COMMUNICATION OF FOOD LOCATION BETWEEN HUMAN AND DOG (CANIS FAMILIARIS)[*]

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ABSTRACT

Two domestic dogs (*Canis familiaris*) participated in a series of studies in which they communicated with a human about the location of hidden food. In the first study both dogs were able to follow human pointing reliably to one of several locations where food was hidden, both in front of them and behind them. They also showed some skills at following human gaze direction in this same task, when both head and eyes indicated the same location. They did not follow eye direction when it conflicted with head direction. A second study clearly ruled out a low-level visual tracking explanation for at least one of the subjects. In a third study one of the two dogs was able to lead a naive human to one of three locations containing food consistently, mainly by barking and orienting its body to the food. The subject did not behave differently, however, when the human turned his back or covered his eyes; he continued to orient to the food and bark under all conditions. In a fourth study in which more clearly visual signals were involved, both subjects strongly preferred to drop a retrieved object at the front of, rather than at the back of, the human — even when the human turned his back so that subjects had to bring the object around his body upon return. The knowledge of human pointing and gaze direction displayed by these two domestic dogs is in many ways comparable to that displayed in experimental studies by nonhuman primates.

Human domestication of animals of the genus *Canis* has resulted in the origin of a relatively new species, the domestic dog (*Canis familiaris*), which has many well-known "breeds" (Clutton-Brock 1995). One of the features that distinguishes domestic dogs from other members of the genus is their ability to communicate with human beings. This is most evident among breeds that have been specifically bred for helping humans in tasks such as hunting, shepherding, and protecting. Also, individual dogs of different breeds sometimes are trained in specific tasks that require them to communicate with humans, for instance, assisting blind persons to navigate or police to locate contraband (Coppinger & Schneider 1995).

In attempting to understand the nature of these communicative interactions from a cognitive point of view, the most important questions concern how dogs understand their communicative partners and the process of communication. Do dogs comprehend human signals as communicative acts from social partners or merely as discriminative stimuli that have been previously associated with reinforcement? When dogs produce signals for humans do they understand how the process of communication works — e.g., that humans must perceive the signal and choose to act — or do they merely emit instrumental behaviors that have been reinforced in the past? There is no question that dogs can be trained by humans to emit and react to signals for very subtle and complex communicative functions (e.g., Wolters 1964), but how do dogs communicate with humans in relatively novel communicative circumstances?

There are few experimental studies of the process of communication between dogs and humans. Of most direct relevance, Warden & Warner (1928) found that a highly-trained circus dog learned to obey many dozens of verbal commands from a human trainer in quite flexible ways. McConnell & Baylis (1985) found that border collies used the whistles of their trainers as either instigations to greater action or inhibition of action, but did not use them as information for a specific behavior or direction of movement. Mitchell & Thompson (1993) observed dogs playing with familiar and unfamiliar humans and found high levels of what they termed "deception". Fillaitre, Millot & Montagner (1986) observed some interesting social and communicative interactions between young children and their pet dogs.

The most interesting experimental work on the social-cognitive bases of animal communication, however, has been conducted by Cognitive Ethologists interested in primate communication, in some cases among conspecifics but in

other cases between nonhuman primates and humans. An especially fruitful paradigm involves humans pointing, looking, or otherwise attempting to direct primates to specific locations in the immediate environment. Another paradigm involves the reverse: primates attempting to direct humans to specific locations where they (but not the humans) have seen food hidden.

In terms of primates following human communicative signals, Povinelli & Eddy (1996a) had a human experimenter orient both her eyes and head to a distinct location for young chimpanzees, in some cases to the corners of the room above and behind them (see also Povinelli & Eddy, in press). The chimpanzees followed the human's gaze direction quite readily in this situation. They were also successful in a situation in which the experimenter moved her eyes only toward these same locations (keeping head direction constant), as well as in another in which the subject encountered the human already looking at a location, thus demonstrating that movement of the head and eyes was not a crucial aspect of the social cue. Using a similar paradigm with 11 different primate species (2 species of lemur, 2 species of cebus monkey, 1 species of squirrel monkey, 4 species of macaque, and 2 species of great ape: chimpanzees and an orangutan) Itakura (1996) found that most species followed human pointing, but only the single orangutan subject followed human gaze direction (head + eyes) in the absence of pointing.

