anim Cogn
DOI 10.1007/s10071-011-0446-x

ORIGINAL PAPER

Comprehension and utilisation of pointing gestures and gazing in dog–human communication in relatively complex situations

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Received: 6 May 2011 / Revised: 15 August 2011 / Accepted: 28 August 2011

Abstract The aim of the present investigation was to study the visual communication between humans and dogs in relatively complex situations. In the present research, we have modelled more lifelike situations in contrast to previous studies which often relied on using only two potential hiding locations and direct association between the communicative signal and the signalled object. In Study 1, we have provided the dogs with four potential hiding locations, two on each side of the experimenter to see whether dogs are able to choose the correct location based on the pointing gesture. In Study 2, dogs had to rely on a sequence of pointing gestures displayed by two different experimenters. We have investigated whether dogs are able to recognise an 'indirect signal', that is, a pointing toward a pointer. In Study 3, we have examined whether dogs can understand indirect information about a hidden object and direct the owner to the particular location. Study 1 has revealed that dogs are unlikely to rely on extrapolating precise linear vectors along the pointing arm when relying on human pointing gestures. Instead, they rely on a simple rule of following the side of the human gesturing. If there were more targets on the same side of the human, they showed a preference for the targets closer to the human. Study 2 has shown that dogs are able to rely on indirect pointing gestures but the individual performances suggest that this skill may be restricted to a certain level of complexity. In Study 3, we have found that dogs are able to localise the hidden object by utilising indirect human signals, and they are able to convey this information to their owner.

Keywords Dogs · Communication · Human gestures · Indirect pointing

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Introduction

Visual communication between dogs and humans is a complex and interwoven process. During their everyday activities, humans communicate with dogs by the means of a wide range of different gestural signals, and similarly, dogs display visual signals in order to impact human activities.

Dogs have been reported to be very skilful in comprehending a variety of human pointing gestures in many independent studies (e.g. Hare and Tomasello 1999; McKinley and Sambrook 2000; Miklósi et al. 1998; Soproni et al. 2001). However, the numerous investigations on dog–human visual communication have always relied on relatively simple experimental paradigms of dog–human interaction. One popular procedure is the so-called two-way object-choice task, in which the subject has to find hidden food at one of two locations by utilising the experimenter's gestural signals (for a review see Miklósi and Soproni 2006). Importantly, this test situation reduces the complexity of 'real-life' scenarios because the subject is usually faced with a relatively simple form of pointing gesture, and there are only two hiding locations to choose from, even though in a real situation there are many different possible target locations when the owner uses pointing gestures to signal something to the dog.

Although dogs perform well under these simpler conditions, the cognitive aspects of these skills remain elusive

Published online: 17 September 2011

(see Wynne et al. 2008; Udell et al. 2008; Gácsi et al. 2009a, Hare et al. 2009). Here, we report 3 studies performed with independent subjects, which provide a more complex insight into the cognitive nature of human–dog communicative interactions in more lifelike situations.

The communicative and the referential nature are particular features of the human pointing gesture. This prompted some researchers to argue that the receivers need to have some understanding of referentiality for being able to decode the signal. However, in the simplified versions of these test, dogs (and subjects from other species) do not necessarily rely on referential cognitive mechanisms for being able to succeed. Simple pointing gestures can be processed as beacons because the body of the pointing experimenter splits conspicuously the space of interest into two halves (the left and right side) each of which contains only one object. Thus, dogs may simply go for the side of the human at which they saw a protruding body part and/or movement (Soproni et al. 2002). This assumption was strengthened by the findings of a recent study that showed dogs perform poorly with gestures in which, from the observer's point of view, the pointing arm and hand stay within the silhouette of the pointer's upper body (Lakatos et al. 2009). This suggests that in the case of dogs, the protrusion of a body part from the pointer's body torso is the key feature of the pointing gesture (Lakatos et al. 2009). In another study, we have found that by making the gesture visually more conspicuous, dogs' performance increased even in cases where the gesture did not stick out from the body torso. Thus, in a two-way object-choice situation when processing the human pointing signal, dogs rely on a clearly distinguishable visible patch, which appears conspicuously and asymmetrically at one side of the body (Lakatos et al. 2007).

However, these findings do not exclude that dogs utilise other mental mechanisms in processing the pointing gesture if the situation is more complex. For example, referential processing of the pointing gesture in infants is often attributed to the notion whether the observer is able to track visually the direction of the pointing finger in space (e.g. Desrochers et al. 1995). Morissette et al. (1995) reported that 12-month-old infants showed an invariable preference for the target that was closer to the pointer if there were two objects on the same side. However, by the age of 18 months, they developed the ability to distinguish between targets on the same side of the pointer on the basis of the pointing gesture.

In Study 1, we utilise a similar design to that of Morissette et al. (1995). The implication of using two targets on the same side is that the hand of the pointing human is always closer to the target which is nearer to his body. Thus, in order to be successful, subjects need to utilise different mechanisms than following the simple rule of the 'protruding body part' for decoding the location of the referent in space.

In most experiments, the signal of the sender refers directly to a target in space, which means another limitation to the earlier studies as referential signals could also refer to other signals which may also have a referential function. For example, as a response to the question 'Which way should I go to Budapest?' the addressee may not point in the direction of the town but points to a road sign nearby which indicates the correct direction by an arrow. Analogue examples could be taken from interactions of gun dogs when during the hunt one dog points (orients his body) to the other dog that points to the direction of the game. Such type of pointing could be referred to as being indirect with regard to the intended final referent. The receiver should be able to find the primary target and decode their looking direction (secondary signal). In the Study 2, we investigate whether dogs are able to utilise such indirect forms of pointing gestures.

Dogs have been found to be skilful in directing humans to places of their interest. Miklósi et al. (2000) reported that if dogs witnessed the hiding of food at some inaccessible locations, later they showed increased looking at the owner and gaze alternation between the hiding location and the owner in comparison with conditions when no food was hidden. The authors argued that this increase in communicative behaviour may be interpreted as some form of intention to 'show' the target of their interest (Zimmermann et al. 2009). However, others opposed that looking at the target is a direct consequence of witnessing the hiding action, that is, the mental representation of the hidden food evokes directly a goal directed behaviour, which is manifested in gazing toward the target. Thus, dogs' behaviour simply reflects its inner motivation to get the food and it has no communicative features.

