Dogs (*Canis familiaris*) Account for Body Orientation but Not Visual Barriers When Responding to Pointing Gestures

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In a series of four experiments we investigated whether dogs use information about a human's visual perspective when responding to pointing gestures. While there is evidence that dogs may know what humans can and cannot see, and that they flexibly use human communicative gestures, it is unknown if they can integrate these two skills. In Experiment 1 we first determined that dogs were capable of using basic information about a human's body orientation (indicative of her visual perspective) in a point following context. Subjects were familiarized with experimenters who either faced the dog and accurately indicated the location of hidden food, or faced away from the dog and (falsely) indicated the unbaited container. In test trials these cues were pitted against one another and dogs tended to follow the gesture from the individual who faced them while pointing. In Experiments 2–4 the experimenter pointed ambiguously toward two possible locations where food could be hidden. On test trials a visual barrier occluded the pointer's view of one container, while dogs could always see both containers. We predicted that if dogs could take the pointer's visual perspective they should search in the only container visible to the pointer. This hypothesis was supported only in Experiment 2. We conclude that while dogs are skilled both at following human gestures, and exploiting information about others' visual perspectives, they may not integrate these skills in the manner characteristic of human children.

Keywords: dog, cognition, pointing, perspective taking, theory of mind

The key feature of cognition is that it allows for flexible problem solving. Dogs have shown flexibility in communicative tasks using human gestures and in tasks requiring them to discriminate what a human can or cannot see (Hare & Woods, 2013). However, it is unclear whether dogs exhibit the level of flexibility seen in human children. By 12–14 months, human children begin to integrate information about others' visual perspectives and knowledge states when interpreting communicative gestures (Liebal et al., 2009; Moll et al., 2006; Moll & Meltzoff, 2011; Tomasello et al., 2007; Tomasello & Haberl, 2003). The ability to model another individual's attention during communication has been proposed to scaffold learning during human language acquisition (Akhtar et al., 1996; Tomasello, 2008). Given the communicative flexibility observed in dogs—including skills that are not observed in our closest living primate relatives—dogs provide an unusual opportunity to test whether the skills we see in human children are shared by other species.

Dogs use a variety of human gestures to find hidden food or objects including dynamic and static pointing, gaze direction, and novel arbitrary communicative gestures (e.g., Hare et al., 1998; Lakatos et al., 2012; Riedel et al., 2006; Soproni et al., 2002). Several studies have ruled out the possibility that dogs simply rely on olfactory cues, proximity of the experimenter to the target, or the movement created by the gesture (e.g., Agnetta et al., 2000; Hare et al., 1998; Riedel et al., 2006; Soproni et al., 2002). Whereas dogs spontaneously use a variety of communicative cues, they do not use equally salient noncommunicative cues to find hidden food (Kaminski et al., 2012; Soproni et al., 2001; Udell, Giglio, et al., 2008).

Although a variety of species have been shown to exploit some cooperative-communicative gestures (e.g., Giret et al., 2009; Hernádi et al., 2012; Kaminski et al., 2005; Proops et al., 2010; Smet & Byrne, 2013) dogs are remarkable with respect to the wide range of cues that they use, and the flexibility with which they do so. The flexibility with which dogs use human gestures has not been observed in other species that have been directly compared with dogs (Gácsi, Gyori, et al., 2009; Hare et al., 2002; Hare et al., 2010; Miklósi et al., 2003; Virányi et al., 2008; but see Udell et al., 2008, 2010, 2013, 2012, 2011). While great apes and wolves can slowly learn to rely on one type of human gesture with extended contact with humans, they do not generalize this acquired skill to novel gestures or even slightly modified gestures (Povinelli et al., 1997; Tomasello et al., 1997; Virányi et al., 2008). In contrast, dogs not only show flexibility when interpreting novel cues, but also do not require intensive exposure to humans to exhibit these skills. Even dog puppies as young as 6–9 weeks, and puppies

reared in litters without intensive exposure to humans, use pointing and arbitrary gestures well above chance levels (Hare et al., 2002; Riedel et al., 2008; Virányi et al., 2008; but see Dorey et al., 2010). While explicit training of dogs has in some cases been shown to help them use human gestures even more faithfully (Elgier et al., 2009; Mckinley & Sambrook, 2000), large surveys of dog owners show no relationship between performance and a variety of rearing history measures (Gácsi et al., 2009). Overall then, dogs' understanding of human gestures is more similar to the early emerging communicative skills seen in human children than any other nonhuman species studied to date (Hare & Tomasello, 2005)

While dogs are similar to human children in their understanding of communicative gestures they do not acquire human language or culture (but for examples of label learning see Grassmann et al., 2012; Griebel & Oller, 2012; Kaminski et al., 2004; Pilley & Reid, 2011). Thus, dogs provide a unique opportunity to examine hypotheses regarding sociocognitive processes unique to human development. One proposal for how children interpret gestures and words so flexibly emphasizes their understanding of others' attention. For example, Tomasello and Haberl (2003) gave children experience playing with two toys together with an experimenter (E1). Then this experimenter left the area while a second experimenter (E2) played together with the child and a third toy. Afterward, all three toys were placed together on the floor, E1 looked ambiguously in their direction and reacted with surprise while requesting that the child "give it" to her. In this case the majority of 18-month-olds selected the toy that E1 was unfamiliar with (even though children were familiar with all three objects), presumably inferring through exclusion that E1's attention was directed toward something that was new and unfamiliar to her. These results, and related findings (e.g., Liebal et al., 2009), suggest that it is the integration of 1) skills for following social cues and 2) skills for reasoning about others' attention that allows humans to communicate in ways unlike any other species (Moll & Meltzoff, 2011; Tomasello & Haberl, 2003).

The current studies were designed to test this hypothesis by evaluating whether dogs can use information about what humans can or cannot see to respond appropriately to their gestures. Numerous studies suggest that dogs are sensitive to cues associated with what others can and cannot see. First, several studies have shown that dogs are less likely to obey a command, and more likely to steal a prohibited piece of food when the experimenter cannot see or hear them (Bräuer et al., 2004; Call et al., 2003; Kaminski et al., 2013; Kundey et al., 2012; Schwab & Huber, 2006). Second, several studies illustrate that dogs are more likely to beg or seek interaction from a person who can see the dog or the reward being requested than someone who cannot (Cooper et al., 2003; Gácsi et al., 2004; Udell et al., 2011). Third, multiple studies have shown that dogs also make inferences about others' visual perspectives during communication. For example, Soproni et al. (2001) reported that dogs used a human's gaze direction to find hidden food when the experimenter turned and oriented toward a baited container, but not when the experimenter oriented into space above the container. Further, Kaminski et al. (2009) have shown that dogs use information about what a human can and cannot see when inferring the referent of a verbal command. In this study, two objects were placed on the dog's side of a transparent and opaque barrier such that the experimenter could only see one object while the dog could see both. When the experimenter gave a "fetch"

command dogs were more likely to retrieve the object that the experimenter could see. Thus, current evidence suggests that dogs have basic perspective taking skills, and may use these skills in communicative contexts.

