Anim Cogn
DOI 10.1007/s10071-008-0175-y

ORIGINAL PAPER

Attention to attention in domestic dog (*Canis familiaris*) dyadic play

Alexandra Horowitz

Received: 24 May 2008 / Revised: 13 July 2008 / Accepted: 19 July 2008
© Springer-Verlag 2008

Abstract The social cognitive capacities of dogs, including their communication skills and use of visual attention cues, have recently been investigated in numerous experimental studies. This paper reports on research of domestic dog behavior in a natural setting, which shows sensitivity to the visual attention of their partners when engaged in dyadic rough-and-tumble play. The sequential behaviors and head-direction of both dogs were noted throughout the bouts. The behaviors were differentially used according to the partner's posture. Play signals were sent nearly exclusively to forward-facing conspecifics; attention-getting behaviors were used most often when a playmate was facing away, and before signaling an interest to play. In addition, the mode of attention-getter matched the degree of inattentiveness of the playmate: stronger attention-getters were used when a playmate was looking away or distracted, less forceful ones when the partner was facing forward or laterally. In other words, these dogs showed attention to, and acted to manipulate, a feature of other dogs that mediates their ability to respond: which feature in human interaction is called "attention".

Keywords Visual attention cues · Dogs · Social cognition · Play

A. Horowitz
University of California, San Diego, USA

Present Address:
A. Horowitz (✉)
Department of Psychology, Barnard College,
3007 Broadway, Milbank Hall, New York,
NY 10027, USA
e-mail: ahorowitz@barnard.edu

Introduction

Investigation into the cognitive capacities of animals has traditionally focused on primates, especially great apes. As a result of our shared ancestry, they have been considered the likeliest candidates to show inceptive forms of cognitive skills which appear fully formed in humans. Recent research with domestic dogs (*Canis familiaris*) has shown that dogs perform at a surprisingly high level on social cognitive tasks, often at levels rivaling chimpanzees (Hare et al. 2002), though chimpanzees out-perform dogs on simple cognitive tasks like invisible displacement (Collier-Baker et al. 2004; Fiset and LeBlanc 2007). Domestic dogs, though much more distant evolutionarily, have a long recent association with human society: from 14,000 to possibly over 100,000 years (Clutton-Brock 1999; Vilà et al. 1997).

As a result, it has been speculated that dogs, by way of their selection by human beings, are unusually adept at interpreting and producing signals salient to humans (Hare and Tomasello 1999; Horowitz and Bekoff 2007; Miklósi et al. 2004). Their communicative skill may be a result of the process of domestication (Cooper et al. 2003; McKinley and Sambrook 2000; Miklósi et al. 2000), although the use of the pointing gesture by some non-domesticated animals indicates that domestication is not necessary for a species to be so skilled (Miklósi and Soproni 2006). Dogs, like other social species, have various means to communicate: signals combine body position, including head and tail (Quaranta et al. 2007); expressive use of eyes, lips, and teeth; and vocalizations such as growling, barking, howling, grunting, and whimpering (Bekoff 1972; Bradshaw and Nott 1995; Fox 1978). Dogs are also sensitive receivers of vocalizations, gestures, or tone communications from their human caretakers (Serpell 1995). Recent experiments have shown that dogs respond to social cues which involve the attention of others. Dogs follow others' gaze, head and body orientation (Agnetta et al. 2000; Miklósi et al. 1998), and pointing (McKinley and Sambrook 2000; Soproni et al. 2002). They learn to follow glances and eye direction pointing (Miklósi et al. 1998) and can follow a point or gaze already underway (Hare et al. 1998; Hare and Tomasello 1999). There is some evidence of manipulation of others' attention: research has found that dogs use attention-getters and gaze to "show" a naive human subject the location of a hidden treat (Miklósi et al. 2000) or toy (Virányi et al. 2006), and are attuned to the attentional state of humans when approaching food (Call et al. 2003), in play, when fetching, or when begging (Gácsi et al. 2004).

Given these results, a logical next step is to examine dogs' communication usage and use of others' gaze in combination. The present research looks at dogs' use of visual attention cues while or before communicating to other dogs. Sensitivity to the attentional state of one's audience is a definitional condition for intentional communication (Bruner 1981; Tomasello et al. 1994): it is what distinguishes such communication from functionally effective yet unmindful transmissions. Research with primates has looked at the animals' detection and use of visual attention cues, including unobstructed gaze, response to head and body direction, and audience presence or absence (e.g., Call et al. 1998; Povinelli et al. 1990; Tomasello et al. 1999; Whiten 1997). Recognition of the attentional state of others is invoked in a number of tests of non-human theory of mind, such as those that ask if chimpanzees can discriminate knowledgeable and ignorant helpers (Whiten 2000) or are able to connect "seeing" and "knowing" (Call 2001; Hare et al. 2001; Povinelli et al. 1990). Research with non-human animals has also looked at what is called "attention-getting" in social interactions (Call and Tomasello 1994; Gómez 1996; Miklósi et al. 2000; Theall and Povinelli 1999; Tomasello and Call 1997). These behaviors—such as, in chimpanzees, hand-clapping, vocalizing, touching, and gesturing appropriately before communicating—are described as "attention-getters" in reference to the change of eye or head gaze they effect (Tomasello et al. 1994). Attention-getting is demonstrated by purposive behavior directed toward another, inattentive, animal: by making noise (Miklósi et al. 2000), putting oneself in front of, or touching the other. Attention-getters used by humans in human–dog play include vocalizations before play signaling (Horowitz and Bekoff 2007), whistling, and making dog-imitative sounds (Mitchell and Edmonson 1999).

To examine the topic of dogs' attention-getting and use of visual attention cues when communicating, the present research uses a natural interactive behavior: social play. Dyadic rough-and-tumble play is prototypical play in dogs (Burghardt 2005). This play is characterized by a labile series of coordinated behaviors, moderated in force or exaggerated in form. It often involves turn-taking, self-handicapping [but not always (Bauer and Smuts 2007)], role-reversal, and seeming acts of pretense (Bekoff and Byers 1998; Bruner et al. 1976; Burghardt 2005; Fagen 1981). To capture the context of application of communicative signals and the concurrent attention cues of each dog, in the present study episodes of social play were videotaped. Play sessions were then transcribed into an itinerary of behaviors, resulting in lists of sequential or concurrent behaviors. After transcription, behaviors were identified as play signals and attention-getters, and were selected for analysis. Corresponding postural direction of the audience can be examined in relation to these behaviors.

Play signals

Play signals are used to begin, and to continue, social play (Bekoff 1972; Fagen 1981; Smith 1982). Because play borrows behaviors—such as nipping, chasing, vocalizing, mounting, and tackling—that are also used during aggressive interactions, a playing animal must communicate to its desired play partners that it is not trying to injure or consume them. Identified play signals in canids include the high-rumped crouch of a "play bow", an open-mouthed "play face", a more subtle "face paw", and a "teasing", "chase me" posture (Bekoff 1972, 1974). These behaviors are similar to play behaviors in non-human primates such as "ground slap", "head bob", "poke-at", and "invite-chase" (Tomasello et al. 1994).

