Developmental Science

Developmental Science 15:2 (2012), pp 222–232 DOI: 10.1111/j.1467-7687.2011.01120.x

PAPER

How dogs know when communication is intended for them

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Abstract

Domestic dogs comprehend human gestural communication in a way that other animal species do not. But little is known about the specific cues they use to determine when human communication is intended for them. In a series of four studies, we confronted both adult dogs and young dog puppies with object choice tasks in which a human indicated one of two opaque cups by either pointing to it or gazing at it. We varied whether the communicator made eye contact with the dog in association with the gesture (or whether her back was turned or her eyes were directed at another recipient) and whether the communicator called the dog's name (or the name of another recipient). Results demonstrated the importance of eye contact in human–dog communication, and, to a lesser extent, the calling of the dog's name – with no difference between adult dogs and young puppies – which are precisely the communicative cues used by human infants for identifying communicative intent. Unlike human children, however, dogs did not seem to comprehend the human's communicative gesture when it was directed to another human, perhaps because dogs view all human communicative acts as directives for the recipient.

Introduction

Human communication is intentional on several different levels. For example, the communicator typically intends the recipient to attend to something (the referential intention) and then to either know, do, or feel something as a result (the social intention, in the terminology of Tomasello, 2008). Another important level is the so-called communicative intention (or Gricean communicative intention) in which the communicator intends that the recipient recognize his intention to communicate with her (Sperber & Wilson, 1986). Thus, communicators typically direct their communicative acts at other individuals accompanied by such things as eye contact or calling the recipient's name. Recognition of this communicative intention turns otherwise meaningless behaviors – e.g. protruding a finger or patting the top of my head – into richly meaningful communicative acts such as pointing to inform someone of approaching danger or gesturing iconically that you forgot your hat.

From early in ontogeny, human infants are sensitive to such things as eye contact and the calling of their name (especially when it is in a high pitch) (Csibra, 2003). By around the first birthday, they understand these so-called ostensive cues as indicating that the accompanying behavior or vocalization is intended for them as an intentional communication – and so they make appropriate inferences as a result. For example, in a recent study an adult pointed to an opaque bucket for 14-month-old infants in the context of a toy-finding game (Behne, Carpenter & Tomasello, 2005). The infants immediately perceived that the adult was intentionally directing their attention to the bucket and so they inferred that the toy was inside – and so searched there. This inference is not as automatic as it might seem, as in similar object choice studies great apes follow the gesture to the bucket but then do not infer that the gesturer intended for them to know there was food inside (see Call & Tomasello, 2005, for a review). Importantly, in a control condition in the infant study Behne *et al*. (2005) reproduced the surface characteristics of pointing behavior for infants but in an apparently unintentional manner – by holding the hand in a pointing configuration (just as in the normal communication condition) but without ostensive cues indicating that this was indeed a communication act (e.g. eye contact with the infant was non-communicative). In this case, the infants did not take the pointing hand configuration as an intentional communicative signal directed to them and so did not search in any bucket.

Interestingly, infants also recognize communicative intentions when they are directed to other people, that is to say, they can comprehend some things by 'eavesdropping'. For example, Gräfenhain, Behne, Carpenter and Tomasello (2009) had infants look on from the outside as one adult indicated gesturally the location of a hidden toy for another in an object choice task otherwise similar to that of Behne *et al*. (2005). The result was that 18-month-olds (but not 14-month-olds) inferred the location of the hidden toy even though the gesture was

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directed at another person (see Akhtar, 2005; Akhtar, Jipson & Callanan, 2001; Floor & Akhtar, 2006, for studies of infants' ability to comprehend language addressed to others). A low-level explanation of this behavior is that the infants somehow took this gesture to be for them even though in reality it was not. A more high-level explanation is that they somehow took the perspective of the recipient – put themselves in her shoes, so to speak – and saw the signal as directed at someone (which could have been them, if they had been in that place). In either case, infants from the middle of the second year recognize communicative acts accompanied by ostensive cues as signaling communicative intent, even when these acts are directed to other people.

In recent years it has become clear that, among animals, domestic dogs (*Canis familiaris*) tune into human communication in special ways. Thus, when humans point to buckets for dogs in the context of finding food (i.e. in object choice tasks), they seemingly make the human-like inference and search there for food (in a way that the great apes do not; Bräuer, Kaminski, Riedel, Call & Tomasello, 2006; Hare, Brown, Williamson & Tomasello, 2002). Presumably as a result of their special evolutionary history of domestication (since wolves have no special skills in comprehending human communication and dog puppies are skillful before they have had much human contact; Hare *et al*., 2002; Miklosi, Kubinyi, Topal, Gacsi, Viranyi & Csanyi, 2003; Riedel, Schumann, Kaminski, Call & Tomasello, 2008), dogs attend to human communicative signals such as pointing and respond to them in human-like ways. Importantly, it has been established that dogs' responses in object choice tasks are highly flexible and are not based on either odor or on some kind of low-level, non-communicative cueing (see Miklosi & Soproni, 2006, for a review). For example, they follow a human's pointing gesture to a far-away bucket even as the pointing human is moving bodily closer to another bucket (Hare & Tomasello, 1998).

In all of these object choice studies with dogs, humans provided clear ostensive cues that this was a communicative act intended for the dog. In a recent study using a different paradigm, Topal, Gergely, Erdöhegyi, Csibra and Miklosi (2009) found that humans directing dogs to hidden food with ostensive cues even lead them in some cases to ignore evidence from their own visual perception about the food's location. But despite these findings of dogs' general sensitivity to communicative cues, there has been no systematic research on what specific cues dogs need to recognize a human behavior as a communicative act directed at them. In their everyday life with humans, dogs are continuously confronted with human social behavior, some of which is intended to communicate to them and some of which is not. The question is thus how they distinguish between the two, if indeed they do. Comparisons to what we know about how human infants recognize behaviors as communicative acts directed to them may help to clarify the nature of human communication and how human infants come to participate in this complex social process.

