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Cues to food location that domestic dogs (*Canis familiaris*) of different ages do and do not use

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Abstract The results of three experiments are reported. In the main study, a human experimenter presented domestic dogs (*Canis familiaris*) with a variety of social cues intended to indicate the location of hidden food. The novel findings of this study were: (1) dogs were able to use successfully several totally novel cues in which they watched a human place a marker in front of the target location; (2) dogs were unable to use the marker by itself with no behavioral cues (suggesting that some form of human behavior directed to the target location was a necessary part of the cue); and (3) there were no significant developments in dogs' skills in these tasks across the age range 4 months to 4 years (arguing against the necessity of extensive learning experiences with humans). In a follow-up study, dogs did not follow human gaze into "empty space" outside of the simulated foraging context. Finally, in a small pilot study, two arctic wolves (*Canis lupus*) were unable to use human cues to locate hidden food. These results suggest the possibility that domestic dogs have evolved an adaptive specialization for using human-produced directional cues in a goal-directed (especially foraging) context. Exactly how they understand these cues is still an open question.

Key words Dogs · Arctic wolves · Social cognition · Gaze following · Communication

Introduction

A number of experimental studies have demonstrated that domestic dogs (*Canis familiaris*) can use a variety of cues to locate hidden food. First, in standard object permanence tests, dogs can find hidden food either if they see it hidden (Piagetian stage 5) or if they see it hidden in a container that is then transported to a location inside another container (Piagetian stage 6; Gagnon and Doré 1992, 1993). Dogs thus show a level of understanding of object permanence not achieved by human infants until 18 months of age.

More recently, several studies have focused on social cues – mostly given by humans – that dogs can use to locate hidden food. Miklósi et al. (1998) and Hare et al. (1998) each set up situations in which a human hid food in one of several distinct locations (containers) and then gave a cue to the dog to indicate where the food was hidden, with several different kinds of control procedures used to ensure that subjects could not locate the food without such a cue (e.g., by smell). Across these two studies the majority of dogs were able to use the several different cues to locate the hidden food at above chance levels (and better than in control conditions with no cue, which were always at chance): (1) a human pointing to the target location; (2) a human gazing (head and eyes oriented) to the target location; and (3) a human bowing or nodding to the target location. Hare et al. (1998) also presented several of these cues without subjects being able to see any motion, that is, as subjects entered the testing area the human was already pointing or looking to the target location. The dogs were also very good at using these static cues, and this even included some conditions in which the human locomoted in one direction while pointing to the target container in the opposite direction. In some cases some dogs also successfully used human eye direction only (with no head turn) to find the food.

Hare and Tomasello (1999) replicated some of these results with a sample of ten dogs, and in addition extended them to situations in which another dog gave the

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cue (i.e., the dog cue-giver was on a leash but was bodily oriented to and looking at the target location). One intriguing finding in this study was that the one dog below 1 year of age was quite good at using the cue given by the conspecific, but not at using the same cue when it was given by the human, whereas some older dogs showed the opposite pattern of being better with the human experimenter. One possibility is thus that dogs have to learn to use human cues over a relatively extended period during early ontogeny. This interpretation gains support from the finding that whereas most nonhuman primates perform very poorly in these same tasks – much more poorly than dogs – apes with extensive experience of humans do much better (Anderson et al. 1995; Povinelli and Eddy 1996a; Tomasello et al. 1997; Call et al. 1998, 2000; Itakura et al. 1999; see Call and Tomasello, in press, for a review).

In the three studies reported here we asked several further questions about the skills of dogs in simulated foraging situations. In the main study, we first asked the ontogenetic question of whether young dogs (below 1 year of age) would be able to use human cues to help them find food. This question addressed the issue of how much experience with humans dogs must have before they can show some cue-following skills. We also explored in this study whether dogs would be able to use novel cues presented by humans, cues that they had almost certainly not been exposed to previously. Specifically, we wondered whether dogs would be able to understand that a physical object placed in front of the target location by a human (effected in various specific ways) was in fact a marker (communicative signal) for the food's location. A similar task was given to chimpanzees and orangutans by Tomasello et al. (1997), and not a single ape succeeded in using the marker to locate the hidden food (i.e., without extensive training), whereas human children were quite skillful from 2.5 years of age. In a follow-up study we asked whether dogs have a tendency to simply follow human gaze into space, as do a variety of nonhuman primate species (Tomasello et al. 1998; Call et al. 1998; Povinelli and Eddy 1996b) – or whether they simply are able to use gaze as a cue when they are already in a foraging situation. Finally, in addition, we conducted a small pilot study in which two arctic wolves were given the chance to use human cues to locate hidden food.