For effective communication of a play signal, the audience must be able to receive the sent signal. Differential communication based on the very presence or absence of someone to notice it is known as the "audience effect": 'broadcast' communication may be indifferent to an audience (as a flower's bloom) or to the particulars of an audience (as frogs' mating advertisement calls, delivered en masse); 'directed' signals are used only when a receptive audience is present (Hauser 1996). An ancillary element of the audience effect is a responsiveness to the particulars of the audience: for instance, the relation of the recipient's posture to the sender. Data of the context of the communications in play will show whether play signals are sent only when there is a nearby, candidate audience, or whether they are used without a potential audience in the vicinity. Head- and body-direction data will reveal whether dogs send play signals to present, proximate, and forward-facing audiences or to dogs directed away from the sender.

Effective communication also involves an order of operations related to the attentional state of one's audience. One must enter a closed room before (effectively) speaking to those inside; a dog must be in a visual line of sight before (effectively) using a visual signal of a desire to play. A flexible communicator might follow a sequence that is both ordered correctly and is responsive to the changing state of the audience. Analysis of the data will show whether, when attention-getters and play signals are used sequentially, one more often precedes the other.

Relatedly, after sending a signal, a signaler may seek information as to the signal's reception. A behavioral response, or the lack of a response, indicates whether the signal was received and understood. Specifically, a communicator may pause after signaling to gauge the audience response and determine how to proceed; such a pause in action gives one's interlocutor time to react by looking back. This "look pause", also called "response waiting" (Tomasello et al. 1985), has been examined in primate communication (Tomasello et al. 1994). Data will reveal whether dogs wait for a response after trying to change another's attentional state and before play signaling.

Attention-getting behaviors

Attention-getting behaviors are those which could be used to change a signal receiver's attentional state. Thus, an attention-getter has a potential functional use, but they are also part of the repertoire of behaviors used throughout play. Data are gathered which will reveal whether dogs use behaviors which serve to change another's attentional state more often when attention *needs* to be gained: for instance, choosing a behavior which has an attention-getting function (e.g., "bite"), as opposed to one that does not (e.g., "walk"), when their partner has taken an inattentive pose. "Inattention" is identified by the non-visually-attentive posture of the dog: looking away, looking to the side, or distracted. The hypothesis that dogs recognize the importance of visual attention cues when communicating to conspecifics specifically predicts that the rate of attention-getting behaviors will be higher when the other is inattentive than throughout the play bout.

Further, data will show if dogs persist and vary their attention-getting according to whether it is effective: according to whether attention has been gained. The action performed after an attention-getter can be categorized as play, a play signal, non-play behavior, or an attention-getter; if dogs continue to try to get attention when not yet successful, the specific attention-getters used can be noted.

The context in which attention-getting behaviors are used can also be examined to determine if the modalities of these behaviors correspond to the recipients' availability to receive each type of message. A combination of postural and action data will show whether dogs use attention-getters that are appropriate to the level of physical "attentiveness" of their audience, marked by head and body posture. More forceful methods might be necessary with a dog looking away; less forceful may be sufficient if the intended receiver is already directed toward the sender.

Thus, the present work considers the degree to which communicative acts performed by domestic dogs at play are displayed with sensitivity to others' attentional states, and whether dogs employ appropriate strategies for changing their attentional state. If dogs are aware of the necessity of securing the visual attention of their audience in order for their communications to be received, we would expect to see that dogs modulate their communicative behaviors in response to the head and body posture of another dog: for instance, by communicating a desire to play only to visually attentive dogs, or by attempting to establish visual attention before communicating.

Methods

Study site and subjects

Thirty-nine bouts of social play were recorded and analyzed. These were the complete and visually unimpaired bouts culled from nine continuous hours of digital videotape of full or abbreviated play episodes over 21 months. For purposes of ecological validity, the site for the study was selected which represented the most natural environment for dogs: one which allows dogs untethered interactions with humans and other dogs. The location was a 1.1-ha partially fenced grassy public space in the coastal community of Leucadia, California called "Orpheus Park". The park was mostly open lawn, allowing for numerous simultaneous interactions between animals, while interruptions from newcomers or passing or playing dogs were frequent. Between four and six p.m. three days a week the park was open to off-leash dogs; local dog owners congregated during these hours and the dogs were able to interact. The animals were not only domesticated but regularly interacted with other dogs, and were well habituated to the presence of humans. Their behavior was not visibly altered by the presence of a video recorder.

Attendance at the park varied each session, and between sessions, but over the course of observations there were generally between 20 and 40 dogs at the park at one time (range: 7 to over 50). There was thus ample opportunity for interaction. The coded bouts involved 78 dogs. The dogs' ages ranged from 0.4 to 12.0; the majority (55/78) were 1–2 years old (mean = 1.8 years). Twenty-six were purebred dogs, and 52 were mixed breeds; they varied in size from a mixed breed of under three kilograms to a Newfoundland of 68 kg. Age, breed, and weight information were gathered from owner report. Given the hypothesis that differences between breeds can be partially mapped to differential neoteny (Coppinger and Schneider 1995), and that play styles may vary by age (Scott and Fuller 1965) or by breed, age and breed type were noted, but not controlled for.

The limited dog-park hours served to condense visits by dog owners, which tend to be scattered throughout the day at other parks, into reliable 2-h chunks. Time of day can influence animals' play (Pellis 1991), and in this research each session observed was at the same time of day. Only playing dogs were videotaped. Sampling was opportunistic: bouts were recorded when they occurred among any individuals in the population (Lehner 1996). Distance from the camera to the subjects varied according to their playing behavior, and ranged from 1 m to the periphery of the park, 30 m away, during a chase. Over 200 dogs were videotaped or observed, to avoid the bias of non-random sampling. Circumstantial variables—characteristics of the environment (the size of the congregated group, surface conditions, weather), and subject descriptions (sex, familiarity of dogs, amount of past socializing)—were recorded.

Data gathering

An ethogram of social play and affiliated behaviors was compiled based on preliminary observations and on past canid and other animal research (Bekoff 1972; Bekoff and Byers 1998; Martin and Caro 1985; Tomasello et al. 1994). Ethogram behaviors are mutually exclusive, so only one behavior occurs at any one "instant"—1/30th of a second in digital video—and exhaustive, insofar as each animal is always engaged in one of the actions.