In the current studies we confronted domestic dogs with object choice tasks and varied the ostensive cues available as accompaniments to pointing and gazing gestures. In the first study, modeled on Behne *et al.* (2005), we produced the gesture either with or without accompanying ostensive cues. In the second study, we eliminated eye contact as an ostensive cue by having the human give the gesture with her back turned (in some cases calling the dog's name and in some cases someone else's name). In the third study, we investigated whether dogs can 'eavesdrop' on human communication by having the experimenter present the gestures while she was either communicating directly with the dog or with another person to the side (with the experimenter calling either the dog's or the stranger's name). To see whether dogs' skills are a result of learning during ontogeny, in a fourth study we investigated the main conditions from the first three studies with a sample of young dog puppies. The overall goal was to establish which ostensive cues are most important for dogs – and when in ontogeny they come to use them – in determining when a human behavior is a communicative act directed to them.

Study 1: Intentional versus non-intentional gestures

In this first study we investigated whether dogs would differentiate intentional communicative acts from similar but 'non-intentional' behaviors directed towards the target hiding location. That is, we used the basic procedure of the Behne *et al*. (2005) study with young children in which the human reproduced a pointing hand configuration either with or without ostensive cues to the dog that this was a communicative act directed at her.

Subjects

Twenty-six dogs (12 females and 14 males) from different breeds participated in this study. All dogs lived as pets with their owners and received the training typical for a pet dog. Dogs were recruited from a database of dog owners who agreed that their dogs could participate in studies on dog cognition. To be selected for this study, dogs had to be food motivated, naïve to object choice tasks, older than a year, and comfortable staying with strangers without their owner.

Material

Two cups (12 cm × 8 cm), covered with lids, were placed on a wooden platform (180 cm × 32 cm) with a distance of 110 cm between them. The experimenter (E1) sat behind the platform, opposite to the dog. During pointing, the distance between the index finger and the cup was approximately 50 cm. In experimental trials a wooden barrier (66 cm × 40 cm) was used to cover the baiting process. The reward consisted of a piece of dry dog food. To be able to pretend checking the time in one of the conditions E1 was wearing a watch around each of her wrists. In addition, there was a clock hanging on both walls to the side of E1. The dog, who was held by another person (E2), sat in front of E1 at a distance of 150 cm.

Procedure

Each dog participated first in six warm-up trials. This was to ensure that they were familiarized with the procedure and also food motivated enough to participate in the study. In warm-up trials E1 sat behind the platform and placed one cup on each side of the platform. E1 removed the lids from the cups and placed a piece of food in one of the two cups in full view of the subject. Then, the dog was released and received the food if the choice was correct. If the choice was incorrect the dog was shown that the cup was empty but was not allowed to eat the food from the other cup.

In experimental trials E1 sat behind the platform while the dog was sitting opposite to her on a predetermined spot and attached to a leash held by E2. E1 placed the barrier in front of the cups to ensure that the dog could not witness the baiting. After that she raised her arm presenting the piece of food and in addition called the dog's attention by saying its name. Occluded by the barrier, E1 removed the lid of both cups and placed the food in one of them. Afterwards she closed the cups again, removed the barrier and pushed the cups simultaneously to the right and the left side of the board. During this manipulation the experimenter did not establish eye contact with the dog. This was then only re-established depending on the condition. After the cups had been placed, E1 gave one of four possible communicative cues.

Point intentional: E1 established eye contact with the dog. She then pointed to the correct location, using a cross-lateral pointing gesture, gaze alternating by turning her head repeatedly between the dog and the cup.

Gaze intentional: E1 established eye contact with the dog. She then gazed to the correct location, gaze alternating by turning her head repeatedly between the dog and the cup.

Non-intentional '*point*': E1 did not establish eye contact with the dog. She stretched out her arm and index finger cross-lateral from her body such that it mirrored the pointing cue in the direction of the correct cup. While doing so, E1 pretended to check the time on her watch, repeatedly gazing, with a clear head movement, between the clock on the wall and her watch on her wrist. The movements of the head resembled those in the intentional condition (e.g. speed) to the degree possible.

Non-intentional '*gaze*': E1 did not establish eye contact with the dog but turned her head repeatedly in the direction of the correct cup, and while doing so pretended to scratch the back of her head. The movements of the head resembled those in the intentional condition (e.g. speed) to the degree possible.

While giving the communicative cue, E1 remained silent. After approximately 3 seconds, E1 stopped giving the cues and the dog was released by E2 and was free to choose one of the two cups. A choice was considered made when the dog approached one of the cups at a distance of at least 20 cm. If the dog chose correctly, it was allowed to eat the food. If the dog chose incorrectly it was shown that the cup was empty and was not allowed to eat the food from the other cup. Each dog received six trials in each of the four conditions. The pointing and the gazing cues were blocked, with intentional and non-intentional cues (and side of correct cup) randomized within each block – with the stipulation that a dog should not receive the same condition nor the same correct location on more than two consecutive trials. Half of the dogs started with pointing trials and the other half started with gazing trials.

All trials were videotaped and analyzed by one person (LS) subsequently to the study. For reliability purposes a second coder blind to the research question coded a random 20% of the trials. Reliability was excellent (Cohens Kappa 0.96, $n = 96$). Not all variables (for the pointing and gazing cues separately) passed a normality test (Kolmogorov–Smirnov), which is why for the comparisons to chance and comparisons between conditions non-parametric statistics were used (Wilcoxon-signed ranks test). We checked whether the assumptions for an ANOVA were fulfilled by visually inspecting plots of residuals versus expected values, which showed no obvious violations of the assumptions.

