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ORIGINAL PAPER

Gaze alternation in dogs and toddlers in an unsolvable task: evidence of an audience effect

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Abstract Dogs have been shown to use human-directed gazing behaviour and gaze alternation in numerous contexts; however, it is still unclear whether this behaviour can be considered an intentional and referential communicative act. In the current study, adult dogs and preverbal toddlers were tested using the classic unsolvable task paradigm, but varying the attentional stance of the participating audience (the experimenter and the caregiver). The aims were to assess (1) whether dogs and toddlers would use gaze alternation behaviour in similar manners when the task became unsolvable, and (2) whether both dogs and toddlers would take into account the attentional stance of the audience when initiating a communicative interaction. Results indicated that both toddlers and dogs increased their gaze alternation behaviour between the apparatus and caregiver when the task became unsolvable, and toddlers also showed an increase in pointing behaviour. Furthermore, both species showed a capacity to take into account the attentional stance of the audience when manifesting gaze alternation behaviours towards them. Taken together, these results suggest that gaze alternation is both an intentional and referential communicative act and that both species can take into account the need for audience attention when communicating with them.

Keywords Dogs · Toddlers · Attention · Communication · Gaze alternation

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Introduction

Although dogs have become an important model in comparative cognition studies for a number of reasons, amongst which the suggestion that convergent evolutionary mechanisms may have resulted in similar cognitive adaptations (Hare et al. 2002; Miklósi et al. 2003; Hare and Tomasello 2005), relatively few studies have directly compared human infants and dogs on the same tasks.

The handful of studies presenting a direct comparison has focused mostly on the *comprehension* of communicative cues (Lakatos et al. 2009; Topál et al. 2009; Kaminski et al. 2011). For example, Lakatos et al. (2009) found that dogs' understanding of human referential communication is on a par with 2- to 3-year-old children and Kaminski et al. (2011) showed that similarly to children, dogs will follow a pointing gesture more if it is done intentionally rather than accidentally. Only one study, to our knowledge, has directly compared dogs and infants in their *use* of communicative cues. Virányi et al. (2006) presented a nonverbal test of knowledge attribution where dogs and 2.5-year-old children were required to 'show' a helper the location of an out-of-reach desired toy and the tool needed to obtain it. Results showed that both children and dogs were sensitive to the presence/absence of the helper when the objects were being hidden but the latter had specific difficulties in indicating the location of the tool necessary to obtain the toy.

These studies indicate that dogs behave in ways at least functionally similar to children; however, there are doubts as to whether the cognitive mechanisms underlying the behavioural similarities between these two species are the same. In fact, although it has often been assumed, especially when dealing with the child–chimpanzee comparison, that if similar behaviours are manifested by both species, then it is probable that the same cognitive mechanisms are involved, since the broadening of comparative cognition to species ever more distant from our own, this particular assumption has been questioned. At least one study involving the direct comparison between dogs and children nicely highlights this point. Although Topál et al. (2009) found that both dogs and infants showed a perseverative error in the A-not-B task, whereas infants continued manifesting the error also in the presence of a novel person, dogs showed no such effect. The authors interpret these results as suggesting that whereas infants generalized the message across demonstrators, dogs related the communicative message to a specific context, interpreting the gestures as imperative rather than pedagogical.

The flipside of this argument is that, whereas results from studies on infant communication are often interpreted by referring to mentalistic explanations, if similar results are found with a non-human animal they are more likely to be interpreted with more simple associative explanations. As has been suggested by a number of authors, a more low level approach may suffice to explain results from the infant literature also (Reeb-Sutherland et al. 2012; Butterworth 1991; Corkum and Moore 1998; Moore et al. 1997). Hence, the direct comparison between dogs and infants, using the same procedures and analyses, may help to inform questions relating to the functional similarities and underlying mechanisms of observed behaviours.

Thus, the first aim of the current study was to directly compare preverbal infants and pet dogs in a classic task, the unsolvable task paradigm, which has been used to elicit and measure gaze alternation (as a communicative behaviour) in dogs and wolves (Miklósi et al. 2003).

Human-directed gazing, and gaze alternation in particular, has been considered in these contexts to be a requesting gesture whereby dogs, having realized they can no longer obtain the desired object, turn back to their human partner to ask for intervention (Miklósi et al. 2000, 2003, 2004; Gaunet 2010; Virányi et al. 2006; Passalacqua et al. 2011; Marshall-Pescini et al. 2009). In the infant literature, a distinction has been drawn between protoimperative and protodeclarative gestures, or in other words requesting and joint attention gestures. The former are considered instrumental, used with the intention to regulate another's behaviour towards completing a specific task, whereas the latter are considered deictic, serving to direct and focus an adult's attention on an object or event (Bates et al. 1975, 1979; Zinober and Martlew 1985). In infants, pointing to an object and the propensity to show an object to an adult with gaze alternation emerges around 9–10 months of age, becoming more frequent between 12 and 15 months (Bates et al. 1975, 1979; Tomasello 1995, 1999; Carpenter et al. 1998).