In order to investigate the viability of this simple alternative explanation, we designed a novel version of this experiment, in which dogs are prevented from witnessing the hiding event. In Study 3, dogs are only exposed to the communicative signals of the hider after the hiding had taken place. According to our assumption, if dogs understand that the hider's communicative signals are about the location of the target, they may display intentional communicative behaviours, which direct the naive helper to the hidden object. This experimental set up can reveal whether direct visual information about the hidden food is necessary for the dog to express such communicative behaviour toward a human helper.

Study 1

The aim of this study was to investigate whether dogs are able to encode a more specific referential aspect of the

pointing gesture. To examine this question, we provided the dogs with two potential hiding locations on each side of the experimenter and tested whether dogs are able to choose the correct hiding location based on the pointing gesture.

Methods

Subjects

Sixteen dogs (11 males, 5 females; 10 mixed-breeds, 2 Belgian shepherds, 1 Cairn terrier, 1 Border collie, 1 Parson Russel terrier and 1 Cocker spaniel) participated in this study from the 26 dogs recruited for this experiment. Six owners could not bring the dogs back for the second session, while 4 dogs did not reach the participation criteria. The age of the dogs was 4.5 + 3.2 years (mean + SD) (range 1–12 years). All subjects were kept for companionship.

First session—participation criteria

In the first session, we used the same method as described in earlier studies (e.g. Lakatos et al. 2007, 2009; Soproni et al. 2001, 2002) to select the suitable subjects for the study.

The experimenter placed two bowls (blue plastic flower pots: 13 cm in diameter, 13 cm in height) 1.3–1.6 m apart, in front of her on the floor. During the pre-training, she put a piece of food (a small piece of frankfurter) into one of the bowls in the presence of the subject. The subjects could witness this hiding from a distance of 2–2.5 m with their owner standing behind them. After the experimenter put the food into the bowl, the owner allowed the dog to take the reward out from the bowl. The procedure was repeated twice for each bowl to ensure that the subject knew that either bowl might contain some food.

During the tests, the position of the participants was the same as above, but this time the subject was prevented from observing the hiding. The experimenter picked up the bowls, she put a piece of food into one of the bowls and after that she placed both bowls back on the floor at the same time. During the pointing, the experimenter was standing 0.5 m back from the middle line between the two bowls, facing the subject at a distance of 2–2.5 m. The owner was holding back the subject gently until the experimenter gave the cue. The experimenter drew the subject's attention to herself (any sounds, like clapping or/and the subject's name could be used) and presented the visual cue when the subject looked at her face. During the pointing, the experimenter was looking at the subject. If the subject did not move at the first cue, the experimenter repeated the pointing gesture maximum three times. The subject was allowed to choose only one bowl. If the dog chose the incorrect one, then the experimenter picked up the baited bowl from the floor when the subject approached the unbaited one.

In this experiment, we utilised the momentary distal pointing gesture: the experimenter pointed with extended arm and index finger in the direction of the correct location by her closer hand. After signalling (it lasted about 1 s), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls.

The test session consisted of 20 trials. Trials were scored in real time by the experimenter. The trials were presented in a predetermined semi-random order (10 trials for both sides, the same pot was not baited more than twice in a row).

Only dogs that reached a minimum of 75% performance (so that their performance was above the chance in the individual level according to the binomial test: $P = 0.04$) were invited to participate in the second session. This criterion was introduced to ensure that the eventual poor performance of dogs in the 4 bowls session is not a consequence of some general inability to utilise momentary pointing gestures.

Second session

Procedure The experimenter placed 4 bowls (same bowls as above) in front of her on the floor, in a way that the distance between each bowl and the dog was the same (approximately 2–2.3 m), and the distance between each adjacent bowl was 1.3–1.6 m, while between the two external bowls was about 3.5 m. The owner and the dog stood in the midline (between the two internal bowls) facing the experimenter, who stood behind the two internal bowls, from a distance of 2.5–3 m. The dog stood at equal distance from all four bowls (Fig. 1).

Pretraining The experimenter drew the subject's attention to herself and put a piece of food into one of the bowls in the presence of the subject. The experimenter ensured that the subjects witnessed this hiding. After the experimenter put the food into the bowl, the owner allowed the dog to take the reward from the bowl. The procedure was repeated with each of the four bowls once to ensure that the subject knew that the bowls might contain some food.

Testing Test trials: The position of the participants was the same as above, but during the testing, the subject was prevented from observing the hiding. The experimenter picked up all bowls, put a piece of food into one of them, and placed all bowls back on the ground always in the same order, starting with the external bowl on the right-hand side of the experimenter. After the hiding, the experimenter pointed at one of the bowls while gazing at the

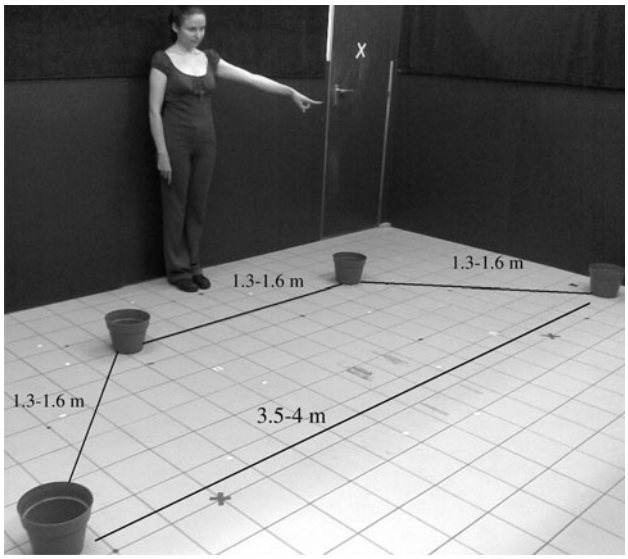

Fig. 1 The presentation of the pointing gesture in Experiment 1. The four bowls were placed in front of the experimenter on the floor, in a way that the distance between each bowl and the dog was the same (approximately 2–2.3 m), and the distance between the two external bowls was about 3.5 m. The experimenter lowered her arm before the dog was released

dog. During the pointing, the experimenter stood 0.5 m back from the middle line between the two internal bowls, facing the subject at a distance of 2.5–3 m. The pointing gesture was carried out with extended arm and index finger in the direction of the given location by her ipsilateral hand in a momentary manner (Miklósi and Soproni 2006). The owner was holding back the subject gently until the experimenter gave the cue. During the pointing, the experimenter was looking at the subject. The dog was released by the owner when the experimenter lowered her arm after presenting the cue. The subject was allowed to choose only one bowl.