Results

When the human gave an intentional pointing cue, dogs selected the correct cup at above-chance levels (Wilcoxon signed-ranks test: T = 186.0, $N = 26$ (7 ties), $p < .0001$), but when she gave a non-intentional pointing cue they did not (Wilcoxon signed-ranks test: T = 91.5, $N = 26$ (10 ties), $p = .21$). In addition, the intentional pointing cue was followed correctly more often than the non-intentional one (Wilcoxon signed-ranks test: T = 133.0, $N = 26$ (9 ties), $p = .006$). When the human gave an intentional gaze cue, there was a trend for dogs to select the correct cup at above-chance levels (Wilcoxon signed-ranks test: T = 110.0, $N = 26$ (9 ties), $p = .09$), but when she gave a non-intentional gaze cue there was not (Wilcoxon signed-ranks test: T = 46.5.0, $N = 26$ (13 ties), $p = .94$). There was no significant difference between the intentional and the non-intentional gaze cue (Wilcoxon signed-ranks test: T = 81.5.0, $N = 26$ (11 ties), $p = .21$).

In order to test for differences between conditions, we conducted a 2 (intentional vs. non-intentional) × 2 (point vs. gaze) repeated measures ANOVA with the between factor order (pointing cue first or gazing cue first). There was a main effect for both condition ($F_{1,24}$ = 11.63, p = .002) and cue type ($F_{1,24}$ = 6.91, p = .015), with no significant interaction between them ($F_{1,24}$ = 1.55, p = .225). This indicates that the dogs successfully used the intentional communicative acts more often than the non-intentional communicative acts irrespective of the type of cue, and that the dogs generally followed the pointing cues more than the gazing cues (see Figure 1). In addition, order had no effect on any of the factors.

To test for learning we conducted a 2 (intentional vs. non-intentional) × 2 (point vs. gaze) × 2 (first half of trials vs. second half of trials) repeated measures ANOVA. Half of trials had no effect on any of the factors, suggesting that no learning took place during the study.

Discussion

The first finding of this study is that dogs clearly differentiate between the pointing and the gazing cues. While dogs seem to use the pointing gesture, dogs did not seem to use the gazing cue alone. However, generally in this study dogs differentiated acts in which a human communicated a location ostensively for them, with communicative intent, from situations in which the human produced similar but non-communicative movements in the same direction. This means that dogs do not follow just any directional behavior of a human. Simple local enhancement cannot account for the dogs' behavior (nor in previous studies either), as in both of the pointing conditions the human's hand was relatively close to the correct cup.

Soproni, Miklosi, Topal and Csanyi (2001) showed that dogs differentiate situations in which a human is gazing towards a cup or gazing slightly above it, suggesting that the dogs see the former but not the latter as intentionally directed at the cup. However, in that study the human's behavior was clearly different in both conditions. While the person was gazing *at* the cup in one condition she was gazing *above* it in the other. The current study found that even though the human's cup-directing behavior with the finger was on the surface identical in the two conditions, dogs followed the intentional cue but not the non-intentional one.

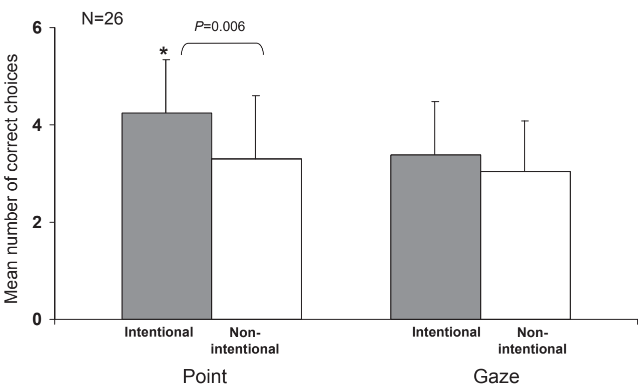

Figure 1 *Mean number of trials (+STD) dogs follow the intentional gesture compared to non-intentional behavior directed at the target in Study 1. * indicates results different from chance (Wilcoxon signed-ranks test,* p < *.05).*

In this study, the main cue indicating the human's intentional communicative act was eye contact. This finding contributes to a growing body of evidence that eye contact plays an important role in dog–human interactions (Call, Bräuer, Kaminski & Tomasello, 2003; Fukuzawa, Mills & Cooper, 2005; Gacsi, Miklosi, Varga, Topal & Csanyi, 2004; Miklosi *et al*., 2003; Viranyi, Topal, Gacsi, Miklosi & Csanyi, 2004). However, it is not entirely clear how this works. For example, it could be that for dogs human eyes simply function as a kind of automatic trigger which raises the level of arousal and so attention to the human – which then leads to greater accuracy in gesture following in conditions with eye contact. Or it may reflect a more discerning use of eye contact to read human communicative intentions. The second and third studies, therefore, were designed to investigate further the role of eye contact in dogs' following of human communicative gestures, and also to explore an additional ostensive cue: the calling of the dog's name (in a high pitched speech register). In these two studies, the human's communication was always intended, but in some situations it was clearly directed at the dog, whereas in others it was not. In Study 2 we explored situations in which the human's back was turned, and in Study 3 we explored conditions in which the human communicated away from the dog, to the side, in some cases to another recipient.

Study 2: Back turned

In this study the human always communicated intentionally, but with her back turned to the dog so that there was no eye contact and no other facial cues. Use of the dog's name and a stranger's name were also explored as cues that dogs could potentially use to determine when intentional communication was directed specifically at them. Because in many previous studies, as well as in Study 1, dogs cannot find hidden food in object choice tasks in the absence of a communicative cue (perhaps because both cups smell like food already), in Studies 2 and 3 experimental conditions were simply compared with each other as well as to chance performance.