Although a number of authors have maintained that dogs' gaze alternation in this context is equivalent to infants' requesting behaviour (e.g. protoimperative pointing) and hence represents an intentional and referential gesture, there is currently some debate as to whether in fact it may not rather be the result of a reinforced behaviour under external cues. A number of studies seem to support an associative interpretation of dog's human-directed gazing behaviour, since for example it has been shown to be sensitive to specific training regimes and a dog's prior life experience (e.g. Bentosela et al. 2008; Marshall-Pescini et al. 2008, 2009). Furthermore, a recent study has shown that although dogs may use their gaze to request an object they themselves desire, they have greater difficulty in doing so to inform of the location of an object desired only by their human partner (more specifically, they do so with their owner but not with a friendly stranger: Kaminski et al. 2012). This lack of flexibility may support the notion that gaze alternation is a behaviour elicited by specific trigger situations as a way to use humans as social tools to obtain a desired goal (Gomez 1990, 2005) and that dogs have learned to do so during their daily interaction with people.

However, there is also some support for a view of dogs' human-directed gazing and gaze alternation behaviour in terms of referential and intentional communication. A number of authors have proposed that referential and intentional communicative acts should fulfil the following operational criteria: (1) presence of successive visual orientation between partner and distant/inaccessible object, (2) occurrence of apparent attention-getting behaviours, (3) an audience whose presence elicits the behaviour, (4) an influence of the attentional state of the observer on the exhibition of the behaviour, (5) persistence in, and (6) elaboration of the communicative behaviours when the partner is not responding (Bates et al. 1975, 1979; Leavens and Racine 2009; Leavens et al. 2005).

Dogs have been shown to use gaze alternation between their human partner and an unreachable, desired object (Miklósi et al. 2000) and they do so using a variety of attention-getting behaviours (Marshall-Pescini et al. 2009; Gaunet 2008); these behaviours have been shown to occur more in the presence than in the absence of an audience (Virányi et al. 2006); and a study by Gaunet (2010) revealed that dogs who received an unexpected toy rather than their expected favourite one showed persistence (but not elaboration) in their requesting behaviour. Furthermore, a more recent study has shown that dogs may also look back to the owner in a non-requesting context. Merola et al. (2012a) found that dogs look back to their owner (and alternate their gaze from owner to object) in a social referencing paradigm, that is, when confronted with a strange and potentially scary object. In fact, recent results also suggest that the owner's positive versus negative reaction to the object determines the dog's behaviour towards it (Merola et al. 2012b) but not their behaviour towards a stranger also present in the room, further supporting the idea that both owner and dogs were sharing attention and communication on that specific object.

Interestingly, however, a number of authors have moved away from a purely mentalistic versus associative/learned interpretation of social cognition, emphasizing that experience is in fact necessary for the emergence of any form of mentalistic understanding (Corkum and Moore 1998; Leavens and Racine 2009; Reddy and Morris 2004, but see also Call 2001). On this view, the associative interpretation of gaze alternation (or pointing) is not in conflict with the notion that these gestures are in fact examples of intentional communication. Rather, it is accepted that infants need to go through a learning process which allows them to perceive some of the consequences of referential gestures (e.g. where their pointing gesture is reinforced by mum handing over the toy), and the relevant question then is when the use of such gestures reveals the acquisition of a more in-depth understanding of the observer's mental state.

For example, in infants, Striano and Rochat (2000) found that in a social referencing paradigm, 7-month-old infants looked to the adult after the appearance of the strange object irrespective of the adult's attentional stance. However, at 10 months, children modulated their looking behaviour on the basis of the adult's attentional focus. Hence, according to these authors, an important developmental change takes place at 10 months, when an intentional stance comes to underlie the infant's referential looking pattern and reveals their burgeoning understanding of 'attention' as a mental state. This is also in line with studies eliciting pointing, which have shown that it is around 12 months of age that infants modify their use of this behaviour depending on the audience's attention and engagement in the task (Liszkowski et al. 2004).

A number of studies have shown that dogs are capable of discriminating between an attentive and inattentive individual based on a number of behavioural cues (Bräuer et al. 2004; Call et al. 2003; Gácsi et al. 2004; Miklósi et al. 2000; Schwab and Huber 2006; Soproni et al. 2001, 2002; Virányi et al. 2004), though they do not always do so (Kaminski et al. 2009; Udell et al. 2011). However, only one study set out to investigate whether dogs' human-directed gazing may in fact be modulated according to the recipient's attentional stance (i.e. facing with eyes open, facing with eyes closed, back-turned) but found no evidence of dogs' being able to flexibly adapt their gazing behaviour in the different situations (Hare et al. 1998). Given the number of studies showing dog's sensitivity to attention in other contexts, the lack of results in Hare et al.'s study may be due to the fact that only one dog was tested. Another possibility is that, as pointed out by a number of authors, a species may be sensitive and attend to behavioural cues evidencing another's attentional state, but be unable to direct another's attention to the target; the latter in fact requires a more in-depth understanding that the mental state of attention can be directed not just at the subject itself, but at external objects/events (Gomez 2005; Hattori et al. 2007).

Hence, the second aim of the current study was to present toddlers and dogs with the same situation to assess whether they would similarly modify their use of gaze alternation depending on the attention of the audience. Dogs' flexibility in adapting their gaze alternation response depending on the audience's attentional stance would suggest that gaze alternation is in fact a communicative gesture, that dogs have at least a basic understanding that for it to be successful the audience needs to be attentive and that dogs have some appreciation that another's attention can in fact be directed to an external object.