In the studies presented here we investigated whether dogs integrate information about the communicator's visual perspective when responding to a pointing cue. We hypothesized that if dogs were capable of inferring a human's visual perspective during communication, they should interpret gestures as more likely to refer to an object that the communicator could see than one that he could not. In our first study we explored whether dogs can use basic information about an experimenter's body orientation (and corresponding visual perspective) when deciding whether or not to follow a pointing cue. In Experiments 2–4 the experimenter pointed ambiguously toward two possible hiding locations, both of which were visible to the dog. However, in test trials only one of these locations was visible to the experimenter. We predicted that if dogs, like children, can reason about shared experiences between themselves and their communicative partner they should strategically search in the only location visible to both individuals.

General Methods

Participating dogs were recruited through the Duke Canine Cognition Center (DCCC) Web site. Owners from the Raleigh-Durham–Chapel Hill, NC, area followed a link on the DCCC Web site to fill out a Dog Registration Questionnaire (http://bit.ly/AmWURq), and their information was then added to our database. The database was screened to remove all dogs with an owner-reported history of aggression or debilitating health problems, including any vision-related impairment such as cataracts. Dogs were then selected from the database and their owners were contacted via email. Owners who were willing to participate brought their dogs for a 1 hr-long session at the DCCC. In the majority of cases, the owner was not present in the testing room. However, if the dog was too nervous or distracted with the owner outside of the room, the owner sat in the room behind the dog and out of sight during trials. In all experiments, if a dog met experiment-specific abort criteria (see below) all data from this subject were excluded from analysis of that experiment and this subject was not retested. Owners participated on a voluntary basis, and were offered free parking. All dog owners signed informed-consent forms before participation. Testing procedures adhered to regulations set forth by the Duke Institutional Animal Care and Use Committee (IACUC #303–11–12). All sessions were digitally recorded from a ceiling-mounted camera, or a digital camcorder in back of the testing room.

Experiment 1

Method

Subjects and Apparatus. Forty dogs completed this experiment and eight dogs were excluded because of the abort criteria specified below. Food rewards were hidden beneath small opaque plastic cups (diameter 10 cm, height 12 cm) that were positioned 2 m apart from one another, each 2.4 m away from the dog's starting position. With the exception of warm-up trials in which the baiting process was visible to the dog, the experimenter occluded

the baiting and sham baiting of each cup using a poster board occluder (35×50 cm).

Procedure

Sit Test. We first conducted four trials to assess subjects' responsiveness to a "sit" command when the experimenter was either facing toward or away from the dog. The dog handler (H) positioned the dog at the start line 1 m away from the experimenter (E1). Depending on the condition, E1 either faced and looked at the dog, or had her back turned. Once the dog was in position and standing upright, H said "ok" to indicate that E1 should command the dog to sit. At this point E1 said "(dog's name), sit!" and subjects were given 10 s to obey the command. If the dog sat or lay down within this 10 s period, E1 praised the dog and the next trial was administered. If the dog did not sit or lay down within 10 s after the command the dog was not praised and the next trial was administered. We conducted four "sit" trials and whether E1 faced toward or away from the dog was alternated between trials. The condition of the first trial was counterbalanced between subjects.

Warm-Ups. Next we conducted a series of warm-up trials to familiarize dogs with the process of finding food in the containers to be used during the test. Warm-ups consisted of two phases for which dogs were required to meet a criterion before advancing to the main test.

Phase 1. Two overturned plastic cups were positioned 3 m apart, 2.4 m in front of the dog at the left and right sides of the room. At the start of each trial H positioned the dog at the start line (midline of the room, equidistant to the two choices) while E1 called the dog's name and showed it a piece of food. E1 then walked directly to one of the two overturned cups, visibly placed the food underneath it, and then walked to the back of the room and turned her back. H then let the dog's leash go slack and said "ok!" encouraging the dog to make a choice. Throughout this experiment choices were defined as the dog's snout or paw entering a 10 cm radius (marked on the floor) around either cup. Dogs were allowed 30 s to make a choice, and if no choice was made during this period, the trial was repeated. If the dog chose the baited cup, E1 lifted the cup, praised the dog, and allowed the dog to eat the food. If the dog chose the unbaited cup, E1 lifted this cup to show that it contained no food, while H walked the dog back to the start line. The baited location was counterbalanced across trials and the same side was never baited on more than two consecutive trials. The side that was baited on the first trial was counterbalanced between subjects. Dogs were required to choose correctly on 4/5 consecutive trials to complete Phase 1 of the warm-ups.

Phase 2. This phase of the warm-ups was identical to Phase 1 with the exception that E1 stood near both cups before the dog's choice. On each trial, after showing the dog the treat, E1 walked to the cup to his right and either visibly baited this cup, or stood passively behind it, and then proceeded to the cup to his left again either visibly baiting the cup, or standing passively behind it. E1 then walked to the back of the room, centered between the two cups with her back turned to the subject and dogs were allowed to make a choice. Dogs were required to choose correctly on 4/5 consecutive trials to complete Phase 2 of the warm-ups.

Test. During the test dogs gained experience with two novel experimenters (E2 and E3) who provided pointing cues. Within a block of five trials, one of these individuals was designated the "facing pointer" while the other was designated the "back-turned pointer." The facing pointer always stood facing the dog and pointed to the cup containing the hidden food. The back-turned pointer stood with her back to the dog and pointed to the cup that did not contain the food. For the first four trials in each block (single pointer trials) only one experimenter (E2 or E3) performed the pointing cue. For the fifth trial in each block (double pointer trials), both E2 and E3 simultaneously performed the pointing cue (each experimenter indicating a different cup). In all trials, E1 performed the baiting.

In single pointer trials the experimenter (E2 or E3) stood 1.82 m directly in front of the dog. E1 showed the dog a piece of food and then hid the food behind the occluder. E1 then baited or sham baited each of the cups (always starting with the cup to her right), walked to the back of the room carrying the occluder with her, and turned her back to the dog. E1 then said "ready, set, point" cuing the experimenter to give the pointing gesture. The pointing gesture was performed with the arm closest to the indicated cup with index finger extended and this posture was maintained until the dog made a choice or the trial timed out. Once the pointing cue was given H slacked the dog's leash and said "ok" allowing the dog to make a choice. If a subject chose the baited container, she was allowed to consume the reward whereas choices to the unbaited container yielded no reward. Because the back-turned pointer always pointed to the incorrect cup, following this gesture led to incorrect responses whereas following the gesture from the forward experimenter led to correct responses.