In a slightly different experimental paradigm, Anderson, Sallaberry & Barbier (1995) also found that capuchin monkeys (*Cebus apella*) did not follow human head and eye gaze direction, in this case to the location of food hidden under one of two opaque containers. The only effective cue was the human placing his hand directly next to the baited container. Itakura & Anderson (1996) were able to train a single capuchin monkey to follow human gaze direction (head + eyes) to hidden food in a similar situation, but it took them over 120 trials to do so — suggesting the possibility that gaze direction (head + eyes) was learned as a straightforward discriminative cue.

In terms of the production of signals for humans, individuals of all four great ape species (and a few monkeys) have learned to "point" for humans, typically using the whole hand and arm (see Call & Tomasello 1996, and Tomasello & Call 1994, for reviews). Of special interest from a cognitive point of view are primates' adjustments for their human partners in unusual communicative circumstances, so-called audience effects that demonstrate subjects' under-

standing of the partner's role in the process (Cheney & Seyfarth 1990; Tomasello, Call, Nagell, Olguin & Carpenter 1994). There are two experimental studies. First, Call & Tomasello (1994) presented two orangutans who knew how to point for humans with two containers of sweet liquid, one of which contained more liquid than the other. The task was simply to indicate to a human the desired container. The two containers were presented as the human did one of four things: (i) left the room; (ii) walked to the opposite side of the room and turned his back; (iii) sat down behind the platform facing the drinks and the subject, but with eyes closed; (iv) sat down behind the platform facing the drinks and the subject, with eyes open. Both orangutans mostly refrained from pointing when the observer left the room or turned his back, and both pointed quite frequently when the observer sat opposite them with eyes open (with mixed results in the eyes-closed condition).

Second, in a series of experiments Povinelli & Eddy (1996b, 1996c) asked similar questions of young chimpanzees but in much more detail. They had young chimpanzees extend their hands toward one of two experimenters to request food that lay on a table between the two humans. Subjects could choose only one human. In a condition in which one was human facing forward and another facing backward, the chimpanzees consistently gestured toward the human who was facing toward them. In a number of other experimental conditions, however, chimpanzees did not distinguish between a human who wore a blindfold over his eyes and one who wore a blindfold over his mouth, or between one who had his eyes closed and one who had his eyes open, or between one who was looking away on who was looking at the subject.

In the current studies we addressed some of these same issues with respect to domestic dogs as they communicate with humans. In the first two studies we hid food and then attempted to direct each of two subjects to it with various cues such as pointing and gaze direction. In the third study one human hid food while the dog watched, at which point a naive human entered the scene and the subject attempted to direct him to the food — with the human adopting different bodily orientations on different occasions (e.g., with back turned). The hypothesis was that the dogs would be as good as most primates in these tasks since they, like most of the captive primate subjects, have had extensive experience communicating with humans.

1.   STUDY 1

1.1   *Method*

1.1.1 *Subjects*

Subjects were two domestic dogs (*Canis familiaris*) living with a human family. Oreo was a 12-year-old male Labrador Retriever. As a puppy he was trained by his owner for various tasks associated with hunting. He was also experienced in the use of human pointing for help in finding objects at large distances, specifically in the context of retrieving. Pretests with Oreo determined that he was quite skillful at moving in the direction in which a human was pointing in order to find and retrieve an object.

Daisy was a 3-year-old female mongrel. She received no training as a puppy, or at any other time, in following human pointing or related tasks. She has been a pet only, with some training to "Sit", "Stay", and the like.

1.1.2 *Materials and Design*

Each subject was individually tested for its ability to follow various types of human cues to food (dog treats) hidden in various ways (under plastic cups). There were 12 different types of experimental trials. These 12 types resulted from the factorial combination of two dimensions. First was the Type of Cue used by the human experimenter (E): pointing, eye+head gaze direction, and eye-only gaze direction. Second was Food Placement: two cups in front of the subject, two cups behind the subject, three cups in front of the subject, and three cups behind the subject. (In both of the conditions involving three cups, the cups were placed in an arc so that they were roughly equidistant from the subject.) Each subject participated in 18 experimental trials and 18 control trials in each of these 12 conditions, for a total of 432 trials per subject. For both subjects, the pointing trials were administered first, the eye+head trials second, and the eyes-only trials last. All trials were administered within a 6 month period.

As a follow up, each subject participated in an additional 72 experimental trials. These duplicated two of the experimental conditions — two cups in front using pointing and two cups in front using eye+head gaze direction — with one difference. In these Static trials, a second experimenter covered the dogs eyes while E took up the position of either pointing or looking, so that the

subject was exposed to only a static display of E's communicative signal with no movement cues available. Two blocks of trials were run. In the first block there were 18 trials of each type, in the order Eye + Head followed by Pointing. In the second block the reverse order was administered. Additional control trials were not run for these follow-up trials because the control trials for the dynamic version of these cues was still applicable.