In sum, by comparing infants and dogs on the same task, we aimed to assess whether gazing would be used in the same way by both species once the task become unsolvable. Furthermore, by varying the attentional stance of the audience (depending on the subject's group allocation), we aimed to assess whether dogs and toddlers would change their attention-getting and directing strategies accordingly, and whether they would do so in similar ways. Considering results from previous studies on human-directed gazing behaviour and attention understanding in dogs, we predicted that they would show an increase in this behaviour when the task became unsolvable and that gaze alternation would be directed more towards the attentive versus inattentive individual. Similar results were predicted also for toddlers.

Methods

Subjects

Fifty-three dog–owner dyads were recruited based on the *Canis sapiens Lab* (University of Milan) database. The dog sample consisted of 19 males and 34 females whose ages ranged from 1 to 10 years (mean = 6.5 years, SD = 3.3). Forty dogs were pure breed and 13 mixed breed (Pure bred: 2 Dachshunds, 2 Scottish collies, 1 Brittany spaniel, 2 Beagles, 2 Flatcoated retrievers, 1 Whippet, 3 Golden retrievers, 3 Poodles, 2 American Staffordshire terriers, 2 German shepherds, 2 Boxers, 2 Jack Russells, 2 pugs, 1 pincher, 6 Border collies, 1 Miniature Schnauzer, 1 Lurcher, 5 American cockers). All the dogs were kept for companionship, lived within the human household and had either no or only basic training experience. A number of dogs had participated in other studies by our group but not studies using the experimental paradigm adopted here.

Fifty-nine nursery school children were recruited from 10 different nursery schools. The children consisted of 29 males and 30 females with an age range between 15 and 27 months (mean = 19.2 months, SD = 3.3). Following a presentation of the procedures and aims of the study, written parental consent was obtained.

Dogs and children were semi-randomly (counterbalancing as much as possible for age and sex within each species) allocated to either one of two groups: the experimenter attentive (Exp-Att) or the experimenter back-turned (Exp-Back) group.

Apparatus

The apparatus consisted of a transparent 15 × 15 cm lidless plastic container (commercial Tupperware), placed upside down over a desirable toy or food (ball or a few bits of smelly kibble for dogs, a colourful toy snake for children) on a 35 × 60 cm wooden board. We started out testing dogs with a ball ($n = 7$); however, the number of dogs motivated by toys in our database was rather limited; hence, we switched to using food. Statistical comparison between dogs tested with the ball and tested with food revealed no differences; hence, they are all included in the sample. The container could either be moved off the platform or overturned to obtain the toy/food (Fig. 1) or it was securely screwed to the board, so the toy/food could not be reached. The apparatus was the same for both species.

Procedure

Dogs were tested in a relatively bare testing room at the Canis sapiens Laboratory, University of Milan. Children were tested in a quiet and familiar room at their nursery school, during school hours. All tests were video-recorded using a wide-angle video camera positioned on a tripod located so as to maintain a full view of all the actors involved.

Prior to testing, the owner was asked to enter with his/her dog into the testing room and the dog was allowed to freely explore the environment whilst the experimenter described the procedure to the owner. Similarly, children were allowed a few minutes to look around the room whilst the researcher went through the procedure with the nursery teacher. For ease of presentation, the owner and nursery teacher will henceforth be labelled as ‘caregiver’. The experimenter was always a female; however, three people rotated testing both children and dogs.

The test consisted of three consecutive solvable trials in which dogs and children could obtain the toy/food by manipulating the container. The solvable trials were immediately followed by an unsolvable trial in which the container was fixed to the wooden board and thus obtaining the toy/food became impossible. Both the experimenter and the caregiver were present during all trials. In the case of toddlers, both adults were seated on the floor, on adjacent sides of the board, whereas for dogs, although the same spatial arrangement was adopted, the adults were in a standing position (see Fig. 1).

For both species, the subjects sat (or stood in the case of dogs) immediately in front of the caregiver, whilst the experimenter showed the subject the toy/food and placed it under the container. Subjects were then allowed to go (released by the owner in case of dogs) and told by the experimenter to ‘Get it’ (for both species). Infants were found to be particularly shy in approaching the task; hence, following a number of infants refusing to approach the apparatus in a pilot study, we modified the procedure slightly so that in the first two solvable trials, the caregiver was told she could verbally encourage the infants if they

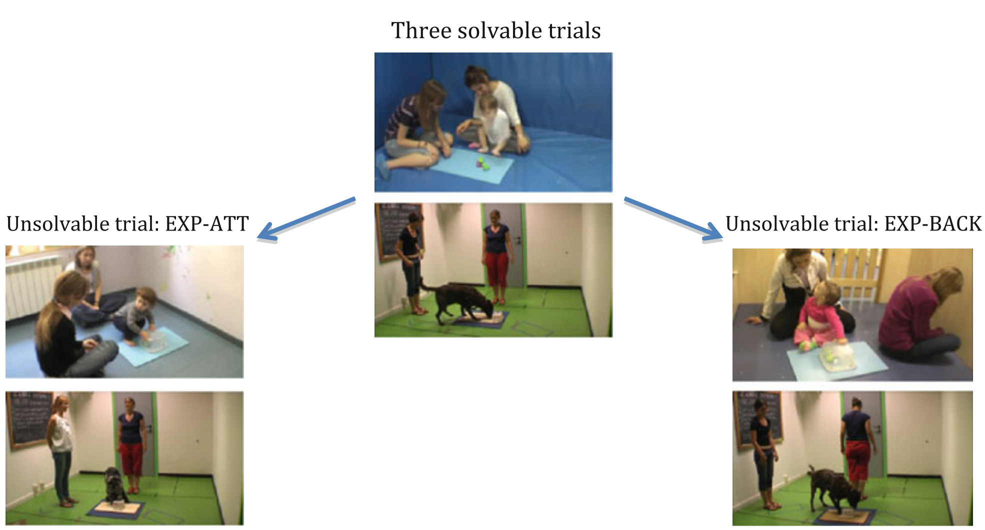

Fig. 1 Photographs of the experimental setup for dogs and toddlers

were reluctant to approach the box. No such encouragement was necessary with the dogs.