Control trials: The procedure was the same as in the testing trials but the experimenter did not point. After the experimenter placed the bowls and stepped back to the midline facing the dog, she kept her arms beside her body and the dog could make its choice without having a signal.

We performed 8 test trials and 8 control trials in a session. The 8 test trials were followed by the 8 control trials. We presented the cues in a predetermined semi-random order, every bowl was equally often used for hiding the reward, and neither the same side nor the same bowl was used more than twice in a row.

Dogs had approximately 30 s to respond to the pointing signal in each trial (also in the control trials). If the dog did not make a choice, the gesture was repeated maximum three times. Trials were presented without any break between them. Minimum 1 day and maximum 2 weeks elapsed between the two sessions.

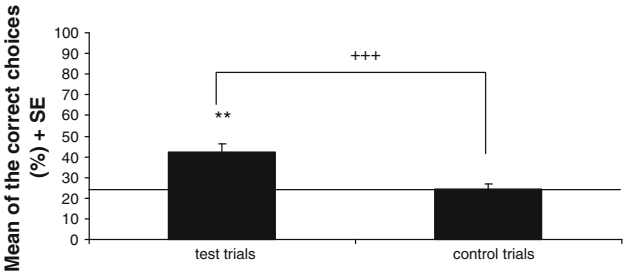

Fig. 2 Dogs' overall performance in the four-way object-choice task in the test trials and in the control trials. *Asterisks* indicate that the group performance was different from chance (25%) (one-sample Wilcoxon signed rank). *Positive signs* indicate that the performance in the test trials was significantly higher than in the control trials (Wilcoxon matched pairs test)

Statistical analysis

The statistical analysis was based on the per cent of correct choices and non-parametric procedures. Wilcoxon matched pairs test was used to compare dogs' performance in the test and in the control trials, one-sample Wilcoxon signed-rank test was used to compare their performance to chance level, and Friedman test was used to test whether there was a preferred bowl by the dogs. Individual performance was analysed by binomial test (5 out of 8 was considered as better than chance in the case of four-way choices, $P < 0.05$).

Results

The comparison between dogs' performance in test and control trials revealed that at the group level, dogs performed significantly better in the case of the test trials than in the control trials (Wilcoxon matched pairs test (T+) = 105.0 $P < 0.0001$) (Fig. 2). However, only two dogs performed above chance level individually (choosing correctly 5 times out of the 8 trials, $P < 0.05$), while the other dogs performed close to the chance level (choosing 2–4 times correctly out of the 8 trials, $P > 0.05$). We compared the dogs' performance also to the expected chance level by one-sample Wilcoxon signed-rank test. We found that dogs performed significantly above the chance level in the case of the test trials also in the four-way object-choice task, while their performance was at chance level in the case of the control trials (test trials: (T+) = 66.0 $P < 0.01$; control trials: (T−) = 12.0 $P = 0.84$) (Fig. 2).

Furthermore, investigating whether the dogs chose the correct side (left vs. right) independently from their success to find the bait, we found that dogs chose the correct side significantly above chance level (50%) (one-sample Wilcoxon signed-rank test (T+) = 91.0 $P < 0.001$). However, in those trials when the dogs took the correct left or right direction, they did not prefer the indicated container (50%

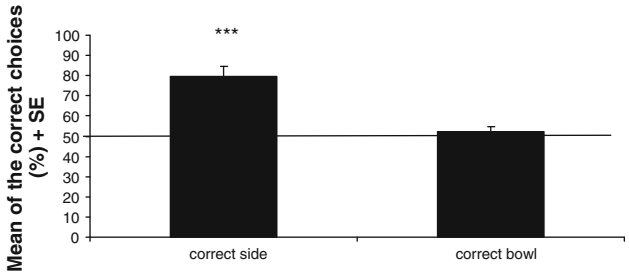

Fig. 3 Dogs' preference for choosing the correct side (left vs. right) versus the correct container. *Asterisks* indicate that the group performance was better than chance level (50%) only in choosing the correct side (one-sample Wilcoxon signed rank)

chance level: choosing correct bowl: (T+) = 33.5 $P = 0.55$) (Fig. 3).

We also analysed the percentages of the dogs' choices for each bowl. In the case of the control trials, no significant differences were found using Friedman test (Fr = 7.21 $P = 0.06$). In the case of the test trials, however, Friedman test showed significant difference (Fr = 12.38 $P = 0.006$), although the Dunn post-test did not identify any significant pair-wise differences. However, there was a tendency for choosing the internal bowls (closer to the experimenter), thus we pulled together the dogs' choices to the two inner bowls and to the two external bowls and compared them by Mann–Whitney U test. We found that dogs chose significantly more often the bowls closer to the experimenter in both the test trials and the control trials (test trials: $U = 207.0$ $P < 0.0001$; control trials: $U = 354.0$ $P = 0.03$).

Study 2

In the second study, we changed the referent of the pointing gesture during a two-step information transfer in order to see whether dogs can also make this mental transition. Here, the owner pointed first toward one of two experimenters, while the two experimenters pointed to one of two containers (see Fig. 4). We tested whether dogs are able to choose the person indicated by the pointing owner and then go for the correct container, which this person is pointing at.