The bouts selected for coding all lasted at least 20-s, primarily involved only two dogs, and did not have significant owner or video interruptions; there were 39 such bouts. Additionally, all coded bouts were instances of successful play, with "success" defined as a bout which achieves a relatively even rate of behavior exchange, and does not spiral into an aggressive encounter. Pauses or moments of inattention were retained: video recording was not stopped when play paused. Since play is highly coordinated and fast-paced, a pause of a certain length tends to disintegrate the play. These moments of disruption, by attenuating the momentum of the bout or straining the balance in the play relationship, provide an opportunity to see if a motivated player will move to revive or, if necessary, re-start a play session. However, once 10 s had passed without any play behaviors performed, or when the distance between the dogs was greater than 10 m, exclusive of chasing behavior, the play was marked as concluded (Lehner 1996). The video was later analyzed, by repeated slow-motion tape playback, with regular frame-by-frame examination, and translated into event-based codes (Bakeman and Gottman 1997) per the ethogram. A concurrent time counter was kept. The result is an exhaustive list of sequential behaviors, done by both players.

In addition, the dogs' head direction, body direction, proximity to one another, contact with one another, and body pose at each behavioral event were recorded (see Fig. 1 for posture codings for three example pairings). Given the stop-motion video playback, changes in posture direction were readily identifiable, though they would be impracticable to specify in real-time observations. Dogs' head and body positions serve as indicators of their potential attention to communications being sent. What counts as physically attentive is in part self-explanatory: a dog who is turned "toward" a signaler can (potentially) receive any communication. An animal's forward-facing posture cannot guarantee that its visual attention is focused on what is in front of its face, but facing forward is a necessary precondition for visual attention. Thus, I considered "toward" to be the most "attentive" state. Varieties of "inattentive" states follow: one whose head is turned "flank" (sidewise) to the sender might receive visual communications: the lateral placement of dogs' eyes allows for 270° of peripheral vision, enabling perception of events on the side of one's head (Fuller and Fox 1969). One whose body or head is turned "away" will only receive tactile or auditory information; and one who is socially interacting with a conspecific (Tomasello et al. 1994), or with a person (Serpell 1995) is considered the most inattentive to the signaler.

After full coding of the bouts per the ethogram, the behaviors of each bout were categorized into one of four groups for consideration with respect to the questions of this research: play signals; attention-getting play behaviors; non-attention-getting play behaviors; other, non-play-specific behaviors. Play signals and attention-getters have been defined in the literature functionally and situationally, by the changes they effect and the context in which they are given (Smith 1991). Play signals ("play bow", "chase-me", "open mouth", "bow head", "play slap", "leap on") are used to communicate play intent (Bekoff 1972, 1974; Fagen 1981; Fox 1978; Rooney and Bradshaw 2002) and are rarely seen outside of play. Signals vary in length and intensity. Play bows and slaps range from "minor" to

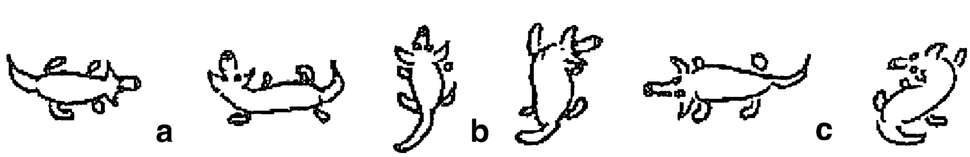

Fig. 1 Bird's-eye view of postures of interactants in three sample pairings. Coded as: **a** dog 1: head toward, body toward; dog 2: head flank, body toward; **b** dog 1: head flank, body flank; dog 2: head away, body flank; **c** dog 1: head away, body away; dog 2: head toward, body away

"exaggerated" in form: from almost perfunctory gestures to those incorporating the whole body. Attention-getting play behaviors ("self-present", "bark", "paw", "bump") serve to alter the sensory experience of another, either by interrupting the visual field, the auditory stream, or by interacting physically. (Note that behaviors were labeled attention-getters even if they were not serving an attention-getting function at that moment: analysis will determine whether they are, in fact, used more often when a play partner's attention is away.) These include reorienting, contact, and acoustic behaviors [such as, in primates, "ground-slap", "hand-clap", "foot-stomp", "poke-at", and "throw stuff" (Tomasello et al. 1994)] and are disjoint with dominance acts (such as "stand-over", "lie on", "mount", "lunge", and "take-down") (Bekoff 1995). The latter acts, non-attention-getting play behaviors, are used in play but would be subject to different interpretation (as of aggression) if not in the context of play or preceded by a play signal. Finally, behaviors that appear in play, but that are not specific to play, were labeled "other". Some are part of a normal play sequence ("self-take-down", "follow"); while others may disrupt the play ("shake", "look away", "leave"). Table 1 lists only the seen play signals and attention-getters; this is a subset of the ethogram behaviors used for coding the bouts.

The author coded every bout from the videotape. An independent observer coded a random selection of eight (21%) bouts. To assess reliability of coding, three measures were used. The first was a measure of agreement on the number of each kind of event (play signal, attention-getter, or other behavior) in each bout. This was done to assure reliability of characterization of the four events used for analysis, though the bouts were originally coded into raw behaviors. Agreement was high (Cohen's kappa = 0.95). The second was a measure of agreement as to head posture (Cohen's kappa = 0.91) and body direction (Cohen's kappa = 0.88). Finally, as the coding was event-based, not time-based, an attempt was made to determine reliability of

Table 1 Glossary of play-signal (ps) and attention-getting (att-g) motor action patterns seen in play by the domestic dog, *Canis familiaris*, characterized by sensory modality

Behavior	Description
Visual	
Exaggerated approach (ps)	Slow, running approach in sightline of other; loose, rolling nature to run
Exaggerated retreat (att-g)	Backwards leap; head toward partner
Play-bow (ps)	Forelimbs down; hind end raised; tail erect or wagging
Chase-me (ps)	Withdraw with looks backward; at a reduced pace or with loping stride
In-your-face (att-g)	Position body or face inches from other's face
Self-present (att-g)	Approach or leap up within 1 m, positioned forward in the line of sight of another
Open-mouth (ps)	Frontal display with teeth and lips showing; no biting
Bow head (ps)	Nod head below shoulder level; maintain or nod up
Play slap (ps)	Usually simultaneous slap of ground with two forelimbs (element of play bow)
Present (att-g)	Turn body to allow rear end proximate to other's face (close enough for potential contact)
Tactile	
Leap-on (ps)	On hind legs, with front paws around other's head; tail up
Bump (att-g)	Use named part of body to knock into other dog
Nose (att-g)	Put nose and closed mouth to other; non-investigatory
Bite (att-g)	Make firm mouth contact (of scruff, rump, face, or body); force is tempered
Bite-at (att-g)	Can have no clear object: biting at air in the direction of, but not touching, other dog; can be partial or repeated
Paw (att-g)	Paw at other's face or body
Auditory	
Play pant (ps)	Breathy exhalation (Simonet et al. 2001); not always audible
Play slap (ps)	Usually simultaneous slap of ground with two forelimbs; not always loud enough to be audible
Bark (att-g)	Can be directed toward other or broadcast

event boundaries. This was done by a tally of the number of agreements and disagreements on assignment of a behavior as a play signal or attention-getter, including errors of omission as disagreements (Bakeman and Gottman 1997). Agreement was 88%.