1.1.3 Procedure

All trials, both experimental and control, followed the same basic procedure. The trial began as E arranged the cups appropriately for that trial, at which point the subject took up his position and was instructed to "Stay" (see Figure 1). E then proceeded to place his closed hand under each of the cups in a constant order, leaving the food treat under one of them. E then obtained the dog's attention and gave the appropriate cue (in the control condition a "neutral" cue was given) for approximately 5 seconds. The subject was then verbally released to find the food. Food placement was counterbalanced so that each cup was baited an equal number of times in each condition, with the same cup never baited 3 times in a row. All trials were videotaped from behind E's location.
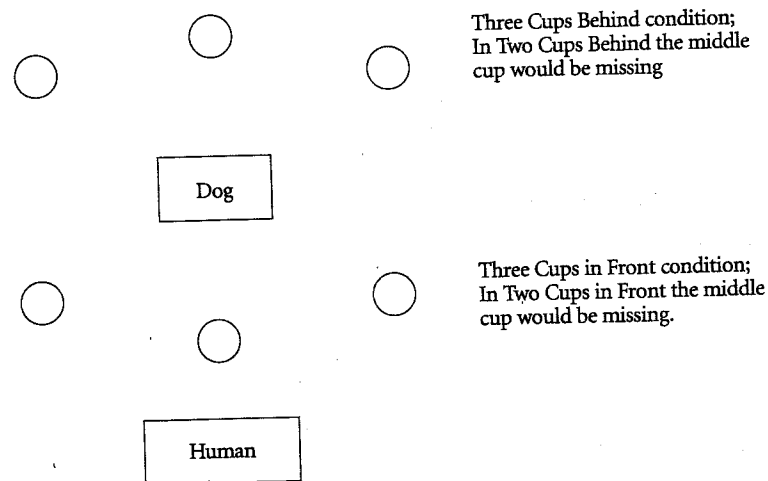

Three Cups Behind condition;
In Two Cups Behind the middle cup would be missing

Three Cups in Front condition;
In Two Cups in Front the middle cup would be missing.

Dog

Human

Figure 1. Layout of the four cup arrangements in Study 1. Note that spatial arrangements are not to scale precisely.

Cues were given in the following manner. In the pointing trials, E pointed to the cup containing the food and alternated his gaze direction (head and eyes) between the dog and the cup. In the eye + head gaze direction trials E simply alternated his gaze direction (head and eyes) between the dog and the cup. In the eyes-only gaze direction trials E alternated his eye direction between the dog and the cup, but kept his face aimed at the dog throughout. For all control trials, E closed his eyes and aimed his face either straight up or down before releasing the dog. In the Static trials, the procedure was the same except that a second experimenter covered the dog's eyes while E arranged the cue, so that when its eyes were uncovered the subject saw a static version of either the pointing or eye + head gaze direction cue.

On every trial, after verbal release, subjects went straight to a cup and turned it over with their noses or paws. If correct, they were allowed to eat the food. If incorrect, they were shown where the food was located as E retrieved it from under another cup; in this case they were not allowed to eat it.

1.1.4 Scoring

A subject's choice for a given trial was the first cup it touched. Responses were totally unambiguous (and subjects touched a cup on every trial), so E simply noted after each trial which cup the subject had chosen. A small number of randomly chosen trials were scored by an independent observer using the videotapes, resulting in 100% agreement with E's scoring.

1.2 Results

Results are presented in Table 1. Data analysis consisted of testing each number correct against chance, for each subject for each of the 14 types of trial separately. When 2 cups were involved, 14 out of 18 trials correct (or greater) was different from chance, two-tailed binomial probability (13/18 for one-tailed); when 3 cups were involved, 12 out of 18 trials correct (or greater) was different from chance.

The results show that both subjects were able to follow human pointing to the correct cup quite reliably, no matter the arrangement of cups (and never at greater than chance levels in the control conditions). This also held when pointing was presented to the dogs statically (for both blocks of trials for one

Table 1. Number of trials correct (out of 18) in each condition by each subject in Study 1.