Double pointer trials were identical to single pointer trials with the following exceptions. Both E2 and E3 stood side by side in front of the dog with one individual facing forward and the other facing backward (consistent with their roles in the preceding four trials). After E1 baited the cups, she walked to the back of the room, turned her back, and said "ready, set, point!" to instruct the experimenters to point to the cups. In these trials, only the cup indicated by the facing pointer contained the reward. As in single pointer trials, only choices to the baited cup yielded reward. We did not include trials to rule out the use of olfactory cues because numerous studies have documented that dogs do not use odor cues in this context (Bräuer et al., 2006; Hare et al., 2002, 1998; Hauser et al., 2011; Ittyerah & Gaunet, 2009; Mckinley & Sambrook, 2000; Riedel et al., 2006, 2008; Szetei et al., 2003; Udell, Giglio, et al., 2008) and odor controls in our subsequent studies replicate this phenomenon (see below).

Design and Analysis

We conducted 20 trials per subject, composed of four, 5-trial blocks. Each of the 5-trial blocks began with four single pointer trials (two facing pointer, two back-turned pointer) followed by a single double pointer trial. The identity of the facing and back-turned pointers was consistent within a block but counterbalanced between blocks to assure that differences between conditions were related to the positional orientations of the pointers, and not reputational differences between the experimenters. The role of E2 and E3 (facing or back-turned pointer) was alternated with each successive block of trials. Within each block the forward and backward pointers each indicated the left and right cups on one trial (single pointer trials) and the cup that the forward pointer indicated during double pointer trials was counterbalanced across the session. Lastly, the order of which experimenter provided the

pointing cue during single pointer trials followed an A-B-B-A design, and which experimenter provided the first pointing cue in each block (facing pointer or back-turned pointer) was counterbalanced across the session.

For the sit test we compared the number of trials that dogs obeyed the command when the experimenter was facing forward versus backward using a paired-sample t test. In pointing trials we compared performance in both conditions of the single pointer trials (facing and back-turned pointer) to chance using one-sample t tests. We compared performance between these conditions using paired-sample t tests. For double pointer trials we compared subjects' performance to chance expectation using one-sample t tests with the number of trials in which subjects followed the forward-facing pointer as the dependent measure. To explore the possibility of learning within the session we compared the first and second half of each trial type (facing, back-turned, and double-pointer) using paired-sample t tests. All statistical tests were two-tailed.

On all trials, dogs were allowed 30 s to make a choice. If a subject did not choose within 30 s the trial was repeated. If a subject did not choose on five consecutive trials, or on a total of 10 trials over the course of the session, the session was aborted. If subjects were unwilling to consume food placed on the floor, or showed excessive stress at any point during the test, the session was aborted. Partial data from aborted sessions were excluded from analysis and these subjects were not retested. A second coder naïve to the purpose of the study coded 20% of trials from video to assess interrater reliability. Reliability was almost perfect (Landis & Koch, 1977) both for the sit test and the pointing trials (κ–sit test = .93; pointing trials = .91) and live coding was used in cases of disagreement.

Results

In the sit test, dogs obeyed the sit command significantly more often when the experimenter faced the dog (56 ± 7%), than when the experimenter faced away from the dog when giving the command (29 ± 6%; $t_{39} = 3.73$, $p < .01$). In the single pointer trials, dogs followed the direction of the pointing cue more frequently than expected by chance when the experimenter faced forward and indicated the correct location (Figure 1; 62 ± 3%; $t_{39} = 4.13$, $p < .01$) but not when the experimenter faced backward and indicated the incorrect location (55 ± 3; $t_{39} = 1.58$, $p = .12$). The difference between these conditions was significant with dogs following the forward facing pointer's cues more frequently than the backward facing pointer ($t_{39} = 2.27$, $p = .03$). Dogs followed the facing pointer's gestures at higher levels in the second compared with the first half of trials ($t_{39} = -2.25$, $p = .03$) indicating a small learning effect, but followed gestures from the back-turned pointer at similar levels across the session ($t_{39} = -0.71$, $p = .48$).

When both the forward and backward pointers simultaneously gestured to different cups, dogs had a significant preference to follow the gesture from the forward facing pointer (mean percent choices to cup indicated by forward facing pointer: 58 ± 4, $t_{39} = 2.18$, $p = .04$) and their tendency to do so did not differ between the first and second half of the session ($t_{39} = 0.12$, $p = .90$).

Lastly, we assessed whether dogs' sensitivity to the experimenter's body orientation in the sit test related to their tendency to follow the forward facing pointer in the double pointer trials, both possible indicators of visual perspective taking. Specifically, we
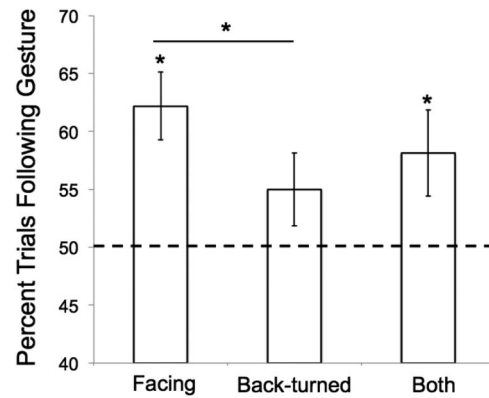

Figure 1.   The main findings from Experiment 1. Dogs were more likely to follow a pointing gesture from an individual who faced them compared with one with his back turned. The bar for "both" indicates the percentage of trials that dogs followed the gesture from the forward facing pointer when both the forward and back-turned pointers gestured simultaneously toward different locations. The dotted line indicates chance expectation and error bars reflect the *SEM*. Asterisks indicate significance at $p < .05$.

assessed the correlation between a difference score from the sit test (percent trials dog sat when E1 faced dog minus percentage trials dog sat when E1's back was turned) with the percentage of trials that dogs followed the pointing cue from the forward facing pointer in double pointer trials. These scores were not correlated ($R = .08$, $p = .61$).

Discussion

Experiment 1 showed that dogs given experience with a forward facing pointer who accurately indicated the location of hidden food, and a backward facing pointer who deceptively indicated the incorrect location, preferred to follow the pointing cue from the forward facing pointer when these gestures were pitted against one another. In trials when the back-turned pointer indicated the incorrect location, dogs still followed the direction of the point (to the unbaited cup) on the majority of trials. This finding replicates two other studies demonstrating that dogs tended to follow a dishonest pointing cue despite repeated experience in this context (Kundey et al., 2010; Petter et al., 2009), and another study showing that dogs reliably follow points from a backward-facing pointer (Udell et al., 2013).