Subjects

Originally, seventy-two dogs (36 females and 36 males) from the same dog database as Study 1 participated in this study. Two dogs later had to be excluded due to mistakes by the experimenter, therefore the data of 70 dogs were used for analysis. None of the dogs had participated in Study 1. Prior to the study dogs were randomly assigned to one of three experimental groups, 24 dogs per group.

Materials

Two blue, opaque containers (24 cm × 15 cm × 13 cm) were placed on either end of a table (170 cm × 31.5 cm × 30 cm) with a distance of 1.30 m between them and with their opening facing the experimenter. E1 sat on the same side as the dog but with their back turned towards the dog. A second person (E2) was sitting next to E1 and in one condition opposite to her (at a distance of 1.60 m) and functioned as the addressee of E1's communicative actions in some of the conditions. A third person (E3) held the dog on a leash on a predetermined spot and 1.50 m away from the table (see Figure 2 for an overview of the general setting). The food reward was a piece of dog sausage. E1's hands were covered with white gloves to make it easier for the dog to see the reward. During the pointing, E1's hand was approximately 50 cm from the cup.

Procedure

Each dog first participated in two warm-up trials. This was to ensure that they were familiarized with the procedure and also food motivated enough to participate in the study. In warm-up trials E1 sat behind the table, facing the dog, which was sitting opposite to E1. E1 placed the containers on the table with the opening of the containers directed to the dog and placed food in one of the containers in full view of the dog. Then, the dog was released by E3 and received the food if the choice was correct. If the choice was incorrect the dog was shown that the container was empty but was not allowed to eat the food from the other container.

From this point on, dogs from each experimental group experienced different procedures. Each dog in each group received six pre-test trials which resembled the experimental trials (procedure explained below) with the major difference that here dogs could always see in which location the food ended up. This was to ensure that dogs were further familiarized with the procedure. In addition, dogs learned that they could approach the container freely in any of the conditions and without extra permission to do so. The three experimental conditions were as follows:

Back Turned + Dog's name: The human was sitting with their back turned towards the dog such that E1 was facing the containers from the same angle as the dog. During E1's communicative interactions the dog could never see the human's face. Gaze was instead directed at the wall opposite E1 and during gaze alternation was altered (indicated by clear head movements) between the wall and the correct container. Opposite E1 was no other person and E1's communication was not directed at anyone specifically.

Back Turned + Stranger's name: This condition resembled the *Back Turned to dog + Dog's name* condition with the exception that E1 used a random name ('Franzi') during the communicative interaction. Again, opposite E1 was no other person and E1's communication was not directed at anyone specifically.

Back Turned + Stranger's name, addressing third person: This condition resembled the *Back Turned to dog + Stranger's name* condition with the exception that E1 was now actually addressing someone other than the dog as she had another person sitting opposite her (E2).

The cue was constantly given until the dog made a choice. Five seconds after E1 started giving the cue the dog was released and allowed to make one choice. If the choice was correct the dog received the food; if it was incorrect it was shown that the container was empty and was shown the food in the other container. Each dog received 12 trials altogether, six pointing and six gazing trials. Pointing and gazing trials were presented blocked. Half of the dogs in each group received the pointing cue first and then the gazing cue and the other half vice versa. Pointing was always conducted with the contra-lateral arm across the body with the extended index finger indicating the correct container. The arm was held in mid-line of the body to avoid local enhancement cues. During the gazing trials E1 repeatedly turned her head to the correct container gazing at it, and then turned her head back again always emphasizing the communicative intent.

The location of the food was randomized with the stipulation that it could not be in the same location on more than two consecutive trials. All trials were videotaped and coded subsequently from videotape by LS. For reliability purposes a second coder coded a randomly selected 20% of the trials. Agreement was 100%. All variables passed a normality test (Kolmogorov–Smirnov), which is why parametric statistics were used. We checked whether the assumptions for an ANOVA were fulfilled by visually inspecting plots of residuals versus expected values, which showed no obvious violations of the assumptions.

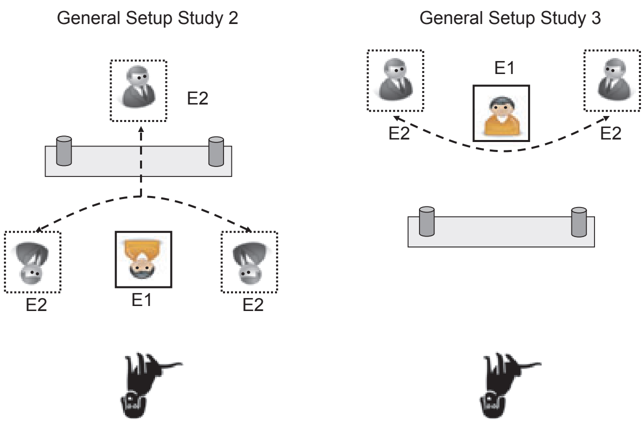

Figure 2 *General setup for Studies 2 + 3 + 4.*

Results

Comparisons to chance (see Table 1) found that for the pointing gesture, dogs' performance was above chance in

Table 1 *Mean number of trials (±STD) in which dogs chose the correct cup in the different conditions of Study 2 with both types of cue compared against chance (one-sample t-test). * indicates results different from chance. Human's back turned to the dog in all cases*

	Dog's Name (N = 24)	Stranger's Name (N = 23)	Stranger present + Name (N = 23)
Pointing	4.08* (1.248)	4.17* (1.230)	3.52* (1.123)
Gazing	3.46* (0.977)	3.69* (1.295)	3.04 (1.186)

all three experimental conditions (*Dog's name*: one sample t-test: $t_{23} = 4.25$, $p < .001$, *Stranger's name*: one sample t-test: $t_{22} = 4.58$, $p < .001$, *Third Person*: one sample t-test: $t_{22} = 2.23$, $p = .036$). For the gazing gesture, dogs followed the gesture when the human called the dog's name (one sample t-test: $t_{23} = 2.29$, $p = .031$), and also when she called a stranger's name (*Stranger's name*: one sample t-test: $t_{22} = 2.58$, $p = .017$). However, they did not follow the cue when she called a stranger's name and the stranger was the one addressed (*Third Person*: one sample t-test: $t_{22} = 0.18$, $p = .86$).