	Daisy		Oreo	
	Experimental	Control	Experimental	Control
Point				
2 Cups in Front	18*	9	18*	8
2 Cups Behind	17*	9	18*	8
3 Cups in Front	17*	5	15*	6
3 Cups Behind	12*	10	15*	2
Eye + Head				
2 Cups in Front	15*	8	18*	6
2 Cups Behind	13	9	16*	5
3 Cups in Front	7	7	9	4
3 Cups Behind	9	6	13*	7
Eye-Only				
2 Cups in Front	8	9	10	7
2 Cups Behind	4	10	8	10
3 Cups in Front	5	4	8	5
3 Cups Behind	8	4	7	6
Static				
Point #1	11	–	16*	
Point #2	17*		17*	
Eye + Head #1	9	–	9	
Eye + Head #2	14*		10	

* Different from chance, p < .05 or less.

dog and for one block for the other dog). On the other hand, the results also show that neither dog was able to follow human eye gaze alone to the correct cup, no matter the arrangement of the cups. None of these values was different from chance. Gaze direction involving the eyes and head together produced mixed results. Oreo was above chance on three of the four types of dynamic trials (failing at 3 cups in front), but was not above chance on the static version of this cue. Daisy was above chance on one type of trial involving eye + head gaze direction using a dynamic cue (2 cups in front), and on one of the blocks of trials using the static version of this cue.

Inspection of the response patterns of the two subjects provides additional information about their mixed performance in the eye + head gaze direction condition. A major problem for both dogs was the center position in the two

conditions involving 3 cups (back and front). Of the 144 trials of this type (18 trials with 3 cups in front and behind, experimental and control, for both subjects), they went to the center cup on only 6 occasions (as compared with, for example, 31 times in the comparable pointing trials). One hypothesis is thus that the straight-ahead direction of the gaze cue when the correct cup was in the center position (either in front or behind) caused the dogs special problems, perhaps because E's gaze cue in this situation was not so different from the "neutral" cue in the control condition — in which E also kept his head oriented in a straight ahead orientation, looking either up or down in the process. Indeed, if only those 3-cup trials in which the food was hidden to the right or left are counted, Daisy was correct on 16 of the 24 experimental trials (p < .10) and Oreo was correct on 19 of 24 trials (p < .01). It should also be noted that Daisy was above chance in her second block of trials with eye + head presented statically, which involved two cups only.

1.3 Discussion

Both dogs tested were able to follow human pointing reliably to hidden food. They did this even when the pointing was presented statically, thus ruling out the possibility that what they were doing was visually tracking the movement of the hand and then continuing on that trajectory. One of the dogs had received previous background training with human pointing, although it took place in a very different context (viz., in the context of retrieving objects). The other dog had no background training in following human pointing.

The dogs also showed some evidence of the ability to follow human gaze direction (including both eyes and head), especially with two cups. One of the dogs showed some signs of being able to use this skill when there were 3 cups as well, while the other was at chance in both of these conditions. However, analysis of the subjects' errors showed that the main problem was when the food was in the center cup, in which case the gaze cue was very similar to the neutral cue given in the control condition (in both cases E kept his head in a straight-ahead direction, moving it up or down to varying degrees). When these center-placement trials are eliminated one dog was above chance and the other was almost above chance (p < .10) — the latter being above chance in the static version of this cue as well.

Neither dog followed E's eyes to the food when his head stayed in a straight-ahead orientation (i.e., in the Eye Only condition). In some ways this is not surprising as this is a very subtle cue requiring a certain amount of visual acuity on the subject's part, as well as the ability to use a cue that conflicts with one with which it is normally correlated. That is, human eye and head direction are almost always correlated in situations in which dogs would need to attend to them, and in this case the head direction was pointing straight ahead while the eyes were indicating something different. It is relevant in this context that human infants do not follow eye gaze uncorrelated with head direction until some months after they follow eye+head gaze direction, typically not until after 18 months of age (Corkum & Moore 1995). Overall, the evidence is clear that the dogs used head direction, not eye direction, as their primary cue in those conditions not involving pointing; one dog could use this cue statically.

2.   STUDY 2

One intepretation of the dogs' behavior in Study 1 is this. Dogs visually track motion, and so when the human pointed or turned his head the dog tracked this motion and then, when released, simply went to the cup in the direction in which his head was already pointing. This explanation works less well for the static trials (at which the dogs were less skillful), but it could cover those trials as well if we assume that (1) in the static pointing trials the dogs looked first to the human face and then to his extended hand, and (2) in the gaze trials they followed the head movements involved in the gaze alternation and this led them in the direction of the correct cup. In Study 2, therefore, we controlled for this intepretation by standing in different places and giving different kinds of cues so that the dogs would not get a "head start" by tracking the human's hands and eyes in a direction that led them, accidentally, to the correct cup.