Study 1: dogs use marker

Methods

Subjects

Sixteen domestic dogs (*Canis familiaris*) of various breeds and ages participated in the study (Table 1). Eight of the dogs were enrolled in a private training/boarding establishment in the city of Atlanta, Georgia, United States, and eight of the dogs were recruited privately from around Boston, Massachusetts, United States. Testing was done

in a large, quiet room in each of the two cities (approximately 10 m²).

Procedure

The foraging task had the same basic structure in all experimental conditions. On each trial, one experimenter (E1) held the dog behind a large barrier while a second experimenter (E2) prepared for the next trial by hiding food inside one of two circular plastic dog bowls. When E2 was ready, E1 brought the dog to a predesignated location 2.5 m in front of the two bowls (equidistant from each) to begin the trial. The bowls were placed on their edges 1.5 m apart, with the open sides of the bowls facing away from the dog. The food (dog treat) was placed inside one of the bowls so that the dog could not see it. Chalk marks on the floor were used to ensure that both experimenters, both bowls, and the subject were always in the same location at the beginning of each trial. Each trial consisted of E2 giving a cue, as determined by experimental condition, and E1 then releasing the dog so that it could make its choice (by simply approaching and nosing its way inside one of the bowls).

There were five different experimental conditions, determined by the nature of the cue E2 gave before the dog made its choice:

1. Place + gaze. In this condition E2 obtained the dog's attention, and then placed a marker (a small sponge) in front of the bowl inside of which the food was hidden (using no excessive movements). In doing this, E2 looked deliberately at the bowl while placing the sponge. After placement, he then resumed a waiting position, looking straight ahead at the dog.
2. Place only. In this condition E2 again obtained the dog's attention, and then placed the sponge in front of the bowl inside which the food was hidden. The difference was that in this case E2 did not look at the target while placing the sponge, but instead looked straight ahead at the dog throughout the placement processes. After placement, he resumed a waiting position, looking straight ahead at the dog.
3. Gaze only. Again E2 began by obtaining the dog's attention, but in this case no marker was placed. E2 simply turned and looked for about 5 s at the correct bowl. After giving this cue, he resumed a waiting position, looking straight ahead at the dog.
4. Occlude placing. This condition was similar to the place-only condition, except that a barrier was placed by E2 on the dog's side of the bowls so that it could not see E2's hand and arm actually approaching the bowl for sponge placement; what the dog saw was essentially the placement process from the shoulders up (no arms, hands, or sponge). Once the marker was placed, the barrier was picked up and moved behind the bowls. One difference with the place-only condition was that before the placement process E2 held up the sponge briefly so that the dog

could see it. After placement, he then resumed a waiting position, looking straight ahead at the dog.

5. Marker only. This condition was very different from the others. In this condition E2 prepared for the trial by placing the sponge in front of the correct bowl so that when the dog approached the testing area the marker had already been placed. In this condition E2 simply stared straight ahead at the dog for a few s (roughly comparable to the time it would take to have given one of the other cues) and then, as in the other conditions, the dog was released to make its choice (E2 staring straight ahead the whole time).

The experimental design was within-subjects so that each subject experienced each experimental condition. Each dog experienced the marker-only condition twice, as the first condition and then again as the last condition. The other four conditions were administered in counterbalanced order across subjects (using a Latin squares design). Each condition was administered in a series of 18 trials per day, with only one condition per day, over no more than a 2-week period. Each day began with four warm-up trials to orient the subject to the task. In each warm-up trial, the dog was brought to its starting position and then E2, in full view of the dog, placed the food inside one of the bowls. All subjects were virtually always perfect in these warm-up trials. In the few cases of mistakes, the dog was given additional warm-up trials until it was correct on four consecutive trials.

A subject's choice for a given trial was designated as the first bowl it approached and touched. Responses were totally unambiguous, and so E1 and E2 simply noted together after each trial which bowl the subject had chosen.

Results

Table 1 presents the results for each subject in each condition. The overall pattern is very clear. In all conditions in which subjects either saw E2 place the marker in front of the bowl or saw him gaze at the correct bowl, dogs were above chance as a group. One sample *t*-tests, were as follows: place + gaze $t(15) = 9.65, P < 0.001$; place-only $t(15) = 3.44, P < 0.01$; gaze-only $t(15) = 4.74, P < 0.001$; and occlude placing $t(15) = 5.82, P < 0.001$. In contrast, in neither administration of the marker-only condition – in which E2 did not behave towards either bowl overtly – were the subjects above chance ($t < 1$ in both cases).