Statistical analyses

As the question of interest is how dogs use visual attention cues in communication, data here presented focus on the use of two communications (play signals and attention-getters), their use in combination, and the concurrent attentional state of the potential recipient of the signals. Analysis compares the rate of various attention-getting behaviors to attentive (forward-facing) and visually inattentive (variously defined) recipients, and on the use of attention-getting behaviors of different modalities: visual, auditory, and tactile. As body posture is not sufficient for visual attention, but head direction is, analysis used the head-direction data as measure of visual attention.

Since the data were not normally distributed, nonparametric tests of statistical significance were used. Ad libitum sampling for the behavior of play allowed for true frequencies and allowed for analysis of significant sequences of behavior (Martin and Bateson 2007). Event-coding allowed for simple frequency and percentage rate information to be gathered, and preserved a continuous sequence of behaviors, so correlations between behaviors could be investigated. Expected rates of various behaviors, based on averages across bouts, were compared to observed rates at particular moments within the bout.

In analysis of one animal's contingent responses to another animal's postural state, a sociometric matrix table was used. The sociometric matrix plots behaviors of one individual at time t_0 to behaviors of another at t_1 (Lehner 1996). It is presented here to determine differences between observed and expected rates of behavior at focal points during the play bouts.

Results

Thirty-nine bouts of social rough-and-tumble play between pairs of dogs (78 dogs) were analyzed. Bouts ranged from 23 s to over 3 min, with a mean time across bouts of 1 min 13 s. After grouping the behaviors into categories, expected rates of behavior were considered on a bout-by-bout basis; Table 2 lists the percentage rates of each of the four aforementioned categories of play behaviors across all bouts. The average rate of each kind of behavior at any moment during the play bouts serves as a baseline to compare against rates of behaviors at moments of one dog's inattention. Data-analysis focuses on three elements: characterization and use of play signals, attention-getters, and the behaviors in combination.

Table 2 Constitution of 39 play bouts, with behaviors characterized as either play signals, attention-getting or non-attention-getting play, or other

Percentage of bout so engaged				Mean time (min:s)	Mean age (years)
Play signals (%)	Att-g play (%)[a]	Non-att-g (%) play	Other		
12	34	31	23	1:13	1.8

Time of each bout and age of players (from owner report) are also provided

[a] att-g = attention-getting

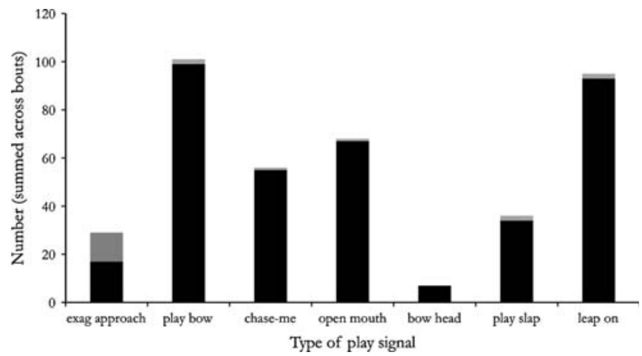

Fig. 2 Frequencies of various play signals (pooled across bouts) ($n = 39$ bouts; 397 play signals total). *Dark component* of bars represents number performed toward attentive recipients (376/397); *light component*, toward inattentive recipients (21/397)

Play signals

Dogs used a number of alternative means to express an interest in, or attempt to begin, play (Fig. 2). In total, 397 play signals were recorded (Table 3), by subjects in 38 of 39 bouts. In one bout, no play signals were seen. Overall, play signals accounted for 12% of the play behaviors recorded (Table 2).

Many of the seen play signals have already been identified by previous research. Other new play signals—"leap on", "bow head", and "play slap"—were identified. They are, respectively, extrapolations from other carnivore play (Fagen 1981), and intention movements: components of other sig-

Table 3 Play-signaling behavior across bouts

	# Play signals	Type of signal[a]								To attentive audience
		EA	PB	CM	OM	BH	PSL	LO	CB	
Total	397	30	100	56	68	7	36	95	5	376/397

[a] *EA* exaggerated approach, *PB* play bow, *CM* chase-me, *OM* open mouth, *BH* bow head, *PSL* play slap, *LO* leap on, *CB* combination

nals that seem to be used among some dogs as shorthand, perhaps conventionalized (Tomasello et al. 1994).

Of interest is the posture—head direction—of the recipient in the application of play signals. Of the 397 play signals observed over these bouts, a significant number, 376, were to a forward-facing audience (Wilcoxon signed ranks test, $z = 5.25$, $n = 37$ bouts, $P < 0.001$) (Table 3; light bars, Fig. 2). Seven percent (26/371)[1] of play signal usages were sequential or repetitions. As only play bouts were videotaped, every play signal seen was performed toward an audience (397/397).

Play signals were also differentially used when play was underway. Some "pauses" in play, moments of one or both dogs' inattentiveness or pause from activity, occurred in every bout. On these occasions, play signals were used at high rates. Considering the observed versus the expected rates of play-signaling, 41% of the play signals (162/397) used in all bouts were within 1-s of the end of such a pause: a rate of 0.21 per second, as versus 0.09 per second throughout the overall bouts ($\chi^2 = 128.6$, $df = 1$, $P < 0.001$).

Attention-getters

In most play sessions, one or both dogs became visually inattentive numerous times: with their head turned to the side (flank) or away from their partner, or by being socially distracted. This context appeared 410 times throughout the bouts. In 48% of the cases (198/410), the visually inattentive dog (dog 1) looked back on its own before its partner (dog 2) could act. In the other 212 cases, the behavior sequence following dog 1's inattention can be characterized (Table 4).

Seventy percent of the time (148/212), dog 2 acted to change the direction of its partner's gaze, using one of nine attention-getting behaviors: "bite", "paw", "bark", "in-your-face", "nose", "bump", "exaggerated retreat", "present", and "self-present" (column *t*1, Table 4) (after Gómez 1991; Theall and Povinelli 1999; Tomasello et al. 1994). In those cases, play continued 88% (130/148) of the time (column *t*2, Table 4). When dog 2 used another behavior—a play signal or other form of play, not an attention-getter—or did not act at all, play resumed only 20% (13/64) of the time, and the rest of the time play ended ($z = 9.3$, $P < 0.05$).