For all subjects, the solvable trials were interrupted after a maximum of 1 min or as soon as the child/dog obtained the toy/food, after which a new solvable trial started. A total of three solvable trials were presented. Only subjects that succeeded at least twice in obtaining the toy/food in the solvable trials were tested in the single unsolvable one. This criterion was set to ensure that all subjects learned the task before going on to the unsolvable trial.

In the unsolvable trial, the apparatus was identical but the container was screwed to the board, so the toy/food could not be reached even though it was clearly visible inside. At the start of the trial, the experimenter placed a hand over the container lightly tapping it then adopted a specific position according to group allocation. The unsolvable trial lasted 1 min.

Whereas the solvable trials were identical for all subjects, the unsolvable trial differed depending on group allocation. In the experimenter attentive group (Exp-Att), after tapping the container, the experimenter adopted the same position as in the solvable trials. During the trial, the experimenter and caregiver remained standing/sitting silently at the two sides of the wooden board, looking towards the container and not paying attention to the subjects. If the subjects made eye contact with them, they would briefly smile encouragingly without however saying anything and looking back to the container. In the experimenter back-turned group (Exp-Back), after tapping the container, the experimenter sat/stood in the same location as in the solvable trials but with her back turned to the container. The caregiver was asked to behave as in the solvable trials, that is, to sit/stand quietly looking towards the container, not paying attention to the subject. If the subjects made eye contact, the caregivers were told to briefly smile encouragingly without however saying anything and then look back to the container. Similarly, if the subject went around the experimenter and established eye contact with her, she would smile briefly and then return to looking straight ahead.

In an initial pilot study, children and dogs were also tested with both caregiver and experimenter turning their back to the container in the unsolvable trial; however, children showed signs of distress and refused to interact with the container: this procedure was hence dropped from the final study. This is similar to Striano and Rochat's (2000) results where dropout rates for 10-month-old infants in the experimenter 'look-away' group were double (68 %) compared to that in the experimenter 'look-towards' group (33 %) because of infant 'discomfort'.

Data analysis

Digital video footage was taken for all trials and the Solomon Coder (beta 091110, copyright 2006–2008 by András Péter, developed at ELTE TTK Department of Ethology, Budapest, Hungary) was used to record the subject's behaviour during testing. Based on previous studies (Marshall-Pescini et al. 2009), the mutually exclusive behavioural categories outlined in Table 1 were used.

Furthermore, in the final solvable and the unsolvable trial, the subject's two-way Gaze alternation behaviour between a) experimenter and container and b) caregiver and container were analysed. A gaze alternation was defined as a look to the object immediately followed by a look to the person (or vice versa). For children, we also recorded the frequency of pointing behaviour and the percentage of pointing behaviour exhibited together with, immediately before or immediately after a gaze at the person.

EC coded the data from video and a random selection of trials (20 %) was coded by CP & IM; inter-observer reliability on frequency of behaviours was calculated using Cohen's K (gazing at experimenter, gazing at owner, interacting with the container, interacting with experimenter all above 81 %); inter-observer reliability for gaze alternation was calculated for the unsolvable trials (experimenter apparatus 72 %; owner apparatus 88 %).

To test whether gaze alternation was used more when the task became unsolvable than when subjects were proficient at solving the task alone (when both experimenter and caregiver were attentive), we compared the frequency of this behaviours divided by the total trial time (rate) in the last (third) solvable versus the unsolvable trial. Comparisons were done separately for each species using a Wilcoxon test.

To test the effect of species, group, sex and tester identity on the behaviours exhibited during the unsolvable test, we used a generalized linear model (GLM). Since sex and tester identity were not significant, these variables were not included in the final model. The behavioural categories were considered response variables whilst the species and group allocation (Exp-Att vs. Exp-Back) were included as independent factors. All post hoc comparisons were Bonferroni corrected.

Results

Eleven of the 53 dogs tested and 12 of the 59 children tested were removed from the analysis because they did not meet criteria for inclusion (i.e. two out of three solvable trials in which the subject obtains the toy/food). This resulted in the following group composition: experimenter attentive: 21 dogs (14F and 9M) and 22 toddlers (13F and 9M) versus experimenter back-turned: 21 dogs (12F and 9M) and 26 toddlers (13F and 13M).