Analysis of individuals confirmed this overall set of findings. Between 7 and 13 of the 16 subjects were above chance in each of the four conditions in which E2 behaved in some way towards the correct container (one-tailed binomial test for each dog in each condition), whereas no individual was above chance on its 36 trials in the marker-only condition (note that Reggie was above chance on his last 18 trials, but was at chance for all 36 trials combined). To test the possible effect of age, two methods were used. First, dogs' ages were correlated with their performance in the different conditions. No significant correlations were found. As another test of age, the performance of dogs aged 1 year and below (8 dogs, average age = 0.55 years) was compared to that of dogs over 1 year of age (8 dogs, average age = 2.67) in the various conditions. No age differences were found (all *t*-tests nonsignificant).

Finally, a 6(condition) \times 2(location: Boston vs. Atlanta) \times 4(order) repeated-measures analysis of variance (ANOVA) revealed that there was no effect of city of testing, no effect of order, and no significant interactions among any of these three variables. The only significant effect was experimental condition ($F(5,15) = 12.24$;

Table 1 Number of trials correct (out of 18) for each subject in each condition

Subject	Age (years)	Breed	Marker only 1	Place + gaze	Place only	Gaze only	Occlude placing	Marker only 2
Paolo	0.3	Poodle	11	13*	10	14*	12	8
Mao	0.4	Ridgeback	12	15*	13*	11	10	6
Cody	0.5	Laborador	9	12	15*	12	17*	7
Bosco	0.5	Mixed	5	14*	10	6	8	9
Emaline	0.7	Poodle	10	11	9	9	13*	9
Tanner	0.7	Beagle	6	17*	14*	13*	18*	10
Hershey	0.8	Spaniel	10	15*	9	12	13*	11
Reggie	1.0	Terrier	6	16*	6	13*	16*	13 *
Rowly	1.5	Mixed	7	16*	9	11	16*	11
Chloe	1.8	Mixed	11	14*	15*	13*	18*	10
Xena	2.0	Border Collie	10	17*	17*	10	9	11
Timber	2.5	Mixed	12	16*	10	16*	14*	8
Stowie	2.5	Mixed	8	14*	16*	11	18*	10
Prudence	3	Laborador	12	14*	8	11	14*	8
Sitka	4	Shepherd	7	9	14*	16*	10	11
Maggie	4	Laborador	10	15*	15*	14*	17*	9
Total			9.1	14.3	11.9	12.0	13.9	9.4

* Value different from chance, one-tailed binomial test, $P < 0.05$

$P < 001$). In Bonferroni pairwise comparisons, none of the conditions that was significantly above chance (i.e., all except the marker-only condition) differed significantly from any of the others.

Discussion

These results replicate those of previous investigations in showing that domestic dogs are quite skillful in following human communicative cues to hidden food in a simulated foraging situation. They extend these findings to novel cues with which dogs have had no previous experience. As a group, the dogs in the current study were excellent at locating the hidden food in all conditions in which they could witness the human behaving in some way towards the target location, that is, by placing a marker in front of its location or looking towards its location (or both). This type of cue even worked when the dog did not see the actual placement of the marker but simply saw the human's upper torso moving slightly towards the target location, with a marker left behind. The dogs' ability to use novel cues so readily argues against the hypothesis that all they are doing in this and similar studies is displaying the effects of some previous learning experiences in which they were rewarded for following specific cues such as looking and pointing.

Supporting this interpretation was the finding that the puppies (ranging in age from 4 months to 1 year) were just as good at using the human cues as were the older dogs (ranging in age from 1.5 to 4 years). It is of course possible that much learning about human social behavior occurs in the first few months of a dog's life, and so what we are witnessing is simply the end result of a very rapid ontogenetic process. But puppies typically do not open their eyes or go to a human home until the 2nd or 3rd week of life, meaning that any learning involved must be very rapid indeed. The current study thus finds no support for the speculation of Hare and Tomasello (1999) that domestic dogs might take some ontogenetic time to transfer their "natural" skills of conspecific cue reading to the reading of human communicative cues. Much more likely is the possibility that domestic dogs have been artificially selected ("bred") for their ability to use human social cues, as generation after generation of humans have allowed only certain, socially attuned individuals to mate with one another.