In those 212 cases when a player was visually inattentive to its partner, and did not look back on its own, the probability of the partner using an "attention-getter" can be compared to its average rate of attention-getting moves throughout the bout: P(att-g/away) versus P(att-g/overall). Figure 3 shows the percentage rates for every individual bout that had relevant cases of looking away ($n = 33$): in each bout the rate of attention-getting was higher when the other dog was looking away than the average rate of those behaviors over the course of the bout. Pooling the data across all bouts, the dogs used attention-getters significantly more often when their partners were looking away than throughout the bouts [P(att-g/away) = 0.82, P(att-g/overall) = 0.34; Wilcoxon signed ranks test, $z = 4.93$, $n = 33$ bouts, $P < 0.001$].

In addition to the increase in the number of attention-getters used when a player's partner was visually inattentive, there was a decrease in the number of play signals or outright play moves used at those moments. Table 5 is a sociometric matrix of observed and expected rates of behaviors in two contrasting conditions: of dog 2's behaviors when dog 1 is looking or not looking. Summed across bouts, there was a significant ($\chi^2 = 137$, $df = 3$, $P < 0.001$) difference between observed and expected rates of behavior in these conditions: attention-getters were used more often (than expected values) when one's partner was not attentive ("no look"); play moves and play signals were used more often when one's partner was attentive ("look").

Figure 4 presents the data of the mean number of visual, tactile, and auditory attention-getters (see Table 1 for examples of each) used in each bout, to either a partially or fully visually inattentive recipient ($n = 39$ bouts). Dogs did not direct significantly more visual attention-getters to dogs who had their side to them (Wilcoxon signed ranks test, $z = 1.93$, $n = 19$ bouts, $P = 0.0536$); but dogs directed more tactile attention-getters to dogs who were looking away or socially distracted (Wilcoxon signed ranks test, $z = 2.37$, $n = 33$ bouts, $P = 0.0178$). Tactile gestures were preferred in both cases (64% of total attention-getters for "flank"; 78% of total for "away" states). Auditory attention-getters were used by only a few dogs ($n = 2$), providing insufficient data for comparison.

In 32 cases, in a subset of the described bouts ($n = 12$), one dog was not only turned away from its play partner, but was also interacting with another dog or a person. In these 12 cases, tactile attention-getters were used more often (22/32; 69%) than any other attention-getter, and significantly more often than visual attention-getters (Wilcoxon signed ranks test, $z = 2.22$, $n = 12$ bouts, $P = 0.0264$).

Forty percent (53/130) of the time, after an attention-getter, the other dog (the recipient) immediately re-commenced play (column *t*2, Table 4). In the remaining cases, the signaler either waited for a response, or acted outright, by play-signaling, playing, or doing another attention-getter. The former case, a "look pause", describing the signaler's pausing until its audience looks back, was taken in these bouts 30% (39/130 incidents) of the time; the signaler acted outright 29% (38/130 incidents) of the time. Neither strategy dominated.

In a subset ($n = 24$) of the latter cases, dogs continued to use attention-getters, one after the other, until the other dog

[1] The figure 371 derives from subtracting the number of repeated instances (26) from the total number of play signals (397).

Table 4 Application of attention-getters at moments of inattention, and subsequent behaviors

*t*0	*t*1	*t*2					
# Episodes of inattention (dog 1)	# Followed by att-g (dog 2)	Behavior (by either dog) immediately following att-g					
		Dog 1		Dog 2			Pause or end
		Look	Play	att-g	ps	Play	
212	148	39	53	24	5	9	18

From left to right, this table lists the behaviors seen at time *t*1 and *t*2 following one dog (dog 1)'s inattention at *t*0: (*t1*) the number followed by the use of an attention-getter by the other dog (dog 2); and (*t2*) the next action done by either dog

att-g attention-getter, *ps* play signal, *play* non-attention-getting play

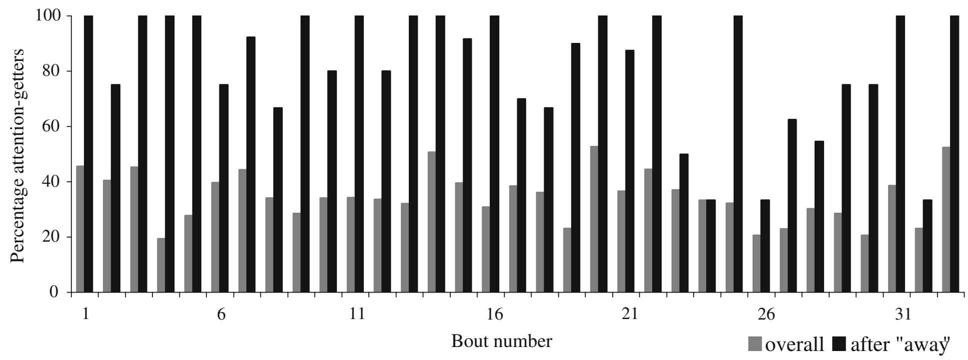

Fig. 3 Percentage of behaviors in each play bout that could be called "attention-getting behaviors": over the entire bout (*light bars*), and after one dog has turned "away" from the other (*dark bars*) ($n = 33$ bouts)

Table 5 Data from all bouts ($n = 39$) showing observed and (expected) number of behaviors by players (dog 2) for each posture by its partner (dog 1)

		Dog 2 behavior	
		Play which can serve as attention-getter	Non-attention-getting play, or play signal
Dog 1 attentional state	Look	890 (963)	1,356 (1,280)
	No look	156 (80)	30 (106)

Note that the overall number of all play behaviors was highest when a dog's partner was looking

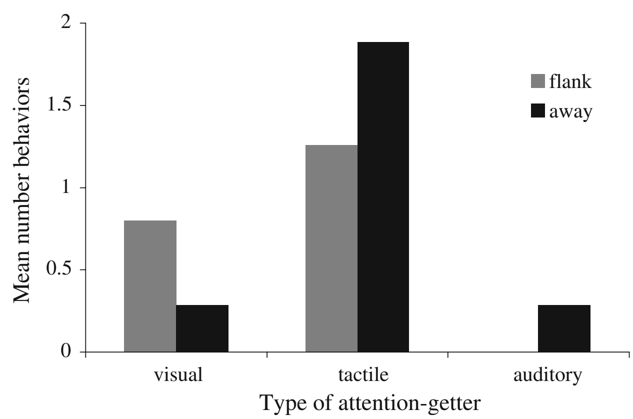

Fig. 4 Mean number of visual, tactile, and auditory attention-getters used toward inattentive or distracted recipients (with posture "flank" or "away") ($n = 39$ bouts)

looked, or responded with play. In most (21/24) cases, dogs varied the attention-getter used, resulting in a sequence of from two to six different behaviors (Table 6). In three cases, the same single behavior was used repetitively.

Behaviors used in combination

In 42 cases (in 23 bouts) dogs used attention-getters and play signals together: one after the other. In 31 (74%), the actor preceded the play signal with the attention-getter: significantly more often than the inverse (11/42: 26%) (goodness-of-fit test: $\chi^2 = 9.52$, $df = 1$, $P < 0.01$).