2.1   Method

2.1.1 Subjects
Subjects were the same two dogs as in Study 1.

2.1.2 Materials and Design
Again each subject was individually tested for its ability to follow various types of human cues to food hidden under plastic cups. There were 12 different types of experimental trials — involving 4 human cues crossed with 3 cup placement conditions — plus some additional control trials. The cup placements were designed so that in some conditions the dogs would not be looking at the correct cup after the cue was given no matter how they visually scanned the human and his behavior. Thus, there were always two cups (aligned as in Study 1, food hidden under each an equal number of times, randomized), with the dog always sitting opposite the midpoint between the two cups when the cue was given. For one-third of the trials the human stood opposite the dog at the midpoint as well (as in Study 1), but for the other trials E stood behind one of the cups on the extremities (one-third each). From each of these positions E indicated each of the two cups an equal number of times.

The four human cues were as follows:

(1)   Cross-Pointing, in which E used the hand farthest from the correct cup and pointed across his body (when standing behind correct cup a random hand, pointing down, was used);

(2)   Belly-Pointing, in which E used his opposite hand to point across his body but with the hand/finger directly at the body midline (when standing behind correct cup the outermost hand, finger pointing down, was used — as in Povinelli & Eddy, in press);

(3)   Gaze, in which E looked at the correct cup but without gaze alternation;

(4)   Gaze + Step-Back, in which E looked toward the correct cup but simultaneously stepped back in the opposite direction so that if the dog were tracking E's eyes his head would be led in the opposite direction from the correct cup.

Each subject participated in 18 trials in each of these 12 experimental conditions, plus 36 control trials identical to those in Study 1, for a total of 252 trials per subject. For both subjects, the trials were administered in the order: Gaze, Gaze +Step-Back, Cross-Pointing, Belly-Pointing. All trials were administered within a 1 month period.

2.1.3 Procedure

All trials followed the same basic procedure as those in Study 1: E arranged the cups, placed the dog in his canonical position, placed his closed hand under each of the cups in a constant order, left the food treat under one of them, gave the appropriate cue for approximately 5 seconds, and then verbally released the dog to find the food. Food placement was randomized so that each cup was baited an equal number of times in each condition, with the same cup never baited 3 times in a row. All trials were videotaped from behind E's location.

2.1.4 Scoring

Scoring was done as in Study 1 (first cup dog physically touched), and reliability scoring on a small sample of trials was again 100%.

2.2 Results

Data analysis consisted of testing the number correct against chance for each subject for each of the 12 types of trial separately (plus the control trials). Since 2 cups were involved, 13 out of 18 trials correct (or greater) was significantly different from chance (one-tailed binomial probability; 14/18 for $p < .05$ two-tailed). Results are presented in Table 2. In this table, Middle refers to trials in which E stood at the midpoint and gave a cue to one of the extremities; Close refers to trials in which E was standing directly behind the correct cup (all cues given directly down); and Distant refers to trials in which E was standing behind the incorrect cup at the opposite extreme.

Results show that both subjects were able to follow E's Gaze cue at above chance levels no matter the position from which the cue was given. This was also true when E used the Gaze + Step-Back cue for Oreo, although Daisy only managed to use this cue at above-chance levels in the Close condition. In the Cross-Pointing condition, Daisy was above chance in all conditions, but Oreo had trouble in the Distant condition. The Belly-Pointing proved to be an ineffective cue, with Oreo performing at chance in all conditions, and Daisy performing at chance in all but the Close condition. Both subjects were at chance in the 36 control trials.

Table 2. Number of trials correct (out of 18) in each condition by each subject in Study 2.

	Oreo	Daisy
Gaze		
Middle	15*	17*
Close	16*	17*
Distant	14*	16*
Gaze + Step-Back		
Middle	16*	12
Close	15*	18*
Distant	13*	9
Cross-Point		
Middle	18*	18*
Close	17*	17*
Distant	12	13*
Belly-Point		
Middle	8	10
Close	12	16*
Distant	3	7
Control (out of 36)	17	22

* Different from chance, p < .05 or less.

2.3 Discussion

The point of this study was to manipulate both the human cues and the spatial layout of the cups so that very simple mechanisms having to do with visual tracking were eliminated as possible explanations of the dogs' gaze following and point following behaviors. The tracking explanation can clearly be eliminated for Oreo. Oreo was above chance in all three conditions using the Gaze cue. He was thus skillful even though E did not alternate gaze between dog and correct cup, and even though in the distant condition the subject had to go to the cup furthest from his own current gaze direction. With the Gaze + Step-Back cue Oreo was again very good in all three conditions, even when the step-back meant that tracking human gaze would give him a "head start" in the wrong direction (middle and distant positions). Oreo was a bit less skillful with Cross-Pointing — he was not successful in the distant condition — and did not comprehend

the Belly-Pointing at all. One possible explanation is that these styles of pointing conflicted with those he was used to from previous interactions with humans.