The most difficult interpretive issue arises from the fact that the dogs performed at chance in the marker-only condition, administered both before and after the other conditions, and there were no individuals above chance in this condition either. Apparently the dogs were not able to use a physical marker as a communicative cue for finding hidden food in the absence of any overt human behavior towards the target location – even though in the case of the 18 trials administered at the end, they had already had a chance to associate the marker with the food's location on 72 previous trials (i.e., the four previous conditions using a marker, in each trial of which the subject ultimately

observed the correct location). (It is likely that the one dog who did successfully use the marker as a cue in the final 18 trials had learned this association.) How to interpret this failure is not straightforward. On the one hand, it might be argued that a physical object sitting in front of a container, with no associated human contact or behavior, should not be seen as a communicative cue at all, since it is involved in no social interactions between human and dog. It is thus reasonable for the dog to ignore this non-social cue. On the other hand, it is also possible to argue that the situation is inherently social. The dog enters the area with a human sitting behind the two containers in the same way that he had on many other trials in which he indicated the location of the food overtly. Whereas it is presumably the case that in this situation an adult human being would understand the marker by itself as an indication of the experimenter's communicative intention (why did the human place that marker there?), apparently dogs do not make this social-cognitive leap.

Choosing between these two hypotheses must of course await further research. In particular, the current results reveal an ontogenetically early ability that depends on a specific directional component in the human behavior used as a cue. This means that the dogs' skill could actually be a fairly narrow adaptive specialization, albeit with the flexibility to include many different behaviors with a directional component. If future research revealed a more flexible skill – if dogs were able to exploit cues other than directional cues to a target location, for example – this might indicate a more cognitively based appreciation for the communicative significance of human behavior in general.

Study 2: dog gaze following

In study 1 and other similar studies, the situation was a simulated foraging situation in which the dog began each trial knowing that food was in one of a small number of hiding places. In this situation, even a simple gaze cue (human looks to target location) is sufficient to enable dogs to locate the hidden food. Nonhuman primates are not nearly as good as dogs in this situation, that is, unless they have had extensive experience with humans (Call and Tomasello, in press). This is a curious finding because many nonhuman primates follow both conspecific and human gaze in other, non-foraging situations quite readily (Tomasello et al. 1998, 1999). Therefore, in a small follow-up study we simply asked whether domestic dogs would follow human gaze in a non-foraging situation, to a location off to the side or behind them, with no food-finding task.

To test this possibility, the eight dogs from the Atlanta sample population (and two others from the same facility) participated in a gaze-following task. The methodology was similar to that originally employed by Butterworth and Jarrett (1991) with human infants. That is, each dog was encouraged to sit directly in front of a human experi-

menter, who looked at it and gained its attention. The experimenter then attempted to direct the subject's gaze to one of three predetermined locations (straight up, directly to the left, or directly to the right of the dog) by turning his head and looking at that location for approximately 5 s. As a control condition, the experimenter simply continued to look straight at the dog for approximately 5 s. Each dog was given 18 trials (6 looks up, 6 control looks, 3 looks to the left, and 3 looks to the right). Trial type was counterbalanced for order across subjects, and the dogs were not rewarded in any way for any particular response. Dogs' reactions to the change in the experimenter's gaze were videotaped and then these tapes were coded for changes in the dog's direction of gaze as related to that of the experimenter's. For each trial a dog was coded as either looking at one of the three possible target locations or elsewhere (e.g., at the experimenter), as indicated by its first detectable head turn after the cue was given.

Results were uniformly negative. In the 12 experimental trials, the dogs followed the human's gaze to the target location an average of 2.6 times. Assuming a 33% chance of looking to the correct location (or even 25%, which would include "other" locations), this value is not significantly different from chance. Further, in the control trials, even though no cue was given, dogs often looked either left, right, or up as well. If we arbitrarily designate each control trial as either left, right, or up, subjects looked to the "correct" location in the control trials an average of 3.7 out of 12 trials. This value is statistically indistinguishable from that in the experimental conditions. There was also no improvement over trials. The clear conclusion is thus that domestic dogs do not reliably follow human gaze in a "neutral" (non-foraging, no food available) situation. It is noteworthy that this failure was not because they continued to stare at the human fixedly; in both experimental and control trials they mostly did look in one direction or another during the allotted time.

Again, the interpretation of the dogs' behavior in this situation is not straightforward. They do follow human pointing gestures into empty space outside of foraging situations (Hare et al. 1998), but apparently looking alone is not enough to direct their gaze. Another possibility is that dogs rely so much on hearing that a simple gaze cue needs some kind of auditory supplement. And so, for example, it is possible that if there were a very soft sound in the direction of the look, they would look in that direction, even though without the look they would not do so.