In 27 of the 31 cases, each communicative act performed matched the audience's visual attention cues—i.e., attention-getters were used when the audience was not looking; play signals were used when the audience then looked (see Fig. 5 for an example). Within this subset, the actor paused before signaling in 22 of the 27 cases; in the remaining 5/27 (column *t2*, Table 4), he did not (goodness-of-fit test: $\chi^2 = 10.7$, $df = 1$, $P < 0.01$).

Discussion

The data of the behaviors observed in the present study reveal that dogs used visual attention cues in communication, and used flexible means to acquire attention. These results can be considered more fully here.

Table 6 Number of episodes ($n = 24$, in 20 bouts) in which attention-getters were used in succession, listed by the variety seen in the sequences

Sequence of attention-getters used	Number of episodes
a,b	13
a,b,c	4
a,b,c,d	1
a,a	2
a,b,c,d,b	1
a,b,c,d,e,a,f	1
a,b,b,c,b,c	1
a,a,a,a,a,a,a	1

If two separate attention-getters were used, this is coded “a,b”; if three, “a,b,c”. If an attention-getter was repeated, the letter is repeated: “a,a”

Fig. 5 Example of use of attention-getting and play-signaling in succession during a play bout between a Rhodesian ridgeback (*light*) and a boxer (*dark*) (elapsed time <3 s). **a** The *light* dog leaves and is followed by the *dark* dog; **b** the *dark* dog does an attention-getter (self-present); **c** as the *light* dog looks, the *dark* dog play-signals (play bow)

Use of visual attention cues

As the present study looked only at behaviors within bouts of play, the dogs were seen to signal requests for play exclusively to present audiences; they also signaled requests nearly exclusively to attentive audiences (376/397; Table 3). This figure is strong evidence that dogs directed their communications to an audience able to receive those communications.

Dogs used more attention-getters and more play signals at moments of visual *in*attention or pauses in play. Further, dogs used play signals significantly more after having gained visual attention of a play partner than before doing so. The data show that dogs observed an order of operations when performing both acts in succession: attention-getting before signaling. Of these communicatively appropriate sequences, many (27/31) were marked by apparent responsiveness to the updated attentional state of the recipient: play-signaling or playing only after the attention-getter was successful in directing gaze to the signaler (Fig. 5). This sequence does not appear significantly more often than would be expected, when a transition matrix of sequences of the whole bout is created. However, there is a trend toward use of these behaviors in an order suited to best conveyance of a signal.

In 22 of the 27 cases, the actor also paused after attention-getting and before signaling. This “response waiting” has not been statistically assessed, but it is notable that, in a fast-paced social interaction such as play, time may be taken to wait for a response. Pauses were also occasion for a significant increase in play-signaling: where applicable to resume play.

Mechanisms for changing attentional state

The predicted behavior for an animal who understands the need to get visual attention before communicating, or before play can continue, was borne out by the data of the observed dogs: the rate of attention-getting play behaviors was significantly higher immediately after the play partner took an inattentive pose (Fig. 3). Attention-getters were also preferred at those times over other play behaviors (column *t1*, Table 4). There was a correlation between one dog's attentional state and the other's behavior (Table 5). If one animal was not looking, the other changed its behavior to move to get the first's attention.

Considering just those attention-getters that have failed to achieve their desired effect (directing visual attention toward the sender), the data show that these signaling dogs did vary, and persist, in their attention-getting (Table 6). In some cases, multiple attention-getters were tried, with minimal repetitions of the type of attention-getter, and dogs persisted until visual attention was restored and play resumed. In this way, the dogs performed comparably to juvenile chimpanzees who use various attention-getting gestures in succession when one gesture fails (Tomasello et al. 1994). Not every dog was equally proficient at acquiring attention. One sequence of dog interaction involved a dog, for instance, barking repeatedly, and fruitlessly, at an uninterested play partner (final entry, Table 6).

An explanation for dogs' generally appropriate use of attention-getters (or of play signals) might be that it is a fixed response to certain cues: to wit, of the perceptual array of a face, a face or body in profile, or the back of a dog. But the evidence that the dogs used many different attention-getters to achieve their goal renders this explanation incomplete. Attention-getting is not a fixed response to a perceptual input; their strategies indicate some acknowledgement of the desired outcome, and the employment of various means to achieve it.

Notably, these dogs' use of attention-getters was correlated with the posture or attentional state—the level of physical "inattentiveness"—of the intended audience. In other words, the sensitivity of dogs' communications went beyond only using attention-getters when these were necessary to gain another's attention. Dogs further chose types of attention-getters (to a limited degree) based on the posture of their potential audience, or the audience's state of attention (Fig. 4): visual attention-getters (e.g., "in-your-face") were used significantly more often when another dog was the least inattentive (e.g., "flank" or "toward" posture); tactile attention-getters (e.g., "bite") were used more often when dogs dealt with a partner both visually and socially inattentive to them. As dogs' peripheral vision is quite good, dogs facing "flank" can easily notice motion to their sides; this explains the distinction dogs make between "flank" dogs and dogs directed "away" from another. In other words, the modality of attention-getter used was appropriate to the modality that could be received. Attention-getters were used which were sufficient, but not superfluous, to accomplish the goal of getting attention.

The cases when one dog was distracted by an activity or another creature (dog or person) would seem to require the most forceful attention-getters available: the dog is not only visually inattentive, but also socially and mentally engaged elsewhere. And, in fact, more forceful (tactile) attention-getters were used significantly more often than less forceful (visual) ones. The attentional state of the receiver appears to have been highly relevant to the signaler.

In addition, in a few ($n = 3$) cases dogs used a novel (theretofore unseen) behavior when presented with an inattentive audience. In one case a dog grabbed a nearby item (a backpack left on the ground) and solicited play while holding it; in the second, a leash was used; in the last, the dog approached and drank from the bowl from which the partner was drinking, and then began licking the other dog's face. These behaviors were followed by resumption of play, but the small sample warrants hesitation before speaking to their relevance as creative attention-getters. This is worthy of further investigation; the use of novel attention-getting sounds has recently been described in chimpanzees (Hopkins et al. 2007).

Attention to attention

Despite the rambunctious appearance of social play, these dogs used visual attention cues and communicative signals methodically and effectively while playing. They signaled requests for play almost exclusively to present, visually attentive audiences, and showed sensitivity to the order of communication and to feedback from the recipient. They moved to get visual attention before signaling play intent, and they persisted in and modified their means to do so. Their use of attention-getters discriminated appropriately between audiences according to their state of attentiveness. These findings point to an interesting hypothesis about dogs' recognition of attentional states of others.

In humans, social play is thought to be a context in which early stages of "appreciation of states of mind" are developed (Whiten 1997). Given that social pretend play and theory of mind develop coincidently in humans, social play may involve, or build, some precursory abilities important for high level social cognition. While theory of mind appears to be a skill that is unique to humans, some of the precursory skills to theory of mind may appear in other animals, as what might be called a "rudimentary theory of mind" (for elaboration of this concept, see Horowitz 2002).