Methods

Subjects

Twenty-three dogs participated in this experiment (none of them participated in Study 1 or 3). Fourteen males and eleven females; the dogs were 3.2 + 1.8 (mean + SD) years old (the range was 1–9 years). Twelve individuals were

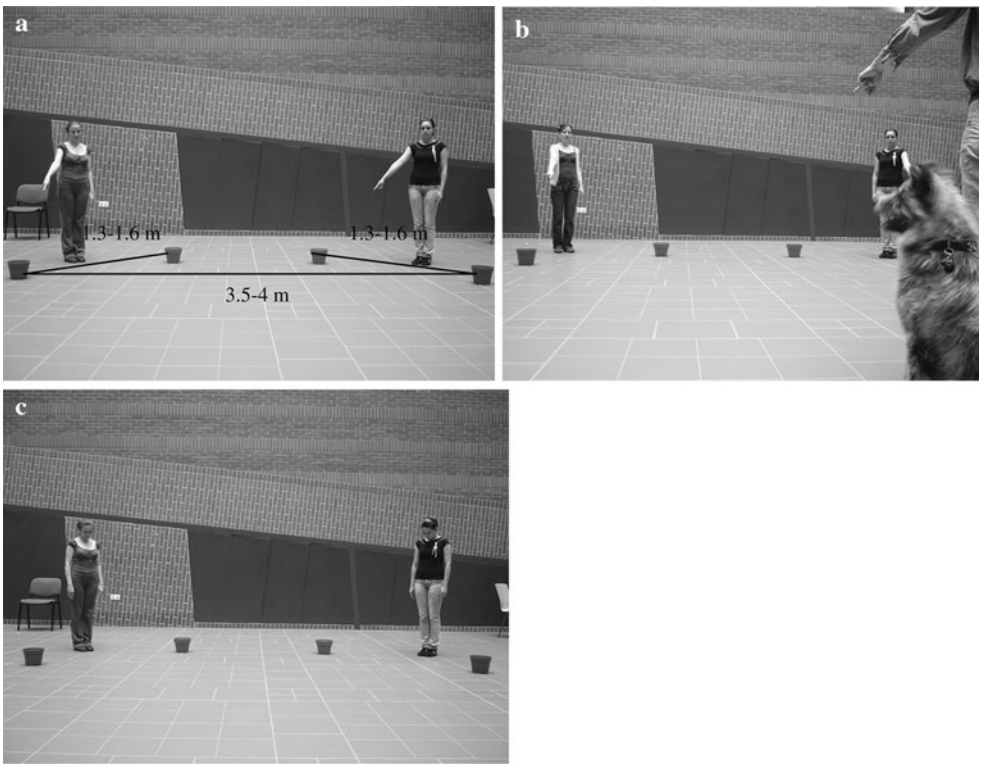

Fig. 4 Critical moments in Experiment 2. **a** The two experimenters point to one of the bowls at the same time in a test trial. The photo presents the dog's point of view. **b** The owner is pointing during a test trial toward one of the pointing experimenter. The picture is taken from an outer perspective. **c** Control trials from the dog's point of view

naïve, and 11 individuals have participated in other experiments previously in which they had been exposed to some other kind of pointing gestures (Miklósi et al. 2005; Lakatos et al. 2007). We tested 12 mixed-breeds, 6 Belgian shepherds (4 Tervuerens and 2 Groenendaels), 2 Mudis, 1 Shetland sheepdog, 1 Cairn terrier, and 1 Vizsla. All dogs were kept for companionship.

Trials were both video recorded and scored in real time by the experimenter. The video recordings of 7 dogs got damaged and could not be analysed. Thus, for these dogs, only the data of choice behaviour are included in the statistical analysis.

Procedure

Two experimenters, the owner, and the dog were present. Both experimenters placed 2–2 bowls (brown plastic flower pots: 13 cm in diameter, 13 cm in height) 1.3–1.6 m apart in front of themselves on the floor, while they stood 2.5–3 m apart from each other, facing half way each other (Fig. 4). The distance between the two bowls, which were placed between the two experimenters, was also 1.3–1.6 m, and the two external bowls were 3.5–4 m from each other. The owner and the dog stood in the midline (between the two internal bowls) facing the experimenters from a distance of 2.5–3 m. The dog stood at equal distance from all four bowls.

Pretraining

One of the two experimenters drew the subject's attention to herself and put a piece of food (a small piece of frankfurter) into one of the bowls in the presence of the subject. After the experimenter put the food into the bowl, the owner allowed the dog to take the food from the bowl. This procedure was repeated with both bowls then the other experimenter performed the same procedure with the other two bowls. The aim of the pretraining was to ensure that the subject knew that the bowls might contain some food.

Testing

Test trials The position of the participants was the same as above. The experimenters stood 0.5 m back from the midline between their two bowls, facing the subject. The owner stood behind the subject, holding back the dog gently. During the testing, the subject was prevented from observing the hiding by the experimenters turning their back to the dog while hiding the bait. The actions of the two experimenters were done in concert. They picked up the bowls, manipulated them, during which one of the experimenters hid the bait in the correct bowl, and finally, they placed both bowls to the ground simultaneously. After the hiding, both experimenters displayed a sustained pointing gesture and gazed into one of their bowls. Only one of them pointed to the actually baited bowl, the other experimenter pointed at an incorrect bowl. A semi-random order determined the pointed side for both experimenters. (The same side was never used more than twice in a row.) The pointing gesture was carried out with extended arm and index finger in the direction of the hidden food by the ipsilateral arm, and the arm was lowered only after the dog chose a bowl. After both experimenters had started to display the pointing gesture and looked into the bowl they were pointing at, the owner drew the subject's attention to herself (any sounds, like clapping or/and the subject's name could be used). She waited until the subject looked at her face, and then, she pointed at one of the experimenters, indicating the person who was displaying a pointing gesture toward the baited bowl. The owner pointed with her closer hand and she kept the dog on the same side, that is, if the owner had to point to her left side, she pointed with her left hand and the dog also started from her left side (Fig. 4a, b). During the pointing, the owner held the dog's collar with her other hand. The subject was allowed to choose only one bowl.

Control trials These trials were the same as the testing trials but the experimenters did not point. They kept their arms beside their body and looked at the ground (Fig. 4c). The owner pointed at the experimenter who hid the reward in that trial. This way the owner always indicated the correct side.

We performed 16 trials with each dog. Eight testing trials and 8 control trials were presented in alternation, that is, each testing trial was followed by one control trial. A semi-random order (balanced for the left–right side and experimenters) determined the location of the reward. Neither the same side (the same experimenter) nor the same bowl was used more than twice in a row. Trials were presented without any break between them.