Daisy was also skillful in all three conditions with Gaze; however she was only able to use the Gaze + Step-Back cue when E was indicating the cup at his feet. She was very good with the Cross-Pointing but not with the Belly-Pointing (except in the close condition). Tracking thus remains a viable explanation for Daisy's behavior since she peformed poorly in all of the conditions in which tracking would most clearly have led to the incorrect cup (Gaze + Step-Back in the middle and distant positions and Belly-Pointing in the middle and distant positions). However, it is important to recall that Daisy was good at 2 of the 4 types of static trials in Study 1, and in this study she was good at the gaze cue even when it meant going away from the human's physical location. If she was using a tracking strategy it involved a subtle strategy using E's eyes only. It is thus possible that her poor performance with the Gaze + Step-Back and Belly-Pointing cues in the middle and distant positions was due to the novelty, indeed oddness, of these cues given her previous experience.

3.   STUDY 3

Studies 1 and 2 investigated two dogs' ability to follow human pointing and gaze direction. Study 3 reversed the roles of human and dog. In this case one human hid food while the dogs watched, and the dog's task was then to direct a naive human to it. During the process, the naive human took up different physical orientations to the dog (e.g., turned his back) to see if this affected the nature of its communicative attempts.

3.1   Method

3.1.1 Subjects
Subjects were the same two dogs. However, it became apparent very quickly that one of the dogs, Daisy, was not interested in showing humans where food was located. She was present for all trials as Oreo communicated with the human, but did not participate.

3.1.2 Materials and Design
Three buckets were hung from a wire approximately 2.5 meters above ground and approximately 2 meters apart. Each bucket had a towel hanging from it. After the food had been hidden by another experimenter (E2), E stood approximately 5 meters away from the buckets, facing the middle bucket. There were three types of trial. In Normal trials E simply took up his position in front of the buckets; in the Eyes Closed trials E stood in the same location facing the buckets but with his eyes closed; and in Back Turned trials E stood in the same location but faced away from the buckets. There were 18 trials of each type, for a total of 54 trials, run in rotating order. Food was placed in the three buckets randomly, with the stipulation that it was in each bucket an equal number of times. All trials were videotaped from behind E's location.

3.1.3 Procedure
To prepare for a trial, E2 placed food in one of the buckets (it was actually placed so that the dog could see it from behind the buckets). E was inside the nearby house and unaware of where the food had been hidden. E2 then left the premises. Twenty seconds after food placement, E emerged from the house and went directly to his location in front of the buckets. In the Normal condition, E stood waiting for approximately one minute. In the Eyes Covered condition, the procedure was exactly the same except that there was an additional one minute period in which E stood facing the buckets while covering his eyes with his hands; that is, he stood facing the buckets with eyes covered for one minute and then uncovered them for one minute. The Back Turned condition was the same as the Eyes Covered condition except that during the first one minute period E had his back turned, at which point he turned around for one minute.

For all trials, when the one or two minute period was over, E made his choice on the basis of the dog's behavior and approached the buckets and chose one. If that bucket contained the food, the dog received it; if it did not contain the food, E found the food in one of the other buckets but the subject did not receive it. E2 then re-entered and a new trial began.

3.1.4 Scoring
As E approached the buckets at the end of each trial, the subject did a number of things that indicated to him the location of the food. Primarily, he looked

toward the food and barked, typically standing under it but slightly to one side, and then alternated his gaze between E and the bucket (on a few occasions he jumped up and tugged at the towel hanging from the correct bucket). Other behaviors were not specifically recorded, but im making his choice E used whatever cues were available.

For purposes of evaluating the subject's behaviors toward E in the different experimental conditions during the one minute period prior to E's approach, three specific behaviors were scored from the videotapes — using the first one minute period for all conditions. We determined the proportion of seconds during the one minute in which E was (1) barking, (2) looking toward E, and (3) in spatial proximity (within 5 feet) of E. (Proportions were used because there were small differences in the number of seconds comprising each trial.)

3.2   Results

Results were very clearcut. On 44 of the 54 trials (81.5%), Oreo led E (who did not know the location of the food) to the food's correct location, $p < .001$, binomial probability. These successes were equally distributed among the three experimental conditions, ranging from 13/18 to 17/18. (Recall that once E had finished taking up his experimental posture, after one minute, he faced the buckets with eyes open in all conditions — so that for purposes of this measure all of the trials were of the same type and we would expect no differences.)