To test for differences between conditions, we also conducted a repeated measures ANOVA with the within factor cue (pointing vs. gazing) and the between factors order (pointing cue first or gazing cue first) and condition (dog's name, stranger's name, third person). There was a three-way interaction of all factors ($F_{2,64} = 3.245$, $p = .045$). We thus looked at each cue, pointing and gazing, separately using univariate ANOVAs, with mean number of correct choices as dependent variable. Neither the ANOVA with pointing as a cue nor the ANOVA with gazing as a cue produced significant results of any of the main factors or their interactions.

To test for learning we compared the first half of trials with the second half of trials for each condition and pointing and gazing separately. None of the comparisons reached significance, suggesting that no learning took place during the study.

Discussion

The results of this study demonstrate that dogs do not need eye contact to know that a communicative gesture is for them. Previous studies have shown that in a competitive context dogs understand that when a human's back is turned she cannot see that they are engaging in a prohibited activity such as, for example, not obeying a certain order (Call *et al.*, 2003; Fukuzawa *et al.*, 2005; Schwab & Huber, 2006). But understanding a human's lack of visual access apparently does not negate a cooperative communicative act for them. In the current study, which name the human used did not change the effect of the communicative gesture if no alternative communicative partner was present. This shows that dogs are probably not recognizing their names specifically, but are only reacting to a high-pitched vocalization, similar to the 'motherese' speech register adults typically use with young children (see Pongracz, Miklosi, Timar-Geng & Csanyi, 2004, for evidence that a human's vocalizations increase the likelihood for local enhancement in dogs' social learning). If the experimenter was addressing a third person, however, dogs basically ignored the communicative act.

One possible explanation for these findings is that the dogs simply assume that a communication is for them by default, especially in the current experimental situation in which the gesturing experimenter was interacting with them between trials as they chose a cup in search of the food. But when a human is clearly addressing someone else, dogs ignore the communicative act. However, we were not convinced that the dogs really saw this as a situation in which the gesturing human was communicating with another person since this new person was, from the dog's point of view, behind the gesturing experimenter and the food, and was not very salient in the situation.

The results of this final condition thus raise the question of whether dogs can actually 'eavesdrop' on humans communicating with one another, and comprehend a gesture from outside the situation in which they themselves are directly addressed. In the third study, therefore, we changed the spatial arrangement of things so that now in some conditions the experimenter was clearly gesturing for another, reasonably salient individual. More generally, in this third study we systematically varied whether there was eye contact with the dog and whether its name (or another name) was called, with one condition in which the experimenter was clearly gesturing for another very salient human (not the dog).

Study 3: Direction of gaze and use of dog's name

In this study, we had four experimental conditions in which the gesturing experimenter either did or did not make eye contact with the dog and called either the dog's name or another name. When the experimenter did not make eye contact with the dog she was looking to the side, in one case clearly addressing another salient person.

Subjects

Ninety-six dogs (46 females and 50 males) from the same dog database as Studies 1 and 2 participated in this study. None of the dogs had participated in Studies 1 or 2. Prior to the study dogs were randomly assigned to one of four experimental groups, 24 per group.

Procedure

We used the same basic procedure as Study 2, except that in this case E1 sat behind the table with her face oriented to the dog. A second person (E2) sat next to her and functioned as the addressee of E1's communicative actions in one condition (see Figure 2 for a general overview). In another condition (the *distracted* condition) there was a green cardboard box (50 cm × 32 cm × 23 cm) standing next to E1 replacing E2. Again, dogs participated in a warm-up phase, which resembled the condition in which they later participated. The procedure of the warm-up phase resembled that of Study 2.

At the beginning of each experimental trial E1 placed the pair of containers in the center of the table. After that E1 behaved according to the experimental condition:

Normal (Eyes at dog + Dog's name): E1 first showed the food to the dog saying '*Dog's name*, look I am now hiding something!' During the hiding E2 closed her eyes and lowered her head to avoid seeing where E1 was hiding the food. Now E1 closed both hands around the food concealing it from the dog's view. E1 then touched both containers simultaneously and hid the piece of food in one of them out of view of the dog. Then E1 pushed both containers simultaneously to both sides of the table. E1 then turned towards the dog and said '*Dog's name* I am now finished hiding!' upon which E2 lifted her head and opened her eyes. Instantly, E1 started to give one of the two possible communicative cues (pointing or gazing towards the correct location). E1's pointing or gazing was always accompanied by gaze alternation which involved clear head movements between the dog and the correct container.

Other Name (Eyes at dog + Stranger's name): This condition resembled the *Normal* condition except that now E1 used a random name ('Franzi') during the communicative interaction.

Distracted (Eyes away from dog + Dog's name): This condition resembled the *Eyes away from dog + Stranger's name* condition in the sense that E1 directed her communicative actions away from the dog. However, in this condition it was because she was being distracted by an object (a green cardboard box) standing next to her. During communicative interactions E1 gaze alternated between the correct container and the cardboard box, each time acting as being distracted by the box standing there. During the entire procedure E1 never gazed at the dog but called the dog by its name.