Statistical analysis

The statistical analysis was based on calculating the per cent of correct choices, and non-parametric procedures (Wilcoxon matched pairs test, one-sample Wilcoxon signed-rank test) were used. Individual performance was analysed by binomial test (5 out of 8 was considered as better than chance in the case of four-way choices, $P < 0.05$).

Results

First, we analysed whether there was any difference between the subjects with and without experience in pointing experiments. The comparison of the two groups showed no difference in either of the trials (Mann–Whitney *U* test:

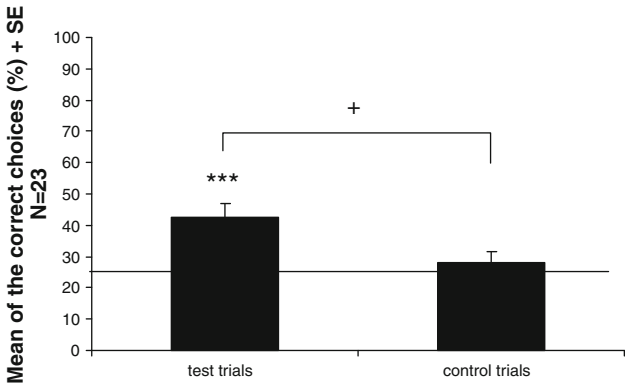

Fig. 5 Dogs' performance in the case of sequential pointing gestures (Experiment 2) in the test and control trials. *Asterisks* indicate significant difference ($P < 0.001$) from the expected chance level (25%). The positive sign indicates that the performance in the test trials was significantly higher than in the control trials

test trials: $U = 48.0$, $P = 0.28$; control trials: $U = 42.0$, $P = 0.15$).

At the group level, dogs performed significantly better in the case of the test trials than in the control trials (Wilcoxon matched pairs test: (T+) = 127.0; $P < 0.05$; $N = 23$) (Fig. 5). At the individual level, only 5 dogs out of 23 performed above chance level (chose correctly at least 5 trials out of 8); the remaining 16 dogs performed 3 test trials correctly (which is close to the average performance of the group).

We compared the dogs' performance also to the expected chance level (25%) in the case of both types of trials by one-sample Wilcoxon signed-rank tests. We found that while the dogs performed significantly above chance level in the case of the test trials, their performance was at chance level in the control trials (test trials: (T+) = 190.0; $P < 0.001$; control trials: (T+) = 86.0; $P = 0.37$) (Fig. 5).

Next, we analysed the 16 dogs' performance (for which we had the video records) in two steps. First, we compared the dogs' performance to the 50% chance level taking into account only whether they followed the direction of the owners' pointing (left or right). We found that the dogs chose the side of the indicated experimenter significantly above chance level in the test trials (one-sample Wilcoxon signed-rank test: (T+) = 88.5; $P < 0.05$), while in the control trials, their performance was at chance level ((T+) = 83.0; $P = 0.46$). Second, in the case of the test trials, we compared the 16 dogs' performance to the 50% chance level examining whether they chose the correct bowl pointed by the indicated experimenter. We found that in this case, their performance was at chance level (one-sample Wilcoxon signed-rank test: (T+) = 76.5; $P = 0.13$).

Comparing the dogs' incorrect choices for each bowl, we found no preference (Friedman test Fr = 0.97; $P = 0.81$).

Study 3

In the third study, we aimed to test whether dogs are able to understand visual information about the location of a hidden object, when they cannot observe the hiding directly but the location of the hidden object is indicated by different human gestural signals and whether they are able to pass this information to the unknowledgeable owner. Using different kind of gestures for signalling, we varied also the difficulty of the task.

Methods

Subjects

Twelve dogs (4 males, 8 females; 6 mixed-breeds, 1 Yorkshire terrier, 1 Siberian laika, 1 German shepherd. 1 Border collie, 1 Beagle, 1 Spitz) aged 4.5 + 1.6 years (mean + SD) (range: 1.5–10 years) participated in this experiment. All individuals were naïve and they were kept for companionship.

Pretraining The training and testing took place in the owner's flat, always in the biggest room (it was usually the living room). We placed three commercial plastic butter pots (9.5 cm in diameter, 5.5 cm in height) in the room at least 1.5 m apart horizontally on shelves, which were out of reach for the dogs at around a height of 1.5 m. During the pretraining, the owners gave a piece of food from all experimental pots six times in two successive days (three times on both days in different periods of the day, once in the morning, once in the afternoon and once in the evening). This procedure ensured that the subject knew that the pots might contain food.

Testing The testing started the day after the 2 days of pretraining. Testing comprised 2 control sessions on 2 different days (3 trials per session) followed by a test session (4 trials) in which signalling was varied.

Control sessions In the absence of the owner, the experimenter showed a piece of food to the dog and took one of the butter pots from the shelf. Next, by a highly conspicuous, visible movement, she placed a small paper ball into the butter pot she took from the shelf pretending that she hid the piece of food (which was put in her pocket).

The experimenter left the room and the owner entered, while the dog was waiting inside. The owner had 1 min to find out which pot contained the paper ball by observing the dog's behaviour. After 1 min, the experimenter knocked on the door and the owner was allowed to check one of the butter pots. If the owner's choice was correct, then she was allowed to give a piece of food to the dog (pretending that

she found it in the pot). If the owner did not find the paper ball in the pot, the experimenter entered the room and placed the food in the correct container in a deceptive attempt to show the dog where the food was.

The same procedure was repeated three times in succession in one session by including all three butter pots one time for hiding. There was approximately a 1 min pause between the trials, during which the dog was staying in the experimental room and the experimenter got another piece of food for the next trial. Two sessions were carried out on two different days. Minimum 1 day and maximum 1 week elapsed between the two sessions.

Test session

In the final (third) session, we staged four different test trials in which we varied the way of signalling. The test trials started when the experimenter showed a piece of food to the dog outside the experimental room. Then, she entered the room and hid the paper ball into one of the butter pots in the absence of the dog and of the owner. After the paper ball was hidden in one of the pots, the dog was allowed into the room and the experimenter signalled the hiding location to the dog by one of four different ways depending on the test type.