Table 1 Behavioural categories and descriptions

Behaviour	Description
Gazing at the caregiver	The subject does not approach the caregiver, but from a stationary position turns/lifts its head towards the person's face
Gazing at the experimenter	The subject does not approach the experimenter, but from a stationary position turns/lifts its head towards the experimenter's face (in the experimenter attentive group) and/or back (in the experimenter back-turned group)
Gazing at the container	The subject from a stationary position turns/lifts its head towards the container
Interaction with the caregiver	The subject approaches and establishes physical contact with any body part of the caregiver, (for dogs, for example, rubbing, nosing, licking, pawing or jumping up; for children, for example, placing a hand/patting/nudging the person's leg/arm/hand/body). These behaviours were considered potential attention-getters
Interaction with the experimenter	The subject approaches and establishes physical contact with any body part of the experimenter, (for dogs, for example, rubbing, nosing, licking, pawing or jumping up; for children, for example, placing a hand/patting/nudging the person's leg/arm/hand/body). These behaviours were considered potential attention-getters
Interaction with the container	Any behaviour involving the subject being physically in contact with the container

Gaze alternation

Overall, most dogs (73 %) and most toddlers (77 %) alternated their gaze from the container to one of the people present (or vice versa) when the task become unsolvable (see Table 2).

To evaluate whether dogs and toddlers used gaze alternation in a similar manner when the task became unsolvable, we compared the rate for this behaviour in the last solvable versus unsolvable trial for both species in the Exp-Att groups. Both dogs and toddlers alternated their gaze more in the unsolvable than the last solvable trial from apparatus to caregiver (Wilcoxon: caregiver-container dogs: $N = 22$, $T = 276$, $P = 0.003$; toddlers: $N = 22, T = 15, P = 0.034$). However, there was no increase in gaze alternation between apparatus and experimenter in either toddlers or dogs (experimenter-container dogs: $N = 22, T = 63, P = 0.89$; toddlers $N = 22$, $T = 59, P = 0.4$) (Fig. 2).

To evaluate the subjects' performance when the experimenter became inattentive (in the unsolvable trial), we considered both the number of subjects in each species performing gaze alternation behaviours and the frequency of occurrence of this behaviour in the different groups.

Fewer toddlers in the Exp-Back alternated their gaze between the container and the experimenter than in the Exp-Att group ($\chi^2_1 = 3.8, P = 0.05$) and significantly more toddlers alternated their gaze between the caregiver and the container in the Exp-Back than the Exp-Att group ($\chi^2_1 = 4.24, P = 0.04$). No such differences emerged in the dog population.

In the experimenter attentive groups, significantly fewer toddlers than dogs alternated their gaze between container and caregiver ($\chi^2_1 = 6.08$, $P = 0.01$). No such difference emerged between species in the experimenter back-turned groups. However, whereas 7 (of 21) dogs (range 1–5 times; mean 2.1) in the Exp-Back group went around the experimenter and looked at their face (without alternating their gaze between them and the container, but simply gazing up at her) only 3 (of 25) toddlers in the group did so (range 1–3; mean 1.6) ($\chi^2_1 = 3.05, P = 0.08$).

In the unsolvable trial, no main effect of species (Wald $= 0.72$, $P = 0.4$) but a main effect of group (Wald $= 6.12$, $P = 0.01$) with no interaction (Wald $= 0.06$, $P = 0.81$) emerged for the frequency of gaze alternating between container and experimenter (including looking at both front and back). Both species alternated more if they were in the Exp-Att (mean: dogs = 2.2; toddlers = 1.7) versus Exp-Back group (mean: dogs = 1.1; toddlers = 0.8) (Fig. 3).

Table 2 Gaze alternation between container and person (or viceversa) in the unsolvable trial for dogs and toddlers in the Exp-Att and Exp-Back groups

Groups	Species (Total *N*)	Exp (back)	Exp (front)	Caregiver	No one
Exp-Att	N. Dogs (22)	–	13 (59 %)	11 (50 %)	6 (27 %)
	Mean and range		(4; 1–10)	(2.2; 1.8)	
	N. Toddlers (22)	–	15 (68 %)	5 (23 %)	5 (23 %)
	Mean and range		(2.6; 1–5)	(1.4; 1–3)	
Exp-Back	N. Dogs (21)	11 (52 %)	3 (14 %)	10 (48 %)	
	Mean and range	(1.4; 1–3)	(2.3; 1–3)	(1.4; 1–3)	
	N. Toddlers (25)	9 (36 %)	2 (1 %)	13 (52 %)	
	Mean and range	(2.1; 1–6)	(1)	(2.8; 1–6)	

Furthermore, no main effect of species (Wald = 0.14, $P = 0.7$) or group (Wald = 0.81, $P = 0.4$) but a significant interaction between the two (Wald = 8.09, $P = 0.004$) emerged for the frequency of gaze alternating between the container and the caregiver. Dogs in the Exp-Att and Exp-Back groups alternated between the container and the caregiver equally often (mean Exp-Att = 1.3 Exp-Back = 0.7; $P = 0.3$) but dogs in the Exp-Att group did so significantly more than children in the Exp-Att group ($P = 0.001$). Toddlers in the Exp-Att (mean = 0.3) group, however, gaze alternated significantly less between apparatus and caregiver than toddlers in the Exp-Back group (mean = 1.5; $P < 0.001$) (Fig. 3).