Third Party (Eyes at stranger + Stranger's name): The procedure for this condition resembled the above with the exception that now E1 first showed the food to E2 saying '*Stranger's name*, look I am now hiding something!' During the hiding E2 closed her eyes and lowered her head to avoid seeing where E1 was hiding the food. After the baiting, during which E1 never looked at the dog, E1 then turned towards E2 saying '*Name of E2*, I have now finished hiding!' upon which E2 lifted her head again and opened her eyes. Instantly, E1 started to give one of the two possible communicative cues. E1's pointing or gazing was always accompanied by gaze alternation which involved clear head movements between E2 and the correct container.

As in Study 2, pointing and gazing trials were presented blocked, with half of the dogs in each group receiving the pointing cue first and then the gazing cue and the other half vice versa. The location of the food was randomized with the stipulation that it could not be in the same location on more than two consecutive trials. The side on which E2 sat or the box was located was counterbalanced across subjects but remained constant within subjects. All trials were videotaped and coded subsequently from videotape by LS. For reliability purposes a second coder coded 20% of the original material. Reliability was 100%. All variables passed a normality test (Kolmogorov–Smirnov), which is why parametric statistics were used. We checked whether the assumptions for an ANOVA were fulfilled by visually inspecting plots of residuals versus expected values, which showed no obvious violations of the assumptions.

Results

First we compared all conditions to chance performance for pointing and gazing separately. Table 2 reports the results. For the pointing gesture, dogs' performance was above chance in all experimental conditions (*Normal*: one sample t-test: $t_{23} = 5.79$, $p < .001$, *Other name*: one sample t-test: $t_{23} = 4.75$, $p < .001$, *Distracted*: one sample t-test: $t_{23} = 5.57$, $p < .001$, *Third Party*: one sample t-test: $t_{23} = 2.83$, $p = .009$). For the gazing gesture, dogs followed the gesture when the human called the dog's or another name (*Normal*: one sample t-test: $t_{23} = 2.79$, $p = .010$, *Other name*: one sample t-test: $t_{23} = 3.10$, $p = .005$) but not when the human was distracted (*Distracted*: one sample t-test: $t_{23} = 0.42$, $p = .679$) or the gesture was directed at a third party (*Third Party*: one sample t-test: $t_{23} = 0.371$, $p = .714$).

In order to compare conditions, we also conducted a repeated measures ANOVA with the within factor cue (pointing vs. gazing) and the between factors Eye contact (Yes vs. No), Naming (Yes vs. No), and order (pointing cue first or gazing cue first). All comparisons were Bonferroni corrected. There was a main effect of cue, with dogs being more successful with the pointing than the gazing cue ($F_{1,88} = 37.87$, $p < .0001$). This effect was mediated by the order in which the cues were presented as there was an interaction between cue and order ($F_{1,88} = 4.93$, $p = .029$). Nevertheless, post-hoc pairwise

Table 2 *Mean number of trials (±STD) in which dogs chose the correct cup in the different conditions of Study 3 with both types of cue compared against chance (one-sample* t*-test). * indicates results different from chance.* N *= 24 in all cases*

	Normal	Other Name	Distracted	Third Party
Pointing	4.75* (1.481)	4.46* (1.503)	4.38* (1.209)	3.92* (1.586)
Gazing	3.6* (1.167)	3.79* (1.250)	2.92 (0.974)	3.08 (1.100)

comparisons showed that dogs' better performance with pointing was apparent irrespective of whether dogs received pointing first (paired sample *t*-test: $t_{47} = 2.68$ $p = .01$) or gazing first (paired sample *t*-test: $t_{47} = 6.19$ $p < .0001$). There was also a main effect of *Eye contact*, with dogs being significantly more successful in conditions during which the human established eye contact ($F_{1,88} = 8.89$, $p = .004$), with none of the other factors interacting with this effect. Which utterance the human produced had no effect on the success rate of the subject as *Naming* had no effect ($F_{1,88} = 0.331$, $p = .57$). There was also no interaction between these factors ($F_{1,88} = 0.25$, $p = .88$).

Post-hoc pairwise comparisons between the different experimental conditions revealed that dogs used the cues marginally more accurately in the *Normal* compared to the *Distracted* condition ($t_{46} = 1.988$ $p = .053$) and the *Third Party* condition ($t_{46} = 2.416$ $p = .02$). Dogs also used the cues significantly more successfully in the *Other Name* condition compared to the *Third Party* condition ($t_{46} = 2.084$ $p = .043$). No other comparison reached significance.

To test for learning we compared first half of trials with second half of trials for each condition and pointing and gazing separately. None of the comparisons reached significance, suggesting that no learning took place during the study.

Discussion

The most general result of this study was very clear. When there was eye contact between the dog and the human, dogs used the communicative gesture much more than when there was no eye contact. Whether or not the human called the dog's name did not affect their performance. This again shows the power of eye contact in helping dogs to determine that a communication is for them. It also supports the hypothesis that the dog's name was not a necessary cue which could be easily replaced by any other utterance. Even though dogs used all cues significantly above chance, the results show clearly that dogs' performance increased with the amount of ostensive cues presented. Most likely this is because dogs view human communication as a set of signals which need to be in place to be relevant for them. An especially interesting result is that dogs seemed to have most difficulties with the situation during which the cues were directed at a third party. Even though the information about the food location was displayed basically identically to the normal condition, dogs used the cues significantly less accurately when they were directed at a third party and not at them.

Infants from around 18 months of age eavesdrop on the gestures of others quite readily in a very similar experimental paradigm (Gräfenhain *et al.*, 2009). The infants in that study did not respond differently to gestures directed at them from gestures clearly directed at a third party. This suggests that infants understand communication as being informative – one individual is informing another of the location of the hidden item – and anyone may make use of this information. Dogs, on the other hand, may understand human communication in all cases to be directives to the addressee: a human directs another to do something or go somewhere, and so directives to other individuals are less relevant.