The following types of signals were utilised by the experimenter:

1. 'Pointing (with the owner returning)': The experimenter pointed to the correct pot from a distance of 10 cm while alternating her gaze three times between the pot and the dog and saying 'I hid it there'. We will refer to this type of trial as 'Pointing (Owner)'.
2. 'Touching': The experimenter touched the correct pot with her hand while alternating her gaze three times between the pot and the dog and saying 'I hid it there'.
3. 'Pointing (with the experimenter returning)': The experimenter pointed to the correct pot from a distance of 10 cm while alternating her gaze three times between the pot and the dog and saying 'I hid it there'. After this, she left the room, but this time it was her who came back instead of the owner. The owner stayed outside and waited for the 1 min, while the dog and the experimenter were in the room. This trial is different also in the sense that the returning experimenter is knowledgeable about the place of the paper ball. We will refer to this type of trial as 'Pointing (Experimenter)'.
4. 'Pointing with marker': After the experimenter hid the paper ball in the absence of the dog and the owner, both the dog and the owner were called into the room. Then the experimenter placed a marker (a 25-cm-high red plastic tube) next to the correct pot and then the owner went out of the room. In the absence of the owner, the experimenter pointed to the correct pot from a distance of 10 cm while alternating her gaze three times between the pot and the dog and saying 'I hid it there'. The marker was left next to the correct pot till the end of the trial. In this case, we have to note that the owner could guess the place of the paper ball not only on the basis of the dog's behaviour.

The four different test types were staged randomly for each subject. After the signalling, the experimenter left the room and the owner entered (except in the case of the third type of the trials). The owner had 1 min to find out which pot contained the paper ball based on the dog's behaviour. After 1 min, the experimenter knocked on the door and the owner checked the pot in which she/he thought the paper ball was hidden.

If the owner identified the location correctly and found the paper ball, then he/she was allowed to give a piece of food to the dog (as if she/he had found it in the pot). If the owner did not find the paper ball in the pot, then the experimenter entered the room and placed the food in the correct container in a deceptive attempt to show the dog where the food was.

Each session was recorded on video and was analysed later.

Observed behavioural variables

Dogs' behaviour was coded using a stopper and the following behaviours were analysed.

Looking at the baited bowl: Time(s) spent gazing at (head orientation) the baited pot containing the paper ball from any distance.

Looking at the empty bowl: Time(s) spent gazing at the empty pots from any distance. For the comparative statistical analysis, we randomly chose one of the two empty bowls.

Looking at the owner: Time(s) spent gazing at the owner.

Staying near the baited bowl: Time(s) spent sitting or standing passively next to the baited pot (within a distance of one body length).

Staying near the empty bowls: Time(s) spent sitting or standing next to the empty pots (within a distance of one body length). For the comparative statistical analysis, we randomly chose one of the two empty bowls.

Gaze alternations: The number of gazes at the owner or the experimenter followed directly by a gaze at the pot containing the food within 2 s or vice versa.

Apart from the principal coder (G.L.), a naïve observer coded the behaviour of three dogs in all test trials on the

basis of the list of behavioural units described above by looking at the videotapes. We measured the inter-rater reliability by making the two observers code the dogs' behaviour in certain frames, stopping the video in every 2 s. In this way, we got discrete judgements from both observers for each behaviour variables. The calculation of the Kappa coefficient yielded the following values: staying behaviour near the baited or unbaited bowls (percentage agreement was 100%, $\kappa = 1$); gazing behaviour either to the bowls or to the humans (percentage agreement was 99.6%, $\kappa = 0.98$).

Statistical analysis

The measured behavioural variables had normal distribution parametric procedures thus repeated measures ANOVA and paired *t* test were used. In the case of the control trials we used only the data of the last trial (the third trial of the second session) because by this time, the dogs were completely aware of the task and this was closest to the test trials in time. The previous trials had a function of making sure that the dogs remember the hiding places and are aware that the pots could contain food. Hereby, we analysed the dogs' behaviour in five different trials, the last control trial and the four test trials. For the within-trial analysis, the durations of the observed variables were used, while for comparing the dogs' behaviour across the different trials, the ratio of the time spent looking/staying at the baited and at the unbaited pots (in per cent) were used instead of the durations of both variables for decreasing the number of the statistical tests.

For analysing the success of the owners, Cochran's *Q* test and Binomial test were used.

Results

In the within-trial analysis, we compared the durations of time spent looking at the baited and the empty bowls in each trial, and we found that dogs spent significantly more time with looking at the baited bowl in all cases. The same is true for the time spent near the baited bowl in contrast to the empty bowls in the case of the Control, the Pointing (Owner), and in the Touching trials (Table 1; Fig. 6).

Table 1 Post hoc comparisons within the situations

Duration		Result of paired *t* test			Direction of the difference
		df	*t*	*P*	
Control	Looking	11	4.36	<0.001	Baited > empty bowl
	Staying	11	3.31	<0.01	Baited > empty bowl
Pointing (owner)	Looking	11	3.19	<0.01	Baited > empty bowl
	Staying	11	2.86	<0.05	Baited > empty bowl
Touching	Looking	11	2.77	<0.05	Baited > empty bowl
	Staying	11	2.24	<0.05	Baited > empty bowl
Pointing (experimenter)	Looking	11	3.96	<0.01	Baited > empty bowl
	Staying	11	1.83	0.09	
Marker	Looking	11	2.54	<0.05	Baited > empty bowl
	Staying	11	1.17	0.26	