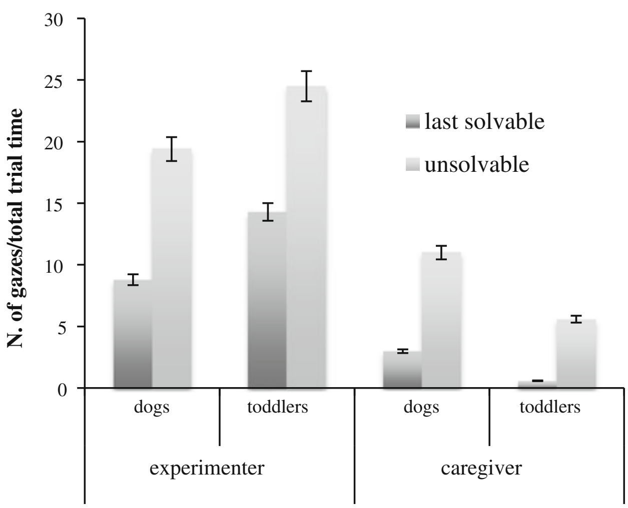

Fig. 2 Mean frequency/total trial time (and 95 % CI) of gazing behaviours towards the experimenter and the caregiver performed in the last solvable and unsolvable trials by toddlers and dogs in the Exp-Att groups

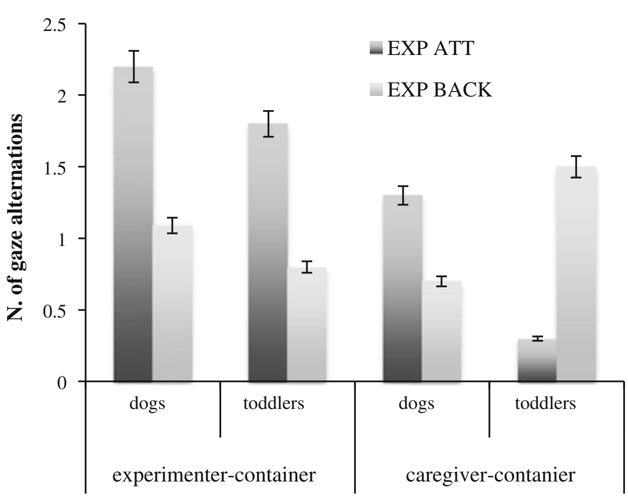

Fig. 3 Mean frequency of gaze alternation (and 95 % confidence interval) between container experimenter and container caregiver for dogs and toddlers in the experimenter attentive (Exp-Att) and experimenter back (Exp-Back)-turned groups (in the unsolvable trial)

Gazing behaviours

To evaluate whether dogs and toddlers gazed at the people present in the room in a similar manner when the task became unsolvable, we compared the frequency/total trial time in the last solvable versus unsolvable trial for both species in the Exp-Att groups. Both dogs and toddlers gazed more often towards the experimenter and the caregiver in the unsolvable than the last solvable trial (Wilcoxon: dogs $N = 22$: experimenter $T = 213.5$, $P = 0.005$; caregiver $T = 170$, $P < 0.003$; toddlers $N = 22$: experimenter $T = 154.5$, $P < 0.02$; caregiver $T = 55$, $P < 0.005$).

In both species, subjects in the inattentive group took longer to look at the experimenter (Main effect group Wald = 110.34, $P < 0.001$; no effect of species Wald = 0.12, $P = 0.7$; nor interaction Wald = 1.19, $P = 0.3$) and gazed at her less frequently (Main effect of group Wald = 64.32, $P < 0.001$; no effect of species Wald = 0.39, $P = 0.53$; no interaction Wald = 0.18, $P = 0.7$) and for a shorter time (Main effect group Wald = 6.44, $P = 0.01$; no effect of species Wald = 0.11, $P = 0.74$; no interaction Wald = 0.1, $P = 0.74$) than subjects in the attentive group (Table 3).

A main effect of group (Wald = 4.58, $P = 0.03$) not species (Wald = 0.16, $P = 0.68$) and a significant interaction between the two (Wald = 13.8, $P < 0.001$) emerged for latency to gazing at the caregiver. In the experimenter attentive group, toddlers took longer than dogs to look at the caregiver ($P = 0.02$) but this species difference did not emerge in the experimenter back-turned groups. Furthermore, toddlers in the experimenter inattentive group looked at the caregiver significantly faster than toddlers in the experimenter attentive group ($P < 0.001$) but no such difference emerged in dogs.

No main effect of species (Wald = 0.46, $P = 0.49$) emerged in the frequency of gazing at the caregiver; however, a marginal effect of group (Wald = 3.7, $P = 0.05$) and significant interaction between the two emerged (Wald = 9.47, $P < 0.001$). Dogs looked at the caregiver more frequently than toddlers in the experimenter attentive condition ($P = 0.05$) but not in the back-turned condition. Whereas dogs in the two groups did not differ in

Table 3 Mean latency, frequency and duration of 'gazing at the experimenter' for toddlers and dogs in the attentive versus inattentive group

Group	Species	Latency (s)	Frequency	Duration (s)
Exp-Att	Dogs	15.5	4.4	9
	Toddlers	12.8	4.3	9
Exp-Back	Dogs	49.65	2.4	2.3
	Toddlers	54.85	2.7	0.5

the frequency of looking at the caregiver, toddlers' looked more at the caregiver in the experimenter back-turned versus experimenter attentive condition ($P < 0.002$).