Study 4: Puppies

To see to what extent ontogeny played a role in the dogs' behavior we tested young dog puppies (below 11 weeks of age) to see how they behaved in the three most important contexts of the current studies: Normal (Studies 1 and 3), Back Turned (Study 2), and Third Party (Study 3). These puppies still lived with their mothers, and so had had very little sustained human contact and no formal training typical for pet dogs.

Subjects

Eighty-four puppies (40 females and 44 males; mean age = 7.9 weeks, age range 6 weeks, 2 days–10 weeks, 2 days) from 22 different litters and 17 different breeds participated in this study. All puppies were naïve to experimental testing. To eliminate possible litter effects, we assigned dogs from each litter to different experimental conditions. All puppies still lived with their mothers and were therefore tested at the breeders' homes. For testing, puppies were briefly separated from their mothers and tested in a separate place (a spare room or the garden). No puppies had had sustained human contact or formal training typical for pet dogs.

Materials

Materials and the general setting were the same as in the studies with adult dogs. We used opaque containers (24 cm × 15 cm × 13 cm) with a distance of 130 cm between them. The food rewards were pieces of dog-sausage and the experimenter's hands were covered with white gloves to make it easier for the puppies to see the hands. E2 held the puppy on a predetermined spot and 130 cm away from E1.

Procedure

Each puppy received a warm-up period. This was necessary to give the puppies an introduction to the general methods and to make sure they attended to the containers, etc. During the warm-up, puppies were presented with a reward which was placed in their full view in one of the two containers. They were then allowed to eat the food if they selected the correct container. Some puppies had to learn to walk to the correct container instead of walking towards the human. Those individuals were shown the reward, which was slowly placed in one container in their full view and with them being allowed to follow the reward to the box. After repeating this several times, E1 returned to the general warm-up. Puppies entered the experimental phase after being correct in four consecutive warm-up trials

For the experimental phase puppies were randomly assigned to one of three groups, with individuals from different litters being in each group. Each puppy in each group received four pre-test trials which resembled the experimental trials (procedure explained below) with the major difference that here dogs could always see in which location the food ended up. This was to ensure that the puppies were further familiarized with the procedure. The three experimental conditions were the following: *Normal (Eyes at dog + Dog's name)*; *Third Party (Eyes at stranger + Stranger's name)* and *Back Turned + Dog's name*. The procedure for each condition was basically identical to the procedure for the adult dogs.

The cue was constantly given until the puppy made its choice. While holding the puppy, E2 looked down on the ground such that she could not see the cue E1 was giving and then released the puppy after 5 seconds. The puppy was allowed to make one choice. If the choice was correct the dog received the food; if it was incorrect it was shown that the container was empty and was shown the food in the other container. Each puppy received 12 trials altogether, six pointing and six gazing trials. Pointing and gazing trials were presented blocked. Half of the puppies in each group received the pointing cue first and then the gazing cue and the other half vice versa. The location of the food was counterbalanced and semi-randomized with the stipulation that it could not be in the same location on more than two consecutive trials. All trials were videotaped and coded subsequently from videotape by LS. For reliability purposes a second coder coded a randomly selected 20% of the trials. Agreement was 100% (N = 180). Not all variables (for the pointing and gazing cues separately) passed a normality test (Kolmogorov–Smirnov), which is why for the comparisons to chance non-parametric statistics were used (Wilcoxon-signed ranks test). We checked whether the assumptions for an ANOVA were fulfilled by visually inspecting plots of residuals versus expected values, which showed no obvious violations of the assumptions.

Results

First we compared all conditions to chance performance for pointing and gazing separately. Table 3 reports the results. For the pointing gesture, dogs' performance was above chance when the gesture was directed at them (*Normal*: Wilcoxon signed-ranks test: T = 162.0, N = 28 (8 ties), p = .03, *Back Turned*: Wilcoxon signed-ranks test: T = 152.5, N = 28 (9 ties), p = .02) but not when it was directed at a third party (*Third Party*: Wilcoxon signed-ranks test: T = 102.0, N = 28 (11 ties), p = .18). For the gazing gesture, dogs' performance was never above chance (*Normal*: Wilcoxon signed-ranks test: T = 115.0, N = 28 (10 ties), p = .017, *Back Turned*: Wilcoxon signed-ranks test: T = 80.5, N = 28 (14 ties), p = .07, *Third Party*: Wilcoxon signed-ranks test: T = 107.5, N = 28 (11 ties), p = .13).

Table 3 *Mean number of trials (±STD) in which dog puppies chose the correct cup in the different conditions of Study 4 with both types of cue compared against chance (one-sample* t*-test). * indicates results different from chance.* N *= 28 in all cases*

	Normal	Back Turned	Third Party
Pointing	3.54* (1.170)	3.50* (1.000)	3.21 (0.833)
Gazing	3.29 (1.049)	3.36 (1.096)	3.29 (1.049)

Again, in order to compare conditions, we then conducted a repeated measures ANOVA with the within factor cue (pointing vs. gazing) and the between factors order (pointing cue first or gazing cue first) and condition. The ANOVA produced a significant interaction of the two between factors order and condition ($F_{1,78}$ = 3.24, p = .045). No other factors or their interactions produced a significant result. We therefore compared the conditions, looking at the two orders (pointing first vs. gazing first) separately. A one-way ANOVA revealed that there was no effect for condition for the dogs which received the pointing cue first ($F_{2,41}$ = 1.94, p = .16). The same was true for the dogs which received the gazing cue first ($F_{2,41}$ = 1.69, p = .19). To see if age had an effect on subjects' success in the three different conditions, we correlated age against success rate in each of the three conditions separately. None of the correlations reached significance.

To test for learning we compared the first half of trials with the second half of trials for each condition and pointing and gazing separately. None of the comparisons reached significance, suggesting that no learning took place during the study.