The use of visual attention cues is a good candidate to be one of those precursors. The recognition and use of others' attentional states underlie many attempts to specify or discover theory of mind [though many different, articulable, levels of attention are invoked (Horowitz 2002)]. Such an ability is also often cited in developmental literature as critical to the emergence of an understanding of the psychological states of others (Baron-Cohen 1991; Moore and Dunham 1995; Tomasello and Call 1997). A surprising result of the present research is that dogs' use of visual attention cues in this communicative context, as in experimental contexts, equals and may sometimes exceed nonhuman primates' use with conspecifics or with humans. Chimpanzees have been shown to use attention-getters matched to the state of the recipient (Tomasello et al. 1994); dogs, too, used attention-getters appropriately. Dogs in addition used attention-getters in sequence with signals of informative content in a way reported in only one subject in Tomasello et al.'s experiment (systematic assessment of chimpanzees' tendency to do so has not yet been attempted). In other research chimpanzees failed to take the state of attention of the experimenter into account when signaling (Theall and Povinelli 1999), whereas dogs reliably used attention cues in signaling. The morphological differences between primates and canids make this comparison especially interesting. While dogs have no arms to point, they seem sensitive to pointing by others; while their visual acuity is not at the level of most primates (Tomasello and Call 1997), they are able to use head direction cues as higher primates may use eye-direction. Successful human–dog play also uses attention in the form of shared gaze between the human and the dog, each orienting his face to the other's (Horowitz and Bekoff 2007).

The generalized effect of dogs' interaction with humans, through domestication, may be some seemingly sophisticated social cognitive skills. The dogs observed in this research were seen to be sensitive to the superficial features of the mental states of others: they acted with attention to attention. Dogs' differential use of attention-getters is consistent with appreciation of the fact that attention can be diverted to a lesser or greater degree. If one is mildly diverted, a minor attention-getter is all that is necessary; if one is engaged with someone else, a more forceful attention-getter is required. One possible explanation for the dogs' use of attention in service to communication is that dogs recognize that there is some unseen feature of others (glossed "attention") mediating their behavior, that is highly relevant to interacting with them.

Recent experimental research has shown dogs to be able to recognize varying attentional states of humans (Call et al. 2003; Schwab and Huber 2006), and to use visual attention cues as an indication of a human's perceptual access (Virányi et al. 2006). The present research suggests that dogs also use visual attention cues capably in communicating to conspecifics, and that they know how to change visual attention. Yet, there is insufficient evidence to claim that dogs have the hallmarks of theorists of mind: spontaneously occurring uses of attentional states in novel contexts may have to be seen before positing this sophistication. Domestic dogs' skill is very immediate in application and may in fact be restricted to play or owner–interaction contexts. Also undetermined is the influence of individual development and socialization levels on behavior. Research that looks at these elements, as well as comparative analysis with non-domesticated canids, would clarify whether this ability is due to domestication, individual development, or being a social species. The current evidence shows that dogs do indeed use behavioral indications of elements of attention in others to guide their own behavior: perhaps describable as a very rudimentary understanding of mind, if still far from an explicit one.

Acknowledgments This article is based on research done in completion of a doctoral dissertation at the University of California, San Diego. I would particularly like to thank Shirley Strum, Jeff Elman, and Aaron Cicourel for their assistance in the development of the theoretical analytic method and for constructive criticisms. Thank you to the dog owners at Orpheus Park for their cooperation in this study and for their endurance of my videotaping of their recreational hours. I also thank the dogs for allowing me to keep such close company. Many thanks to Damon Horowitz and Ammon Shea for comments on the manuscript, and to three anonymous reviewers for their feedback and suggestions.

References

Agnetta B, Hare B, Tomasello M (2000) Cues to food location that domestic dogs (*Canis familiaris*) of different ages do and do not use. Anim Cogn 3:107–112

Bakeman R, Gottman JM (1997) Observing interaction: an introduction to sequential analysis, 2nd edn. Cambridge University Press, Cambridge

Baron-Cohen S (1991) Precursors to a theory of mind: understanding attention in others. In: Whiten A (ed) Natural theories of mind: evolution, development and simulation of everyday mindreading. Basil Blackwell, Oxford, pp 233–251

Bauer EB, Smuts BB (2007) Cooperation and competition during dyadic play in domestic dogs, *Canis familiaris*. Anim Beh 73:489–499

Bekoff M (1972) The development of social interaction, play, and meta-communication in mammals: an ethological perspective. Q Rev Biol 47:412–434

Bekoff M (1974) Social play in coyotes, wolves, and dogs. BioScience 24:225–230

Bekoff M (1995) Play signals as punctuation: the structure of social play in canids. Behaviour 132:419–429

Bekoff M, Byers J (eds) (1998) Animal play: evolutionary, comparative, and ecological perspectives. Cambridge University Press, Cambridge

Bradshaw J, Nott H (1995) Social and communication behaviour of companion dogs. In: Serpell J (ed) The domestic dog: its evolution, behaviour, and interactions with people. Cambridge University Press, Cambridge, pp 115–130

Bruner JS (1981) Intention in the structure of action and interaction. In: Lipsitt LP, Rovee-Collier CK (eds) Advances in infancy research, vol 1. Ablex Publishing Corporation, Norwood, pp 41–56

Bruner J, Jolly A, Sylva K (eds) (1976) Play—its role in development and evolution. Basic Books, New York

Burghardt GM (2005) The genesis of animal play: testing the limits. MIT Press, Cambridge

Call J (2001) Chimpanzee social cognition. Trends Cogn Sci 5:388–393

Call J, Bräuer J, Kaminski J, Tomasello M (2003) Domestic dogs (*Canis familiaris*) are sensitive to the attentional state of humans. J Comp Psychol 117:257–263

Call J, Hare B, Tomasello M (1998) Chimpanzee gaze following in an object choice task. Anim Cogn 1:89–99

Call J, Tomasello M (1994) Production and comprehension of referential pointing by orangutans (*Pongo pygmaeus*). J Comp Psychol 108:307–317

Clutton-Brock J (1999) A natural history of domesticated mammals. Cambridge University Press, Cambridge

Collier-Baker E, Davis JM, Suddendorf T (2004) Do dogs (*Canis familiaris*) understand invisible displacement? J Comp Psychol 118:421–433

Cooper JJ, Ashton C, Bishop S, West R, Mills DS, Young RJ (2003) Clever hounds: social cognition in the domestic dog (*Canis familiaris*). App Anim Behav Sci 81:229–244

Coppinger R, Schneider R (1995) Evolution of working dogs. In: Serpell J (ed) The domestic dog: its evolution, behaviour, and interactions with people. Cambridge University Press, Cambridge, pp 21–47