The findings from Experiment 1 suggest that dogs are sensitive to positional cues that relate to a human's visual perspective toward the dog, and can use this information in a choice context. However, these findings may be explained by a variety of mechanisms unrelated to the dog's ability to consider a human's visual perspective. For example, dogs may have used a simple discriminative rule in which gestures from a forward facing individual were interpreted as a reliable cue whereas gestures from a backward facing individual were not. These contingencies may have been learned over the lifetime or within the experiment itself. Supporting the latter possibility, dogs followed gestures from the forward-facing pointer more faithfully in the second compared with the first half of single-pointer trials. Nonetheless, dogs exhibited some flexibility in their gesture following in that they did

not merely rely on the proximity of the pointed finger to a container, and instead used a combination of information from both the experimenter's body orientation, and the direction of the pointing cue. Although these behaviors do not demonstrate visual perspective taking, they illustrate sensitivity to basic positional cues related to visual perspective during communication, a prerequisite for inferences about visual perspective in this context. Thus, the results from Experiment 1 show that dogs are capable of exploiting basic information about an experimenter's body orientation in the context of a point following paradigm. In Experiments 2–4 we build on this foundation and address the question of whether dogs use information about the pointer's visual perspective when interpreting the referent of a pointing gesture.

Experiment 2

In Experiment 2 we evaluated whether dogs spontaneously exploit information about the pointer's visual perspective when inferring to which of two possible hiding locations the experimenter's pointing cue referred.

Method

Subjects and Apparatus. Thirty dogs (none of which had participated in Experiment 1) completed the experiment and five dogs were excluded because of the abort criteria specified below. Food was hidden inside round buckets (height 36 cm, diameter 23 cm) placed 1.65 m in front of, and 60 cm to the left and right of the dog. For smaller dogs that could not easily reach into these containers we used shorter containers (height 18 cm). In some trials, a large barrier (130 × 80 cm) was placed between these containers occluding the Experimenter's (but not the dog's) view of one of the containers (see below).

Procedure

Sit Test and Warm-Ups. As in Experiment 1 the procedure began with the sit test and a series of warm-up trials to familiarize the dog with finding food in the buckets. The procedure for the sit test and warm-up trials was identical to Experiment 1 with the following exceptions. Before the warm-up trials dogs received two trials in which only a single container was positioned and visibly baited directly in front of the dog. Dogs were required to approach and eat food out of the container on two trials before proceeding to warm-up trials involving two containers. The next stage of warm-ups was identical to Phase 2 warm-ups in Experiment 1, and again dogs were required to meet a criterion of 4/5 consecutive correct choices. Then in Phase 3 warm-ups E1 showed the dog a piece of food, hid the food behind the occluder, and walked to one of the containers where he placed the food in the container, hiding this process from the dog using the occluder (e.g., invisible displacement). E1 then returned to a central position between the containers and H said "ok" releasing the dog to make a choice. Because E1 only visited one of the two locations, dogs were required to infer that the food was invisibly displaced from behind the occluder to under the container that E1 had approached. These trials served to familiarize dogs with the baiting process used in

the test, in which the containers were baited or sham baited behind the occluder. Dogs were required to choose correctly on 4/5 consecutive trials to advance to the test. In all warm-up trials dogs were given 15 s to make a choice and the trial was repeated if no choice was made within this time limit. Throughout this experiment an approach was scored as the dog making physical contact with the container using her snout or paw, or the dog's snout crossing the edge of the container.

Test. The test consisted of two trial types: directional trials and ambiguous trials. Dogs began in the same location on all trial types, 1.65 m away from and centered between the two containers. At the start of the trial E1 showed the dog a piece of food, hid the food behind the occluder, and then approached and baited or sham baited each container, always approaching the container to his right first. In directional trials E1 then stood 2 m from the dog, centered between the two containers, said, "look!", and pointed to the baited container. The pointing cue was performed with contralateral arm from the container being indicated with the index finger extended and head oriented toward the indicated container. This gesture was maintained until a choice was made or the trial timed out. If a dog chose the baited container she was allowed to consume the reward while choices to the unbaited container ended the trial without reward. If no choice was made within 15 s the trial was repeated.

In ambiguous trials E1 showed the dog a single reward but baited both containers (occluding this process from the dog) before moving to a location 2.74 m to the side of the midline with both containers directly in front of him (Figure 2A, B). E1 then raised his arm 90 degrees with index finger extended, said "look!", and pointed along a vector running in the direction of both containers. As in directional trials this gesture was maintained until a choice was made or the trial timed out. On one half of ambiguous trials the barrier was positioned between the two containers so that E1 could only see the container nearest to him (Figure 2A), while dogs could see both containers. On the other half of ambiguous trials the barrier was not present and E1 could see both containers from the location where he pointed (Figure 2B). Choices in ambiguous trials were nondifferentially reinforced.

We predicted that if dogs were capable of taking E1's visual perspective they should interpret E1's pointing cue differently between the trials in which the barrier was and was not present. Specifically, when the barrier was present and E1 could only see one of the two containers, we predicted that dogs should interpret E1's gesture as indicating the only container visible to E1, despite the fact that dogs could see both containers. In contrast, when the barrier was absent and E1 could see both containers, we predicted that subjects should interpret the pointing gesture as being equally likely to indicate either container. On ambiguous trials if dogs approached E1 (crossing a threshold 1.82 m off center and in front of E1), instead of approaching the containers, the trial was aborted and repeated.