Discussion

In line with other studies of dog puppies (e.g. Hare *et al.*, 2002; Riedel *et al.*, 2008), in this study we found that the puppies used the gestures based on basically the same features as the adult dogs. We tested the puppies roughly four to five weeks after they opened their eyes, and so it is not likely that during those weeks major learning took place. Also the puppies tested were still with their mothers and not yet in human families, again making learning from humans highly unlikely and indeed there was no correlation with dogs' success rate and their age. These results also demonstrate impressively that the puppies do not seem to simply follow the hand as a stimulus as has been proposed by some (Wynne, Udell & Lord, 2008; Udell, Dorey & Wynne, 2008). Instead, as for the adult dogs, additional cues, e.g. eye contact, are a necessary accompaniment.

General discussion

The current studies provide strong support for the idea that through the process of domestication, dogs have come to be attuned to some basic aspects of human communication. Some researchers have argued against this idea, instead suggesting that in most studies dogs are simply doing what undomesticated animals can learn to do in interaction with humans fairly readily (e.g. Wynne *et al*., 2008; Udell *et al*., 2008). But the current studies show that domestic dogs treat the same behavior differently if it is, or is not, accompanied by human ostensive cues indicating that the communicative act is directed at them. This effectively eliminates reductive explanations in which dogs learn to treat specific human behaviors as discriminative cues leading to rewards in experiments – with no comprehension of the communicative process.

Clearly the most important ostensive cue used by dogs to determine whether a human's act is communicative and whether it is directed specifically to them is eye contact. In the first study, eye contact was the major distinguishing feature between the intentional and non-intentional conditions, and in the second and third studies eye contact was clearly the strongest cue when all the different conditions were compared. The importance of eye contact during dog–human interactions in general has been suggested by others (Gacsi *et al*., 2004; Miklosi *et al*., 2003; Soproni *et al*., 2001; Viranyi *et al*., 2004), but in the current studies we have demonstrated its crucial role in human–dog communication specifically. These results are in line with the results of Viranyi *et al*. (2004), who found that dogs obeyed a command more often when the owner established direct eye contact as compared to other conditions in which no eye contact was established.

But eye contact is not the only sufficient cue. In the second study dogs successfully followed human gestures when the human's body and eyes were turned away from them, with even some evidence that calling any name is sufficient – possibly based on the high pitch typically used in addressing dogs. Indeed, the communicative gesture led the dogs to find the food successfully in basically all of the conditions in the second and third studies, but much less in the case in which another individual was clearly the intended recipient of the communication. This indicates that dogs' sensitivity to the intentional dimension of human communicative gestures is not an artifact of some species-specific, inflexible reactions to specific cues, but rather constitutes a more general and flexible comprehension. This may be based on a fairly restricted set of cues, such as eye contact and high-pitched vocalizations, but it is no coincidence that these are the very same cues that human infants use to determine when someone is communicating to them (Csibra, 2003).

The performance of the dog puppies in the fourth experiment is striking. As in other studies with young puppies (e.g. Hare *et al*., 2002; Riedel *et al*., 2008), the finding was that performance is very similar to that of adult dogs – even though these puppies had had very little experience with humans. This suggests that traditional learning processes are not the major factor in the ontogenetic emergence of these communicative skills in dogs. One implication for human development is that special attunement to such things as eye gaze and high-pitched voices may in principle emerge in ontogeny without extended learning.

Nevertheless, the current results also suggest that dogs' comprehension of the communicative act differs from that of young children in important ways as well. While young children from 18 months of age see gestures directed to others as still being informative for themselves (Gräfenhain *et al*., 2009), dogs do so much less. This might reflect young children's understanding of the communicative act as informative – so that anyone may take advantage of the information being communicated – whereas dogs may understand the communicative act as imperative – in which case the individual being addressed is the most relevant one. Another, related possibility is that human children may understand social interactions in a generalized way (from a 'bird's eye view') in which they automatically assume that any individual (including themselves) may play any role, or take any perspective, in a social interaction (Tomasello, Carpenter, Call, Behne & Moll, 2005) – making the interpretation of third party interactions straightforward. Dogs may lack this general social-cognitive ability, perhaps in part because in the unusual situation of dog–human communication the dog mostly plays only the role of recipient – with dogs' active use of communicative signals toward humans (especially with respect to external referents) being extremely limited, and not of the same form as the signals they receive from humans. Interestingly, children also use their abilities to learn new pieces of conventional language by eavesdropping on others' conversations (Akhtar, 2005; Akhtar *et al*., 2001). It would be interesting to know whether dogs who are already skilful in learning human words (Kaminski, Call & Fischer, 2004; Kaminski, Fischer & Call, 2008) could learn new words in this indirect way as well (since there is some evidence that they can make reputational judgments by observing third-party interactions; Marshall-Pescini, Passalacqua, Ferrario, Valsecchi & Prato-Previde, 2011).

In any case, in the current studies we have established that dogs are tuned in to several important dimensions of human cooperative communication, and that this is based on many of the same ostensive cues used by human infants and young children. A close comparison of similarities and differences in dog–human and infant–adult communication in humans could conceivably lead us to a greater understanding of the role played by different social-cognitive processes – and different motives for cooperation – in the two species.

Acknowledgements

We are especially grateful to the dog owners for their cooperation. We thank all student assistants with help during data collection and reliability coding, namely Susanne Mauritz, Katrin Schumann, Christel Schneider, Theresia Klein, Marie Nitzschner, Sabrina Viereckel, Dennis Golm, Eileen Glabsch, Marie Nitzschner and Jana Reifegerste. The reported experiments comply with all laws of the country (Germany) in which they were performed. Juliane Kaminski was financially supported by a grant from the Volkswagenstiftung.

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Received: 31 March 2011
Accepted: 19 September 2011