No main effect of species (Wald = 0.09, $P = 0.75$) nor group (Wald = 2.86, $P = 0.09$) emerged in the time spent looking at the caregiver; however, there was a significant interaction between the two (Wald = 5.38, $P = 0.02$). Whereas dogs in the two groups did not differ in the time spent looking at the owner, toddlers looked more at the caregiver in the experimenter back-turned versus experimenter attentive condition ($P = 0.02$) (Table 4).

Other behaviours

No effect of either sex, species or group emerged in either the frequency (sex: Wald = 0.34, $P = 0.9$, species: Wald = 0.03, $P = 0.86$, group: Wald = 0.01, $P = 0.9$) or the duration (sex: Wald = 0.42, $P = 0.5$, species: Wald = 0.02, $P = 0.88$, group: Wald = 0.93, $P = 0.3$) of interaction with the experimenter.

Only a main effect of species (frequency: Wald = 17.55, $P < 0.001$; duration: Wald = 21, $P < 0.001$) but no interaction with group (frequency: Wald = 0.66, $P = 0.44$; duration: Wald = 0.33, $P = 0.6$) emerged for frequency and duration of interaction with the container, with children overall interacting with the container more frequently (mean frequency: toddlers = 4.4, dogs = 2.9) and for longer (mean duration: toddlers = 30.5, dogs = 17) than dogs.

Analyses of the frequency of interaction with the caregiver revealed a main effect of species (Wald = 6.6, $P = 0.01$) but not group (Wald = 1.9, $P = 0.17$) and no interaction (Wald = 0.82, $P = 0.36$). In the duration of this behaviour, a difference was found only between species (species: Wald = 6.9, $P = 0.009$; group: Wald = 0.25, $P = 0.87$; interaction: Wald = 1.02, $P = 0.31$) with toddlers interacting for significantly longer with the caregiver than dogs (mean: toddlers 2.2 vs. dogs 0.4).

Pointing and utterances in toddlers

Considering the Exp-Att group, in the last solvable trial, only one toddler out of 22 pointed (once) to the container, whereas six toddlers did so (range 1–7; mean 2.5) when the task became unsolvable ($\chi^2_1 = 3.5$, $P = 0.06$). In the Exp-Back group, again only one toddler pointed (once) at the container in the last solvable trial, whereas 6 toddlers did so in the unsolvable trial (range 1–3; mean 2); and in this group, 6 toddlers also pointed at the experimenter's back (range 1–3; mean 2).

Considering both groups together, of a total 26 pointing gestures performed by toddlers in the unsolvable trial, 11 were accompanied by a simultaneous look to either the experimenter (1) or the caregiver (10), whereas 10 were either immediately preceded and/or followed by a look either to the caregiver (3) or the experimenter (7).

Although in this study we focused on preverbal infants, our age range was quite wide: hence in an attempt to glean more about the potential motivation behind the toddlers' pointing and gaze alternation gestures, we looked at the verbal utterances expressed by toddlers when the task became unsolvable trial. Including subjects from both groups, a total of 10 toddlers uttered intelligible words, 6 of these were either 'Oh! No!' or just 'No!' and the remaining 4 utterances were slightly more articulated but along the same lines 'Not open here!', 'Not come!', 'Not out' and 'But, But No!'; only one child, after similar utterances added 'Get it'.

Table 4 Mean latency, frequency and duration of 'gazing at the caregiver' for toddlers and dogs in the attentive versus inattentive group

Group	Species	Latency (s)	Frequency	Duration (s)
Exp-Att	Dogs	27.2	2.6	9
	Toddlers	44.4	1	9
Exp-Back	Dogs	34	2.1	4.5
	Toddlers	20	3	5.6

Discussion

The aim of the current study was to investigate whether dogs' gaze alternation behaviour in the unsolvable task paradigm can be considered an intentional and referential communicative act, by assessing whether it would be used in similar ways by dogs and toddlers once the task become unsolvable, and whether it would vary similarly according to the attentional stance of the audience. The study sought to further explore whether dogs would be sensitive to the fact that for their communicative gesture to be effective, their audience had to be attentive to them and to the object of their communication.

Overall, considering that both dogs and toddlers increased their gaze alternation behaviour between apparatus and caregiver when the task became unsolvable and showed more gaze alternation towards the attentive versus inattentive individual, the present results lend support to the idea that gaze alternation in dogs is both an intentional and referential communicative action.

More specifically, both dogs and toddlers used gaze alternation between the container and the caregiver at a higher rate in the unsolvable compared to the last solvable trial, suggesting that this behaviour was used flexibly, depending on the context. Furthermore, both dogs and toddlers appeared to take into account the attentional stance of the actors, since they alternated their gaze less if the experimenter had her back turned to the task. This is further supported by results showing that in both species, subjects in the inattentive group took longer to look at the experimenter, gazed at her less frequently and for a shorter time than subjects in the attentive group.

Various studies have already shown that dogs can discriminate between the attentional states of their human partner: in most studies, dogs were required to perform (or inhibit) an action such as eating a titbit or retrieving a ball (Bräuer et al. 2004; Call et al. 2003; Schwab and Huber 2006). Overall, studies suggest that dogs behave differently according to the behavioural cues exhibited by the actors, and do so in a way consistent with an understanding of the underlying mental state of attention. However, more recent work (Udell et al. 2011) has called this interpretation into question, suggesting that in fact associative processes may be sufficient to account for these results, since dogs (and wolves) appear to show better discrimination when tested in conditions which they are likely to have had prior experience with (e.g. back-turned, book-reading), than in more unfamiliar contexts (e.g. when deciding whether to approach a person wearing a bucket on their head vs. holding the bucket next to their head). However, as pointed out by a number of authors, recognizing attentional states per se, and recognizing that your audience has to be attentive for successful communication to occur, may not be the same (Gomez 2005; Hattori et al. 2007). In the current study, we were interested in the latter question.