In addition to the test trials we conducted four odor control trials with each subject. These trials were identical to the directional trials with the exception that E1 did not provide a pointing cue to the food's location. These trials served to verify that dogs could not locate the reward using olfaction.
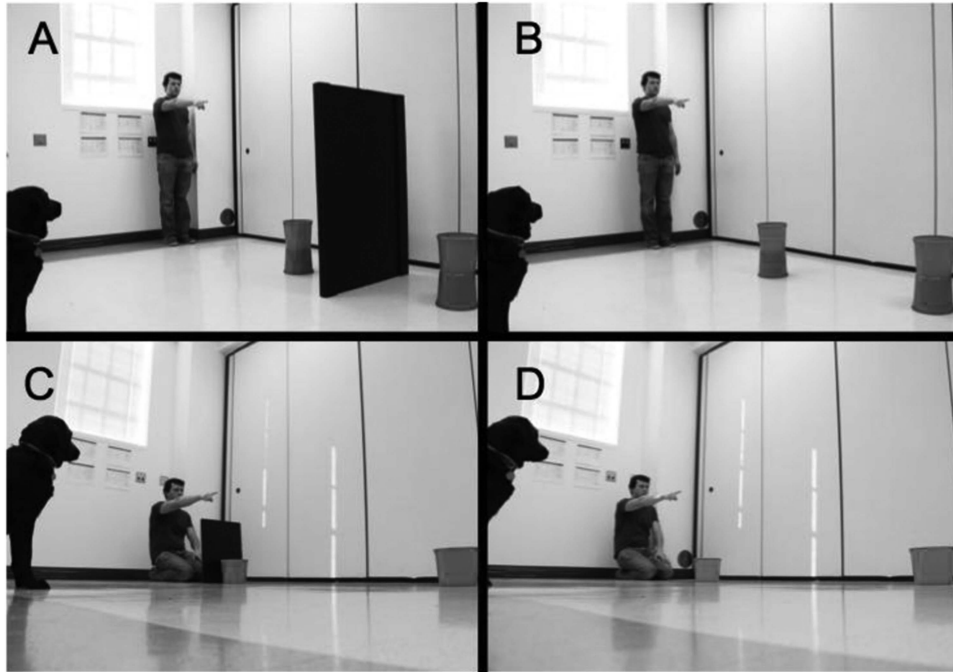
Figure 2. The pointing cue on ambiguous trials in Experiments 2 and 3. In Experiment 2 the visual barrier occluded E1's view of the distant container (A), but E1 could see both containers when this barrier was removed (B). In Experiment 3 the visual barrier occluded E1's view of the proximal container (C), but E1 could see both containers when the barrier was removed (D).

Design and Analysis

We conducted 20 trials per subject consisting of eight directional trials, eight ambiguous trials, and four odor control trials. Within the ambiguous trials the barrier blocking E1's view of one of the containers was present on half of the trials. Trials were administered in blocks of two directional trials followed by two ambiguous trials alternating across the session. The odor control trials were administered in blocks of 2 trials 1) midway through the session, and 2) at the end of the session. The container that was baited was counterbalanced within each block of directional trials and odor control trials. On ambiguous trials the side from which E1 pointed was counterbalanced across the session and the side from which E1 pointed on the first set of ambiguous trials was counterbalanced between subjects.

Analysis of the *sit* test was identical to Experiment 1. We compared dog's accuracy on the directional, control, and ambiguous trials to chance expectation using one-sample *t* tests. In the ambiguous trials we compared the percent of choices to the container nearest to E1 when the barrier was and was not present using paired sample *t* tests. We predicted that if dogs were sensitive to E1's visual perspective they should choose the container nearest to E1 more often when the barrier was present and this was the only container that E1 could see than when the barrier was absent and E1 could see both containers.

On all trials, dogs were allowed 15 s to make a choice. If a subject did not choose within 15 s the trial was repeated. If at any point dogs did not choose on three consecutive trials then two additional Phase 2 warm-up trials were administered to refamil-

iarize subjects with the process of searching for food in the containers. Lastly, if a subject did not make a choice on six consecutive trials, or a total of 10 trials across the test, the session was aborted. Partial data from aborted sessions were excluded from analysis and these subjects were not retested. A second coder naïve to the purpose of the study coded 20% of trials from video to assess interrater reliability. Reliability was perfect for all measures.

Results

As in Experiment 1, dogs obeyed the "sit" command more often when the experimenter faced the dog ($M = 55 \pm 8\%$) than when his back was turned ($M = 43 \pm 7$); however, this difference was not significant ($t_{29} = 1.49$, $p = .15$). In directional trials dogs followed the pointing cue to the baited container on $75 \pm 4\%$ of trials, significantly more often than expected by chance ($t_{29} = 6.3$, $p < .01$). Dogs did not differ from chance in the odor control trials when no social cue was provided ($M = 47 \pm 3$, $t_{29} = -1.0$, $p = .33$).

In the ambiguous trials dogs chose the container nearest to E1 more often than expected by chance both when the barrier was and was not present (barrier present: $M = 90 \pm 4\%$, $t_{29} = 10.8$, $p < .01$; barrier absent: $M = 83 \pm 4\%$, $t_{29} = 7.78$, $p < .01$). Thus, dogs had a strong bias to choose this container regardless of whether or not E1 could see one or both containers. However, as predicted if dogs were capable of taking E1's visual perspective, subjects chose the container nearest to E1 more often when this was the

only container E1 could see than when E1 could see both containers (Figure 2; $t_{29} = 2.1$, $p = .05$).

To assess whether sensitivity to E1's visual perspective and point following skills were related we correlated the difference score from the sit test (percent trials dog sat when E1 faced dog minus percentage trials dog sat when E1's back was turned) with performance on the pointing trials. Performance on the directional pointing trials was positively correlated with this difference score suggesting that dogs who were most responsive to E1's body orientation in the sit test also tended to follow pointing cues at a high level ($R = .36$, $p = .05$). In addition, the difference score from the sit test was also positively correlated with the percent of trials that dogs chose the container nearest to E1 when this was the only container E1 could see.

Discussion

The main finding from Experiment 2 was that dogs were more likely to follow E1's ambiguous pointing cue to a container near to E1 when this was the only container E1 could see, than when E1 could see both containers. Critically dogs could see both containers in each of these conditions making it unlikely that they used an egocentric rule regarding what they could see themselves when choosing. This finding is consistent with the idea that when interpreting the referent of E1's pointing cue dogs inferred which of the two containers E1 was indicating by considering E1's visual perspective at the moment the gesture was provided.

However, there are two alternative hypotheses that may explain dogs' behavior without invoking an understanding of E1's visual perspective. First, it is possible that dogs used a geometric heuristic to follow the direction of E1's pointing cue along a vector until this line was interrupted by a physical barrier (e.g., Tomasello et al., 1999). In this case, the vector running from E1's extended finger toward the containers would have intersected with the barrier (when it was present) leading dogs to search more frequently on E1's side of the barrier. A second possibility is that dogs were averse to following a path that created visual separation between themselves and E1 (e.g., Hare et al., 2006; Melis et al., 2006). In this case, when the barrier was present dogs would have selectively searched in the container nearest to E1 to avoid moving behind the barrier and out of visual contact with E1. We address each of these possibilities in Experiment 3.

Experiment 3

The results of Experiment 2 suggest that dogs may exploit information about a human's visual perspective when inferring the referent of a pointing cue. However, dogs were strongly biased toward choosing the container nearest to E1 (as in Lakatos et al., 2012) in both of the test conditions, a finding that may be explained by multiple phenomena (discussed above). In Experiment 3 we replicated the procedure from Experiment 2 but switched which of the two containers E1 could see by varying the size and position of the visual barrier. Specifically, in Experiment 3 a small barrier prevented E1 from seeing the container nearest to him while allowing him to see the distal container.