Study 3: pilot study with wolves

The results of the first study suggested that dogs are very skillful at using various kinds of human behavioral cues to locate hidden food. Because of their unique phylogenetic and ontogenetic histories, it is likely that this attunement to humans is an adaptive specialization that has evolved since the domestication process some tens of thousands of years ago (Lundeberg and Wayne 1997). An interesting

test of this hypothesis thus involves wolves, who by all accounts are very close genetic relatives to domestic dogs (and by some accounts, still the same species).

In a small pilot study, therefore, we tested two arctic wolves (*Canis lupus*) in the basic experimental situation of Hare and Tomasello (1999). The two juvenile wolves of approximately 1 year of age, one male and one female, lived together in a small group in the Leipzig Zoo (where they were born). For testing, the group was brought inside into a row of small cages (they maintained access to the outside area throughout testing). A human experimenter stood outside these cages, directly between the two center cages. She placed one box in front of one of the two center cages and another box in front of the other center cage, and baited one of them with food (sham baiting the other). Then, standing equidistant between the boxes, she gave a cue which consisted of either (1) pointing and looking to the baited box, (2) looking at the baited box only, or (3) no cue (looking straight ahead, eyes closed). The looking cue involved a clear and distinct head movement. After about 8 s, she then approached the correct box and gave food to whoever was directly in front of it. The task for the two wolves, therefore, was to position themselves in front of the correct box before the experimenter approached it. This simply required them to enter the correct cage and come over to the fencing, as all wolves in the correct cage were given food, whereas no wolves who were in the incorrect cage (in front of the incorrect box) were given food. Each wolf was given 150 trials, 50 in each of the three conditions (look + point, look only, control). Trials were administered in random order, with the stipulation that no more than two trials of a given type occurred consecutively. The number of trials per day was contingent on the cooperativeness of the subjects.

Results were that neither wolf used either of the two communicative cues to obtain food more often than in the control condition. The female did seem to become more skillful over the 50 trials with look+point, so that she was successful on 7 of the last 10 trials. But presumably this represents her learning of the cue during testing, not a social skill that she brought to the experiment. These results should be taken with caution since we tested only two individuals, and the testing conditions were far from optimal (e.g., we could not isolate individuals for testing). Nevertheless, we may conclude preliminarily that wolves do not seem to be as quick as dogs in using human behavioral cues to locate hidden food. This finding supports the hypothesis that domestic dogs have evolved an adaptive specialization for reacting to ("interpreting") human behavior in foraging situations. Since dogs also use conspecific cues (Hare and Tomasello 1999), it is possible that wolves would use conspecific behavioral cues in foraging situations as well. If they did, it would argue that the wolf-dog common ancestor was skilled at using conspecific behavioral cues for foraging direction, and then, during the period of their domestication and selective breeding, dogs just extended this skill, and perhaps magnified it, for interaction with humans.

General discussion

The current studies were designed to shed some light on the nature of the cognitive and learning processes involved when domestic dogs use human communicative signals to locate hidden food. It is now very well established that dogs have remarkable skills in the basic object choice task – much better than nonhuman primates, in fact – but we know very little about the underlying psychological mechanisms involved. The current studies have established four facts that should help in specifying these mechanisms. First, dogs can use human social cues from very early in their ontogenies, and there are no significant developments in this skill from 4 months to 4 years of age. Second, dogs can use novel cues that they have had no previous opportunity to learn in this same way, which is not true of chimpanzees or orangutans (Tomasello et al. 1997). Third, dogs do not perceive a physical object in front of a hiding place as an expression of a human communicative signal, not even after they have witnessed many times this same cue associated with other behavioral cues that they do use (gaze direction, movement towards). And fourth, unlike nonhuman primates, dogs do not naturally follow human gaze outside of foraging or other goal-directed situations.

In combination with the negative findings for the wolves, these findings lead to the hypothesis that domestic dogs have been selected by humans over many generations to be sensitive to a variety of human behavioral cues, including novel cues, that have the component: behavior (including gaze) directed towards some location (see Tomasello and Call 1997, for discussion of the understanding of “behavior directed towards”). They can use cues of this type with few, or perhaps no, specific learning experiences. However, dogs do not follow a human’s gaze into space, nor do they understand that human communicative intentions may be manifest in a physical object in the absence of any directional cues. This suggests the possibility – still awaiting testing – that the skill involved may be a fairly narrow adaptive specialization concerning only directional information in a goal-directed (perhaps only foraging) context. In either case, the question of how best to characterize domestic dogs’ knowledge of the communicative significance of human behavior, in terms of the underlying social-cognitive skills involved, is still an open question.

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