The dog did not behave differently toward E in any of his experimental orientations. He looked toward E for an average of approximately 13% of the experimental period in the Normal condition, for 14% in the Back Turned condition, and for 15% in the Eyes Covered condition. Likewise, he barked toward E for approximately 88% of the time in the Normal condition, for 75% of the time in the Back Turned condition, and for 88% of the time in the Eyes Covered condition. Finally, he came in close spatial proximity to E for approximately 26% of the time in the Normal condition (sd = 39.0), for 9% of the time in the Eyes covered condition (sd = 22.3), and for 26% of the time in the Back Turned condition (sd = 37.8). In all cases one-way ANOVAs (Kruskal-Wallis) showed no differences.

It is important to note, however, that the subject apparently did understand one prerequisite for communication with E in this experimental para-

digm: that E must be physically present. The subject barked for E in 53 of 54 trials. However, during the 20 second period in which E was inside the house to begin each trial, Oreo sat silently outside the door (or near the buckets) waiting for E to emerge, barking in only one of the 54 trials. Because this initial period always preceded E's emergence, it is worthwhile to note that the dog barked for E2 while he was hiding the food on 46 of 54 trials, and this was before the 20 second period in which he sat silently waiting for E to emerge from the house. We also ran a brief 10 minute test in which E was present for one minute and then absent for one minute in alternating succession, and Oreo barked for E in all 5 of the periods in which he was present and in none of the 5 periods in which he was absent. Finally, Oreo also jumped up and tugged on the towel hanging beside the correct bucket on 7 occasions (3 times for E and 4 times for E2; also once incorrectly). This did not result in the food falling or in his obtaining the food as a direct result. He never did this during the 54 20-second periods in which no human was present.

3.3   Discussion

Quite clearly E was able to read Oreo's behavior successfully and reliably in this experimental paradigm. However, the main behavior he used to do this was simply the dog's bodily orientation to the food, which, it could be argued, is not a communicative signal in the sense that the dog produced it with the goal of directing the human to the food. But barking is clearly a communicative signal and it was used only when the human was present. This would seem to indicate that the barking was in some sense a communicative signal directed to the human. He also looked to the human quite frequently, indicating at the very least his understanding that the human was a necessary element in his obtaining the food.

Oreo did not behave differently in any of the ways we measured when E was differentially oriented to the food (facing, back turned, eyes covered). But this is not so surprising, since barking is an auditory signal in which E's visual access to the dog is not crucial, and the dog's looking to E can be seen in all cases as his checking to see if E is responding — again a behavior that should not necessarily be affected by E's visual orientation. Nevertheless, we suspected that dogs do know something about the role of visual access, or at least bodily

orientation, in some situations involving visual signals. Study 4 was thus a brief follow up designed to investigate this possibility.

4.   STUDY 4

In this study we simply set up a situation in which E's visual access would be crucial for the dogs' successful communication with E. Both dogs from Study 1 served as subjects. The procedure was very simple. E played fetch with the two subjects on 36 occasions each. On each occasion E threw a ball, which the subject retrieved. For half the trials, when the subject returned with the ball E was sitting down facing him (Normal). For the other half of the trials, when the subject returned with the ball E was sitting down with his back turned, facing away (Back Turned). For all trials, if the subject dropped the ball where E could see it, he immediately picked it up and threw it again in the same direction, starting the next trial. If the subject dropped the ball where he could not see it, E did not respond. Type of trial alternated across trials for both subjects.

Oreo had played fetch many times previously with E and other humans, and so he played the game very skillfully. In the Normal condition, Oreo returned with the ball and dropped it in front of E on all 18 trials. In the Back Turned condition, he came around E's body and dropped the ball in front of him on 15 of 18 trials. Assuming an equal probability for dropping the ball at E's front or back (even though it took extra effort to drop it in front of E when his back was turned), both of these values are different from chance, $p < .01$ (binomial probability). On the other three trials in the Back Turned condition (distributed throughout the session), Oreo dropped the ball at E's back. When E did not respond immediately he barked and nudged the ball into E's back with his nose.

Daisy had played fetch with humans very little previously. She thus failed to return with the ball on a number of occasions (21 trials). However, she did complete 18 trials in each condition given that E told her to "Come!" as soon as she picked up the ball (staying silent as she approached). In the Normal trials, she dropped the ball in front of E on all 18 occasions. Likewise, in the Back Turned trials she came around E's body and dropped the ball in front of E on all 18 trials. Both of these values are different from chance, $p < .001$ (binomial probability).