Subjects and apparatus

Twenty dogs (none of which had participated in Experiments 1 or 2) completed the experiment and four dogs were excluded because of the abort criteria ($N = 3$) specified below or experimental error during the session ($N = 1$). The apparatus was identical to Experiment 2 with the following exceptions. The containers were positioned 1.82 m from one another, each 91 cm from the midline. We used a small visual barrier (50 × 40 cm) positioned between E1 and the container nearest to him. This barrier occluded E1's view of the container nearest to him (in ambiguous trials) but allowed E1 to see the distal barrier across the room.

Procedure

The procedure for the sit test, warm-ups, directional trials, and odor control trials was identical to Experiment 2 with the exception that E1 gave the dog a treat at the end of each trial of the sit test, regardless of the dog's behavior. This change was implemented to encourage attentiveness to the experimenter during these trials. In ambiguous trials E1 showed the dog a single reward but baited both containers (occluding this process from the dog) before moving to a location 1.68 m to the side of the midline with both containers directly in front of him. E1 then kneeled, raised his arm 90 degrees with index finger extended, said "look!", and pointed along a vector running in the direction of both containers. On one half of ambiguous trials the small barrier was positioned between E1 and the container nearest to him such that it occluded his view of this container but allowed him to see the distal container across the room (Figure 2C). On the other half of ambiguous trials the barrier was not present and E1 could see both containers from the location where he pointed (Figure 2D). Choices in ambiguous trials were nondifferentially reinforced. In these trials if dogs approached E1 rather than the containers (crossing a line 107 cm from center) the trial was aborted and repeated.

Design and analysis

The design and analysis were identical to Experiment 2. We predicted that if dogs were sensitive to E1's visual perspective they should choose the container distal to E1 more often when the barrier was present and this was the only container that E1 could see than when the barrier was absent and E1 could see both containers. The trial length, abort criteria, and procedure for repeating trials on which there was no choice were identical to Experiment 2. A second coder naïve to the purpose of the study coded 20% of trials from video to assess interrater reliability. Reliability was perfect for the sit test, almost perfect (Landis & Koch, 1977) for the pointing trials ($\kappa = .95$), and live coding was used in cases of disagreement.

Results

Replicating the pattern from Experiments 1 and 2, dogs were more likely to obey E1's "sit" command when E1 faced the dog ($M = 65 \pm 10\%$) than when his back was turned ($M = 45 \pm 9\%$; $t_{19} = 2.18$, $p = .04$). Again, in the directional trials dogs followed E1's pointing cue above chance expectation ($M = 79 \pm 5\%$, $t_{19} =$

6.3, $p < .01$), but performed at chance in odor control trials when the relevant social cue was omitted ($M = 51 \pm 5\%$, $t_{19} = .27$, $p = .79$).

In the ambiguous trials dogs were highly biased to choose the container nearest to E1 both when the barrier was present and E1 could not see this container (mean choices to container near E1 = $96 \pm 2\%$, $t_{19} = 22.58$, $p < .01$), and when the barrier was absent and E1 could see this container (mean choices to container near E1 = $93 \pm 4\%$, $t_{19} = 11.57$, $p < .01$). There was no significant difference in dogs' choices between these two conditions (Figure 2; $t_{19} = 1.83$, $p = .08$) and the means were in the opposite direction to the prediction if dogs were capable of inferring E1's visual perspective when interpreting the pointing cue. In contrast to Experiment 2, there was no correlation between the difference score from the sit test and performance in directional trials ($R = -.02$, $p = .95$) or the percent of trials that dogs chose the container E1 could see when only one container was visible to him ($R = -.04$, $p = .88$).

Discussion

The main finding from Experiment 3 was that dogs' choices were biased primarily by the containers' proximity to E1, rather than by E1's visual perspective toward the containers. This finding contrasts with that from Experiment 2 in which dogs were more likely to choose the only container that E1 could see when a barrier occluded his view of the other container. This negative result should be interpreted cautiously as many factors may have influenced dogs' behavior in the ambiguous trials. For example, dogs may have had difficulty inhibiting an impulse to approach E1 leading them to almost invariantly choose the container nearest to him (mean choices to container near E1 across conditions = 94%). This possibility is supported by numerous studies documenting the constraining role of inhibitory control on dogs' problem solving skills (Bray et al., 2014; Osthaus et al., 2010; Pongrácz et al., 2001; Tapp et al., 2003; Wobber & Hare, 2009). Second, the small barrier may not have been perceived as an obvious physical barrier to E1's line of sight in the same way as the larger barrier used in Experiment 2. Consequently, even if dogs were capable of taking E1's visual perspective, other task demands may have overshadowed these abilities. In Experiment 4 we control for these possibilities using a design with reduced demands on inhibitory control and a larger visual barrier between E1 and the hidden container.

Experiment 4

Experiments 2 and 3 showed that dogs' choices were most influenced by the pointers' proximity to, rather than his perspective toward, the containers where food could be hidden. In our final experiment we controlled for this bias by replicating the basic procedure from Experiments 2 and 3 in a context where E1 was equidistant to both containers but sometimes could only see one because of the presence of a large visual barrier. Our test paradigm was similar to that from Experiments 2 and 3 as well as a study by Kaminski et al. (2009) in which dogs were shown to take the visual perspective of an experimenter who communicated verbally with them.

Subjects and Apparatus

Thirty dogs completed the experiment and seven dogs were excluded because of the abort criteria specified below. One of the subjects had previously participated in Experiment 1, and three subjects had previously participated in Experiment 3. The apparatus was identical to Experiment 3 with the following exceptions. The containers were positioned 1.82 m in front of the dog, and 1.82 m apart from one another, equidistant from the midline. When providing the pointing cue E1 sat in a chair 3 m in front of the dog, and equidistant to both containers. On some trials we positioned two large barriers (height 1 m, width 0.8 m) between E1 and the containers. Both of these barriers were constructed of plastic material but one was opaque, preventing E1 from seeing through it, while the other was transparent.