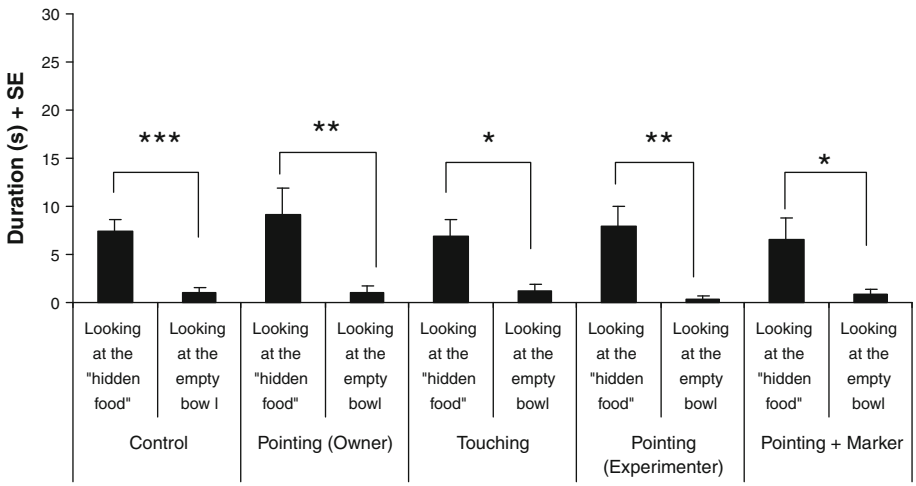

Fig. 6 Durations of looking at the baited pot and at the randomly chosen unbaited pot within the different trials. *Asterisks* indicate that dogs spent significantly more time with looking at the baited bowl in all cases (One-way ANOVA). The same is true for the time spent near the place of the baited bowl in the case of the Control, the Pointing (Owner) and the Touching trials

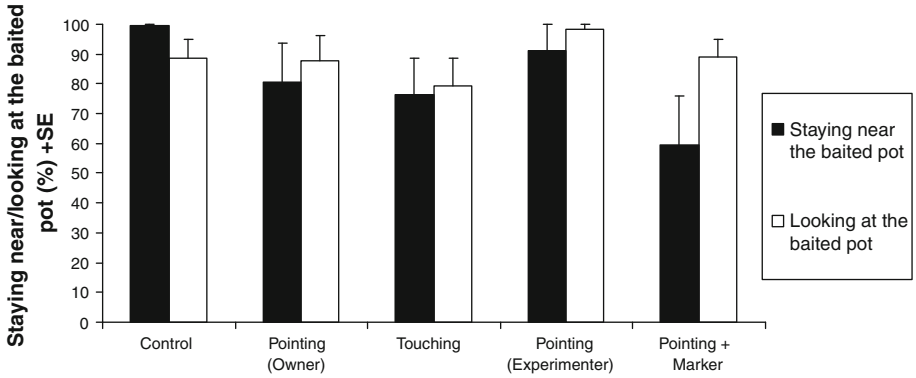

Fig. 7 Ratio of the time spent near the baited and at the unbaited pots (in percent), and ratio of the time spent looking at the baited and the unbaited pots (in percent) in the different trials. There was no significant difference in the ratio of the time spent near the correct and the empty locations or in the ratio of the time looking at the correct and the empty locations (repeated measures ANOVA, for the results see also Table 2)

Table 2 Comparison of dogs' behaviour across the different trials

	Result of the repeated measures ANOVA		
	df	*F*	*P*
Looking at the owner (duration)	4	1.41	0.25
Numbers of the gaze alternations	4	1.03	0.40
Ratio of looking at the baited and the empty pots	4	1.13	0.36
Ratio of staying near the baited and the empty pots	4	0.94	0.47

We compared dogs' behaviour across the five trials. For the sake of simplicity, we used the ratio of the time spent looking/staying at the baited and unbaited pots (in percent) instead of the durations of both variables. We found that the ratio of the time spent looking and staying near the correct location did not differ across the different trials. Moreover, there was no significant difference in the duration of looking at the owner or in the numbers of the gaze alternations between the owner and the baited pot (see Fig. 7; Table 2).

There was no significant difference in the success of the owners in choosing the baited bowl in the five different trials (Cochran's Q ($df = 3$) = 7.36; $P > 0.05$). Thus, for further analysis, we pooled the trials together and compared the owners' success to the chance level (33%). Owners located the correct hiding place significantly above chance level (Binomial test, $P < 0.0001$). Analysing the owners' success separately in each condition, we found that owners localised the correct place significantly above the chance level only in the 'Touching' condition (Control: 9 owners out of 12 were successful, $P = 0.14$; Pointing (Owner): 7 owners out of 12 were successful, $P = 0.77$; Touching: 10 owners out of 12 were successful, $P < 0.05$; Marker: 7 owners out of 12 were successful, $P = 0.77$). However, it is important to note that regarding the relatively small sample size, at least 10 owners out of 12 had to be successful for reaching above the chance level.

General discussion

The present studies were intended to tackle dog–human gestural communication in more complex situations in which subjects can utilise more flexible skills. We hoped to collect new data in order to clarify some aspects of the underlying mental mechanisms in dogs. In Study 1, we found that in a four-way object-choice task, dogs as a group could successfully rely on the human pointing gesture. Interestingly, however, only 2 dogs were successful at the individual level. This contrasts other studies in which dogs were tested with distal momentary pointing gesture in a simple two-way object-choice task (e.g. Gácsi et al. 2009a). These findings are interesting because our subjects had previously successfully performed in the two-way object-choice task as this was the criterion for being included in the present study. This suggests that dogs could not generalise their previous experience to this more complex task, in which the food was hidden at four possible locations. Importantly, dogs could not choose correctly between the 2 bowls that were placed on the same side of the experimenter; however, the 2 dogs that were successful also at the individual level suggest that the ability of comprehending the human pointing signal in a four-way condition is present in the dog as a species.

The results of this study also suggest that under the present condition, dogs may not be able to extrapolate a linear vector corresponding to the pointing hand (and index finger). In the case of human infants, it has been shown that the comprehension of the pointing gesture is unlikely to depend on extrapolating precise linear vectors along the pointing arm (Butterworth and Itakura 2000); however, independently from the underlying mechanism, children are able to perform this task successfully by 18 months of age (Pfandler et al., unpublished data). Other findings also

showed that dogs might not grasp the meaning of the pointing index finger, in contrast to human infants, who are able to decode most forms of pointing by the age of 3 years (Lakatos et al. 2009).

Dogs showed some slight preference for choosing the bowl closer to the human which was also found in other studies (e.g. Soproni et al. 2002). Thus, it seems likely that for dogs, the distance between the tip of the pointing index finger and the target overshadows the decoding of the referential aspects of the pointing.