The results of this study indicate clearly that the two dogs knew to bring the ball to the front of E. This is important because in Study 2, in which Oreo mostly used barking as an auditory signal, it could not be established that he understood something about the importance of the front side of human beings for visually based interactions. In this study both dogs demonstrated an understanding of the asymmetry of the front and back of humans for at least some kinds of communicative interactions.

5.   GENERAL DISCUSSION

There is no doubt that humans and domestic dogs can learn to communicate with one another quite effectively, sometimes with extensive training and sometimes without. In the current series of studies, we found that one dog trained to a limited degree for purposes of hunting and another dog with basically no training in behaviors relevant to the experiment were both quite good at using human pointing and gaze direction to locate food. Neither animal was able to use eye direction alone to locate food when it conflicted with head direction. The actual movement of the hand in pointing or the head in gazing was not a necessary part of the cue for the dogs in either case, and very subtle low-level strategies involving the tracking of human hand or eye movements could be clearly ruled out with at least one of the subjects. It thus seems that in addition to their ability to use olfactory cues to locate food, and their ability to track the invisible displacements of food as it is transported in an opaque container (Gagnon & Dore 1992, 1993), at least some domestic dogs can also use social and communicative cues produced by humans toward this same end.

The interesting comparison is to nonhuman primates. In recent studies of primate social cognition, mixed results have been reported when humans attempt to direct individuals to locations by means of pointing and gazing. Although a number of studies have established that a variety of species can follow human pointing in various situations (see Tomasello & Call 1994, and Call & Tomasello 1996, for reviews), the results with respect to gaze following (eye + head) are mixed — with Anderson et al. (1995) and Itakura (1996) reporting mostly negative results for a variety of primate species and Povinelli & Eddy (1996a, 1996c, in press) reporting positive results for young chimpanzees. Perhaps the most interesting

point in this regard is that the chimpanzees of Povinelli & Eddy have interacted with humans for many hours in many experimental and animal management situations, whereas this was not true of the primates studies by the other researchers. Evidence for the possible influence of human interaction is provided by Itakura & Anderson (1996), who trained a capuchin monkey to follow human gaze direction (eye + head) to food in 120 trials. Both of the dogs in the current studies had interacted with humans for many thousands of hours before the experiment began, one receiving some training in following various types of human directions, and it is very likely that this was instrumental in their learning to use human pointing and gaze as communicative signals. How they understood these signals, in the sense of how they understood human visual and communicative behavior, is not something that was probed directly in the current experiments. However, we see no aspects of their behavior that would differentiate their understanding from that of nonhuman primates, with the exception that some (but not all) chimpanzees seem to be able to use eyes only as a directional cue.

With regard to the production of communicative signals, one of the two dogs studied (the "trained" dog) was quite skillful at directing humans to hidden food. He did this by barking and orienting his body to the food's location. He did not engage in these behaviors when humans were not physically present, indicating at the very least that he knew something of the human's role in the process. He did not behave differently when the human was bodily oriented in different ways, however, but it is not clear that in this situation — in which barking and then checking the human's reaction was his preferred strategy — that the human's bodily orientation should have been crucial. In the fourth study the bodily and visual orientation of the human was important, and here both dogs showed a very clear understanding that certain behaviors need to be performed in front of humans. Their behavior in this regard seems very similar to that of Povinelli & Eddy's (1996b) chimpanzees, who also produced visually based gestures differentially for humans facing toward them and humans with their backs turned — but without differentiating more subtle bodily orientations involving covering of the eyes and the like (even though in other studies they followed human eye gaze without the head).

It is important to note that dogs' communicative behavior with humans may be very different from their communicative behavior with conspecifics. Indeed, in

a recent experimental study Tomasello, Call & Hare (in press) found that five different primate species follow the gaze of conspecifics quite reliably, in contrast with the findings of Itakura (1996) who found that four of these same species did not follow human gaze. This fact simply indicates that communicative signals develop as both participants in the process, sender and receiver, behave in socially coordinated ways leading either to the signal's creation or else to the association of a species-typical signal with specific communicative circumstances. Future research should thus investigate the communicative behavior of dogs with one another, as well as investigate further their understanding of humans in the communicative process. Given the unusual genetic diversity in the species *Canis familiaris*, in the form of artificially selected breeds, within-species differences in communicative skills should be of special interest, as well as differences among different species of undomesticated canines.

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