Procedure

The procedure for the sit test, warm-ups, and directional trials was identical to Experiment 3 with the following exceptions. In warm-ups E1 sat in the chair in front of the dog after baiting the containers. In directional trials E1 sat in the chair when providing the pointing cue, which was performed with the right arm, index finger extended, and head oriented toward the indicated container. In ambiguous trials E1 showed the dog a single treat but baited both containers behind the occluder before sitting in the chair where he performed the pointing gesture. On these trials E1 said "look!", and pointed to a location on the floor directly between the two containers making it ambiguous which of the two containers was being indicated. On one half of ambiguous trials (test condition) the two barriers were positioned between E1 and the containers. Because one barrier was opaque it occluded E1's view of the container behind it while the other barrier was transparent allowing E1 to see through it (Figure 3A). Importantly, from the dog's perspective both containers were visible. On the other half of ambiguous trials (control condition) the barriers were positioned
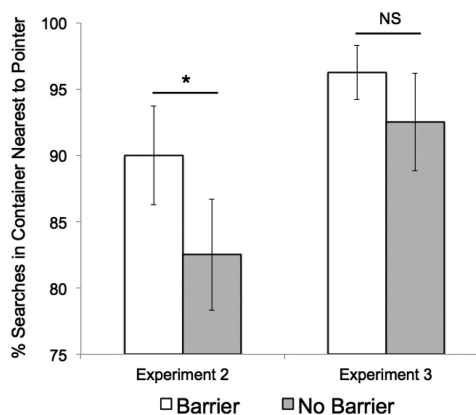
Figure 3. The main findings from Experiment 2 and 3. In Experiment 2 subjects chose the container nearest to E1 more often when this was the only container he could see (because the barrier occluded the other container) than when E1 could see both containers. In Experiment 3 dogs did not selectively search in the container E1 could see when the barrier occluded E1's view of the other container. Error bars reflect the *SEM*. Asterisks indicate significance at $p < .05$. NS = not significant.

perpendicularly to the containers and neither barrier occluded E1's or the dog's view of the containers (Figure 3B). These trials served as a control for any spontaneous preferences for approaching the container near the opaque or transparent barrier when the barriers had no impact on E1's visual perspective. Choices in ambiguous trials were nondifferentially reinforced.

Design and Analysis

We conducted 24 trials with each subject consisting of 16 directional trials and eight ambiguous trials (four test and four control). Directional trials were administered in blocks of four and which container was baited was counterbalanced within these blocks. After each block of directional trials we conducted two ambiguous trials in either the test or control condition, the order of which was counterbalanced between subjects. The order of the blocks of test and control conditions followed an ABBA design. Whether the opaque barrier was positioned next to the left or right container was counterbalanced across the session.

Analysis of the sit test and directional trials was identical to the previous experiments. In ambiguous trials we compared the percent of trials that dogs chose the container next to the transparent barrier to chance using one-sample t tests (in both test and control conditions). We compared the percent of trials that dogs chose the container next to the transparent barrier in the test versus the control condition using paired-sample t tests. We predicted that if dogs were capable of taking E1's visual perspective they should search in the container behind the transparent barrier (from E1's perspective) more frequently when the opaque barrier occluded E1's view of the second container than when the opaque barrier had no bearing on E1's view of the containers.

The trial length, abort criteria and procedure for repeating trials on which there was no choice were identical to Experiment 2. A second coder naïve to the purpose of the study coded 20% of trials

from video. Reliability was almost perfect (Landis & Koch, 1977) for all measures (κ–sit test = .92; pointing trials = .97) and live coding was used in cases of disagreement.

Results

As in Experiments 1–3, dogs obeyed the "sit" command more often when the experimenter faced the dog ($M = 60 \pm 9\%$), than when his back was turned ($M = 42 \pm 8\%$); however, this difference was not significant ($t_{29} = 1.58$, $p = .13$). In *directional trials* dogs again followed E1's pointing cue at levels exceeding chance expectation ($M = 74 \pm 3$, $t_{29} = 7.04$, $p < .01$).

In ambiguous trials dogs did not search in the container next to the transparent barrier more often than chance in either the test or control condition (test: $M = 48 \pm 4\%$, $t_{29} = -.62$, $p = .54$; control: $M = 49 \pm 3\%$, $t_{29} = -.24$, $p = .81$) and there was no difference between these conditions (Figure 4; $t_{29} = -.32$, $p = .75$). Lastly, to assess whether sensitivity to E1's visual perspective and point following skills were related we correlated the difference score from the sit test with scores from the point following trials. The difference score from the sit test was not correlated with performance on directional trials ($R = .13$, $p = .5$) or the percent of trials that dogs chose the only container E1 could see in the test condition of the ambiguous trials ($R = -.06$, $p = .77$).

Discussion

The main finding from Experiment 4 was that dogs did not selectively search in the container E1 could see if only one container was visible to him when he provided the pointing cue. This finding suggests that dogs did not reason about E1's visual perspective when inferring the referent of the ambiguously directed gesture. These results contrast with positive findings from a similar paradigm in which dogs were required to infer the referent of a
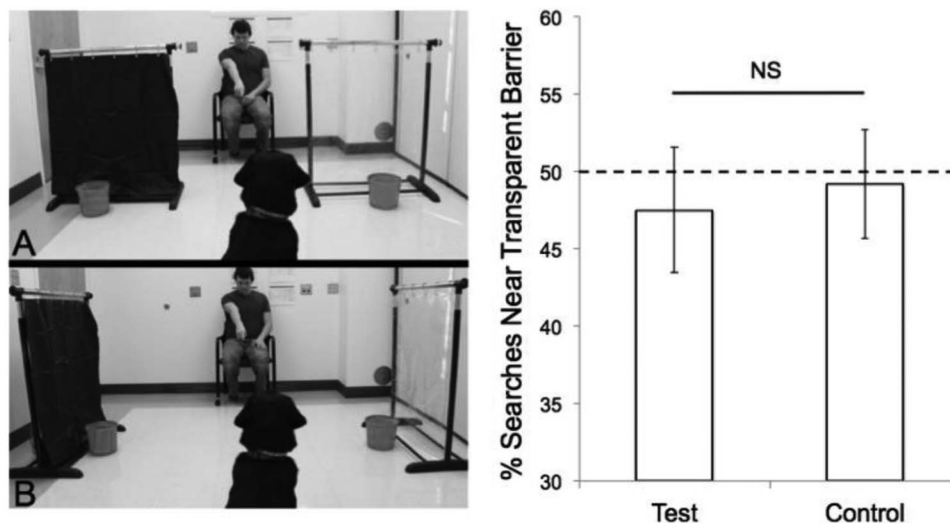

Figure 4. The test (A) and control (B) conditions in Experiment 4. In test trials the opaque barrier occluded E1's view of one of the containers. In control trials the opaque barrier did not affect E1's visual perspective toward the containers. Dogs did not selectively search in the container next to the transparent barrier in either the test or control conditions. The dotted line indicates chance expectation and error bars reflect the *SEM*. NS = not significant.

spoken command ("fetch") when the experimenter could only see one of two possible referents because of a similar arrangement of opaque and transparent barriers (Kaminski et al., 2009). One possible reason for this difference is that the current study used a pointing cue that was directed to a location between the two targets. Thus, dogs may have looked toward the empty space between the containers and then searched indiscriminately after seeing nothing in this location (e.g., Scheider et al., 2011). In contrast, the "fetch" command used by Kaminski et al. had no spatial component perhaps facilitating a more flexible search. Nonetheless, our findings suggest that if dogs are capable of reasoning about a human's visual perspective during communication, these skills may not generalize across all communicative contexts.