In Study 2, we found that dogs were able to rely on indirect pointing signals, when the owner pointed at one of two pointing experimenters. However, individually only 5 dogs out of 23 were successful. Importantly, dogs were successful at choosing the correct person, but then they could not successfully localise the correct target pointed at by the experimenter. Their failure can be explained by several factors. First, the complexity of the situation could have confused the dogs leading to problems of attention and memory (see also Horn et al. 2011). Second, the secondary informants displayed a static pointing gesture (the arm of the experimenter has already been in the pointing position when the owner was pointing at them). Usually, dogs are less skilful to rely on static pointing gestures probably because they utilise also on the dynamic component of the pointing hand (Soproni et al. 2002), and it is also easier for the visual system of the dog to pick on moving cues. It is also possible that in the case of such static gestures, dogs did not perceive the informants as communicating something to them. Third, dogs may have interpreted the owners' point as indicating the hiding location rather than directed the dog to a second pointer. In the first study, it was already shown that dogs do not follow the linear vector of the pointing signal, so the initial point from the owner could be interpreted as toward a number of targets in that direction, including the bowls, rather than one of the experimenters.

These negative findings do not exclude that dogs would be able to perform better with an improved experimental protocol. Earlier studies established that there are strong individual differences among dogs, which are based on selective history and epigenetic effects. Thus, dogs belonging to special breeds or trained for different tasks may perform better in the case of 4-way choice situation or with indirect pointing. Gácsi et al. (2009b) have reported that breeds selected for hunting under visual guidance of humans were superior in comparison to independent hunters in the two-way choice tasks. Furthermore, individuals of some dog breeds (pointers) are traditionally trained to perform well in a similar task with conspecifics. In these exercises, they learn to utilise the signalling body posture of another pointer dog during hunting, which raises the possibility that training and some experience with this task could improve the performance in dogs. Findings of Marshall-Pescini et al. (2009) also support the idea of the possible effects of training, showing that dogs that obtained special training (e.g. agility or search and rescue training) use their gaze more often to communicate with humans in problem-solving tasks. Besides, the fact that 5 dogs were successful also at the individual level shows that the ability of comprehending such indirect gestures is present in this species.

In study 3, dogs could indicate a particular location for the owner without having a direct knowledge of anything being hidden there. Dogs used wide range of behaviours which in general directed the owners' attention to the location of the hidden food. This was independent from the way of signalling (direct: observing the hiding directly; indirect: obtaining information through different gestural cues). Unknowledgeable owners found the hidden food with the same frequency in the different situations, although owners were less successful compared with earlier findings of Miklósi et al. (2000). Possibly owners did not observe dogs' behaviour well enough in this case since the analysis of dogs' behaviour showed that they distinguished among the hiding locations. Hence, dogs are able to recognise the location of a hidden object not only on the basis of direct observation but also utilising indirect human gestural signals, and they are able to convey this information to their owner.

To be successful in this situation, the dogs had (1) to realise the significance of the human gesturing/marking they had, (2) to remember the correct location for a short period of time (until the owner/experimenter came back to the room and they were in the position to signal) and (3) to display communicative behaviours at the correct location (e.g. gaze alternation). This weakens the explanatory value of alternative explanations for earlier findings (Miklósi et al. 2000), that is, that the dogs' gazing behaviour is a direct consequence of witnessing the hiding action. The present results suggest that direct visual information about the hidden food is not necessary for dogs to express communicative behaviour toward the owner.

Dogs used similar attention-directing signals independently of the way of human signalling (touching, pointing at the hiding location or using a marker next to the pointing gesture). This shows a relatively broad capacity for generalisation, which presumably is based on their everyday experiences with humans. This is in line with former studies, which showed that dogs can choose an object if the placement of an arbitrary marker is the signal for the location. Agnetta et al. (2000) revealed that dogs are able to use arbitrary markers as a communicative cue but only if they can see the placement. These findings have been extended recently by Riedel et al. (2006) who varied systematically the amount of human movement associated with marker

placement. Their results were consistent with the previous findings, that is, dogs performed best when they saw the experimenter's hand placing the marker, although they were almost as successful when they saw the experimenter reaching to remove the marker. However, they chose at random when a marker was already positioned by the container.

It is important to note that in the present study, dogs have been trained to be aware that the pots may hide food. The gestural actions (pointing from a short distance, touching, etc.) used as signals may have made the hiding locations more conspicuous, so they can be considered as a form of local enhancement.

All the gestures were accompanied by gaze alternations, which can have an additional stimulus enhancing effect. Other studies have shown that dogs are very sensitive for the human eye-contact or gazing (e.g. Topál et al. 2009). It seems that such ostensive communication from the part of the human is effective in influencing the dogs' behaviour (Erdőhegyi et al. 2007; Kupán et al. 2010).

In conclusion, we demonstrated that dogs have the ability to comprehend indirect or subtle signals in relatively complex situations. Our results suggested that dogs are able to reach a flexible comprehension of human communicative cues through relatively simple mechanisms, though it is unlikely that they can comprehend the human pointing gestures as being referential. In summary, study 1 showed that dogs are unlikely to rely on extrapolating precise linear vectors along the pointing arm when relying on human pointing gestures. Instead, they utilise a simple rule of following the side of the human gesturing, and if there are more targets on the same side, they show preference for the targets closer to the human. Study 2 revealed that dogs are able to rely also on indirect pointing gestures but the individual performances suggested that this ability may be restricted to a certain level of complexity. Finally, study 3 provided further evidence of dogs' ability for generalisation, although their performance possibly could be explained also by relatively simple mechanisms, such as stimulus or local enhancement (Marshall-Pescini et al. 2010). Dogs' high performance is presumably also supported by their motivation to satisfy ostensively signalled human imperatives (Topál et al. 2009).

Acknowledgments The research described here was supported by the European Union (NEST 012787, LIREC-215554), the Hungarian Scientific Research Fund (OTKA T049692) and ETOCOM project (TÁMOP-4.2.2-08/1/KMR-2008-0007) through the Hungarian National Development Agency in the framework of Social Renewal Operative Programme supported by EU and co-financed by the European Social Fund. The authors are grateful to all the owners who participated in this research for their support throughout the study.

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