Results show that both dogs and toddlers took into account the behavioural cues relating to the attentional stance of the audience when exhibiting a referential gesture (alternating their gaze between container and person) suggesting that subjects of both species had some understanding that for the requesting gesture to be effective, their audience had to be looking at both them and the object of interest. Whether this reveals an underlying understanding of 'attention' as a mental state, or whether both the toddlers' and the dogs' flexibility in using gaze alternation is due to their having learned (in daily life) that to communicate with someone else that person has to be looking at them, remains an open question. However, considering that, for many authors, adapting behaviour to the audience's attention (or behavioural signs thereof) is a mark of intentional communication, these results seem to support the idea that gaze alternation in dogs is an intentional communicative act.

Even stronger support for this conclusion would have come from subjects showing active attention-getting behaviours towards the inattentive experimenter followed by gaze alternation to the apparatus (or if they had positioned themselves in such a way so as to alternate between the experimenter's face and the container). In fact, very few attention-getting behaviours (e.g. interacting with the experimenter) were used, and only a minority of dogs (7) went around the experimenter to look at her face or positioned themselves in such a way so as to alternate their gaze between her and the apparatus (3 dogs). However, this was also the case for toddlers. In fact, for both dogs and toddlers, the preferred strategy was not so much to gain the attention of the inattentive experimenter but rather to turn to the attentive caregiver; hence, the poverty of attention-getting signals used towards the experimenter is probably due to the limitations of the current experimental paradigm. Future studies adapting this paradigm by modifying the position, identity and response of the audience to the dog's communicative signals may shed further insights into the different strategies dogs may employ to obtain and direct a person's attention to the desired goal.

Although subjects of both species altered their behaviour according to the behavioural cues indicating audience attention, there were differences. In fact, whereas toddlers alternated their gaze towards the caregiver more frequently when the experimenter had her back turned, this difference did not emerge in dogs. But dogs also looked towards their caregiver (the owner) more than toddlers when the experimenter was attentive. Hence, unlike infants, dogs directed their requesting behaviour both towards the owner and the experimenter when the latter was attentive. Toddlers instead directed their requesting behaviour mainly to the experimenter when she was attentive and only directed their communication towards the caregiver if confronted with an inattentive experimenter.

Possibly, this pattern of results was influenced by the context and the identity of the caregiver: whereas dogs were tested in a relatively unfamiliar environment and with their closest bonded figure, toddlers were tested in a familiar room with their nursery caregiver. Hence, it cannot be excluded that if both had been tested with their close attachment figure (i.e., owner and mother), this difference would not have emerged. Another possibility is that the relationship of dependence between dog and owner may be such that the dogs' first choice of communicative partner is always the owner, and that this may be different for toddlers. Previous studies using similar testing paradigms showed that the dogs' choice of whom to communicate with (owner vs. experimenter) is influenced both by different types of training experiences and contingent behaviour such as encouragement during the solvable parts of the test (Marshall-Pescini et al. 2008; Horn et al. 2012); however, in all tested groups, the owner remained a prominent partner with whom dogs sought to communicate. Furthermore, in a social referencing paradigm, dogs, unlike infants, always looked also to the owner/caregiver when the experimenter acted as the informant; and whereas they regulated their behaviour to the informants' message when this was the owner, they did so to a lesser extent when it was the experimenter delivering the message (Merola et al. 2012b). Taken together, these results may indicate that, although willing to communicate with strangers and being open to their influence in many different situations (Marshall-Pescini et al. 2011; Elgier et al. 2009), if their owners are present, dogs will tend to refer back to them, perhaps more than toddlers towards their mother (although this hypothesis has yet to be tested).

In the infant literature, there is a sharp distinction between protoimperative and protodeclarative communicative gestures, the latter being closely linked to the concept of 'joint attention' where the underlying motivation for producing the signal is not instrumental (to obtain an object) but rather 'to share attention and interest' (Mundy and Newell 2007; Tomasello 2008; Tomasello et al. 2005; Carpenter and Call in press). Interestingly, in the current study, the analyses of the children's utterances when the task became unsolvable did not reflect a requesting motive, but rather a declarative one. Although only approximately half of the toddlers tested said anything, all utterances expressed surprise and inability to do what they had done so far. Only one utterance explicitly requested the unobtainable toy. Of course, this analysis is not possible for dogs; hence, future studies will have to design paradigms to tease apart the motivational factors behind dogs' gaze alternation behaviours (see Kaminski et al. 2011 for an interesting first attempt at this).

In conclusion, by comparing the use of gaze alternation in toddlers and dogs in a requesting paradigm, we found that subjects of both species use this behaviour similarly when the task becomes unsolvable. Furthermore, since the production of gaze alternation behaviour was affected by the behavioural cues indicating the audience's attentional stance, results provide further support for the idea that this is an intentional and referential communicative action.

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