General Discussion

In a series of four experiments we investigated whether dogs use information about a human's visual perspective when responding to pointing gestures. We found that dogs were sensitive to cues about an experimenter's body orientation, and used this information when choosing which of two pointing gestures to follow. However, dogs did not use information about whether a visual barrier occluded the experimenter's line of sight, and generally preferred to search in a location near to the experimenter, regardless of whether the experimenter could see this location when he gestured. Our results suggest that while dogs are sensitive to some cues regarding others' visual perception, and skilled at following human gestures, they do not appear to integrate these two skills as flexibly as human children.

In Experiment 1 we found that dogs were sensitive to the pointer's body orientation (indicative of what he could or could not see); they preferred to follow gestures from a pointer who faced them and accurately indicated the food's location compared with a pointer who faced away from the dog and provided a dishonest point. Thus, dogs showed a basic sensitivity to the communicator's body orientation and used this information flexibly when deciding which gesture to follow. In Experiments 2–4 the experimenter pointed ambiguously in the direction of multiple possible locations where the food could be hidden. In the test trials, a physical barrier occluded the experimenter's view of one of these locations, but dogs could always see both locations. We predicted that if dogs were sensitive to the experimenter's visual perspective, they should selectively search in the location visible to both individuals. The data supported this hypothesis only in Experiment 2, and the means of the test and control conditions in Experiments 3 and 4 were in the opposite direction of the prediction.

Importantly, subjects in these studies were successful at following E1's pointing cue when it was directed unambiguously toward one of the two containers, and also showed sensitivity to information about E1's visual perspective, obeying the "sit" command more frequently when E1 faced the dog than when he turned his back. Therefore, it is unlikely that limited skills in either of these domains explains why dogs did not integrate information about E1's visual perspective when inferring the referent of his pointing cue.

The limited perspective-taking skills in these studies contrast with the impressive abilities that dogs have shown in other contexts presumably requiring similar cognitive abilities. For exam-

ple, when Kaminski et al. (2009) asked dogs to fetch one of two objects, subjects were more likely to retrieve the only object that was visible to the experimenter even though both objects were visible to the dog. As we note above, this difference may be attributable to the fact that our studies included a spatial referent (the pointing gesture) compared with the nonspatial verbal command "fetch." Consequently, dogs may have been biased to attempt to follow the direction of the pointing cue rather than appealing to the experimenter's visual perspective. Previous research has shown that dogs might not follow the spatial vector of pointing cues precisely, and typically approach the location nearest to the experimenter in the general direction being indicated (Lakatos et al., 2012). Our findings from Experiments 2 and 3 replicate this phenomenon, but this tendency cannot explain the findings from Experiment 4 in which both containers were equidistant from the experimenter. A second notable difference between our studies and those of Kaminski et al. (2009) is that our tasks required dogs to infer the location of hidden food, whereas the objects were always visible to dogs in the task used by Kaminski et al. Thus, with both objects in plain view, dogs may have more readily recognized the need to infer to which of the two alternatives the command referred. Nonetheless, these tasks were very similar in that dogs were confronted with a binary choice between an object that the experimenter could and could not see, and ambiguous information about which object was being indicated.

A second alternative explanation for dogs' behavior in our tasks invokes a higher level of perspective taking. Specifically, it is possible that dogs realized that the experimenter had knowledge of both locations (because he visited them when baiting the containers) even when he could no longer see one of the containers from where he pointed. Accordingly, dogs may have searched indiscriminately inferring that the pointing cue was equally likely to be directed to either of the containers that the experimenter *knew* were present. We find this possibility to be unlikely given that there is no strong evidence that dogs represent knowledge states in others (Kaminski et al., 2009; Kaminski et al., 2011; Virányi et al., 2006; but see Topál et al., 2006).

Our findings add to a growing literature on the contextual factors that affect dogs' responses to communicative gestures. For example, dogs are more likely to follow a human's line of sight, or pointing gestures, when these behaviors are preceded by ostensive-communicative cues such as calling the dog's name or direct gaze toward the subject (Kaminski et al., 2012; Téglás et al., 2012). Dogs are also more likely to search for the referent of a gesture when a hiding-finding context has previously been established, or when the cue is accompanied by an affiliative vocalization (Scheider et al., 2011). Thus, dogs are sensitive to a range of social factors that provide context for interpreting social cues and our results from Experiment 1 further illustrate dogs' flexible use of cues from body orientation. However, our data from Experiments 2–4 indicate that dogs may be limited in their ability to infer the shared perceptual environment between themselves and a communicative partner in more complex situations. One possibility supported by our data is that dogs most flexibly infer others' perspectives using cues from body orientation, but are limited in their understanding of visual barriers.

If dogs are sensitive to humans' visual perspectives, as a growing body of evidence suggests, the results of these studies can be interpreted in two ways. First, it is possible that dogs showed

limited flexibility in the current contexts because of difficulty determining the referent of a spatially imprecise gesture. We find this possibility unlikely because dogs do not rely on precise linear vectors when following pointing cues and instead use these gestures to determine the general direction in which to search (Lakatos et al., 2012). Moreover, in these studies the ambiguity regarding to which of the two containers the gesture referred could be resolved through cues about the experimenter's visual perspective. However, dogs did not make these pragmatic inferences. A second possibility is that while dogs are skilled at following cooperative-communicative gestures, and to some extent reasoning about others' visual perspectives, they may not be able integrate these skills similarly to human children. Therefore, it may not be the mere presence of these sociocognitive abilities that is critical for human development, but rather the ability to integrate them when making pragmatic inferences during communication (Tomasello, 2008). This possibility is further supported by studies of chimpanzees who are skilled at taking others' visual perspective (Bräuer et al., 2007; Hare et al., 2000, 2006; MacLean & Hare, 2012; Melis et al., 2006), but who do not spontaneously respond to cooperative-communicative gestures such as pointing (e.g., Herrmann & Tomasello, 2006; Povinelli et al., 1997). Therefore, it may be that both dogs and chimpanzees possess a (different) subset of the sociocognitive skills found in humans, but that neither species has the ability to use these skills in concert. This possibility has important implications for research on the evolution of uniquely human social cognition. Specifically, identifying isolated sociocognitive processes shared between humans and nonhuman animals may document what is necessary, but not sufficient, to explain human cognitive flexibility. Therefore, additional research investigating the extent to which animals can flexibly integrate these cognitive skills will be critical for identifying the traits that do, and do not, make human cognition unique.

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