Fagen R (1981) Animal play behavior. Oxford University Press, Oxford

Fiset S, LeBlanc V (2007) Invisible displacement understanding in domestic dogs (*Canis familiaris*): the role of visual cues in search behavior. Anim Cogn 10:211–224

Fox MW (1978) The dog: its domestication and behavior. Garland STPM Press, New York

Fuller JL, Fox MW (1969) The behavior of dogs. In: Hafez ESE (ed) The behaviour of domestic animals. Williams & Wilkins, Baltimore, pp 438–481

Gácsi M, Miklósi A, Varga O, Topál J, Csányi V (2004) Are readers of our face readers of our minds? Dogs (*Canis familiaris*) show situation-dependent recognition of human's attention. Anim Cogn 7:144–153

Gómez JC (1991) Visual behaviour as a window for reading the mind of others in primates. In: Whiten A (ed) Natural theories of mind: evolution, development and simulation of everyday mindreading. Basil Blackwell, Oxford, pp 195–207

Gómez JC (1996) Nonhuman primate theories of (nonhuman primate) minds: some issues concerning the origins of mindreading. In: Carruthers P, Smith PK (eds) Theories of theories of mind. Cambridge University Press, Cambridge, pp 330–343

Hare B, Brown M, Williamson C, Tomasello M (2002) The domestication of social cognition in dogs. Science 298:1634–1636

Hare B, Call J, Tomasello M (1998) Communication of food location between human and dog (*Canis familiaris*). Evol Commun 2:137–159

Hare B, Call J, Tomasello M (2001) Do chimpanzees know what conspecifics know? Anim Behav 61:139–151

Hare B, Tomasello M (1999) Domestic dogs (*Canis familiaris*) use human and conspecific social cues to locate hidden food. J Comp Psychol 113:173–177

Hauser MD (1996) The evolution of communication. MIT Press, Cambridge

Hopkins WD, Taglialatela JP, Leavens DA (2007) Chimpanzees differentially produce novel vocalizations to capture the attention of a human. Anim Behav 73:281–286

Horowitz AC (2002) The behaviors of theories of mind, and a case study of dogs at play. Ph.D. dissertation, University of California, San Diego

Horowitz AC, Bekoff M (2007) Naturalizing anthropomorphism: behavioral prompts to our humanizing of animals. Anthrozoös 20:23–35

Lehner P (1996) Handbook of ethological methods, 2nd edn. Cambridge University Press, Cambridge

Martin P, Bateson P (2007) Measuring behaviour: an introductory guide, 3rd edn. Cambridge University Press, Cambridge

Martin P, Caro TM (1985) On the functions of play and its role in behavioral development. Adv Stud Behav 15:59–103

McKinley J, Sambrook TD (2000) Use of human-given cues by domestic dogs (*Canis familiaris*) and horses (*Equus caballus*). Anim Cogn 3:13–22

Miklósi Á, Polgárdi R, Topál J, Csányi V (1998) Use of experimenter-given cues in dogs. Anim Cogn 1:113–121

Miklósi Á, Polgárdi R, Topál J, Csányi V (2000) Intentional behaviour in dog–human communication: an experimental analysis of "showing" behaviour in the dog. Anim Cogn 3:159–166

Miklósi Á, Soproni K (2006) A comparative analysis of animals' understanding of the human pointing gesture. Anim Cogn 9:81–93

Miklósi Á, Topál J, Csányi V (2004) Comparative social cognition: What can dogs teach us? Anim Behav 67:995–1004

Mitchell RW, Edmonson E (1999) Functions of repetitive talk to dogs during play: control, conversation, or planning? Soc Anim 7:55–81

Moore C, Dunham PJ (1995) Joint attention: its origins and role in development. Lawrence Erlbaum Associates, Hillsdale

Pellis SM (1991) How motivationally distinct is play? A preliminary case study. Anim Behav 42:851–853

Povinelli DJ, Nelson KE, Boysen ST (1990) Inferences about guessing and knowing by chimpanzees (*Pan troglodytes*). J Comp Psychol 104:203–210

Quaranta A, Siniscalchi M, Vallortigara G (2007) Asymmetric tail-wagging responses by dogs to different emotive stimuli. Curr Biol 17(6):199–201

Rooney NJ, Bradshaw JWS (2002) An experimental study of the effects of play upon the dog–human relationship. Appl Anim Behav Sci 75:161–176

Schwab C, Huber L (2006) Obey or not obey? Dogs (*Canis familiaris*) behave differently in response to attentional states of their owners. J Comp Psych 120:169–175

Scott JP, Fuller JL (1965) Dog behavior: the genetic basis. The University of Chicago Press, Chicago

Serpell J (ed) (1995) The domestic dog: its evolution, behaviour, and interactions with people. Cambridge University Press, Cambridge

Simonet P, Murphy M, Lance A (2001) Laughing dog: vocalizations of domestic dogs during play encounters. Paper presented at the meeting of the Animal Behavior Society, Corvallis, OR

Smith PK (1982) Does play matter? Functional and evolutionary aspects of animal and human play. Behav Brain Sci 5:139–184

Smith WJ (1991) Animal communication and the study of cognition. In: Ristau CA (ed) Cognitive ethology: the minds of other animals. Lawrence Erlbaum Associates, Hillsdale, pp 209–230

Soproni K, Miklósi Á, Topál J, Csányi V (2002) Dogs' (*Canis familiaris*) responsiveness to human pointing gestures. J Comp Psychol 116:27–34

Theall LA, Povinelli DJ (1999) Do chimpanzees tailor their gestural signals to fit the attentional state of others? Anim Cogn 2:207–214

Tomasello M, Call J (1997) Primate cognition. Oxford University Press, Oxford

Tomasello M, Call J, Nagell K, Olguin R, Carpenter M (1994) The learning and use of gestural signals by young chimpanzees: a trans-generational study. Primates 35:137–154

Tomasello M, George B, Kruger A, Farrar J, Evans E (1985) The development of gestural communication in young chimpanzees. J Hum Evol 14:175–186

Tomasello M, Hare B, Agnetta B (1999) Chimpanzees, *Pan troglodytes*, follow gaze direction geometrically. Anim Behav 58:769–777

Vilà C, Savolainen P, Maldonado JE, Amorim IR, Rice JE, Honeycutt RL, Crandall KA, Lundeberg J, Wayne RK (1997) Multiple and ancient origins of the domestic dog. Science 276:1687–1689

Virányi Zs, Topál J, Miklósi Á, Csányi V (2006) A nonverbal test of knowledge attribution: a comparative study on dogs and children. Anim Cogn 9:13–26

Whiten A (1997) The Machiavellian mindreader. In: Whiten A, Byrne RW (eds) Machiavellian intelligence II: extensions and evaluations. Cambridge University Press, Cambridge, pp 144–173

Whiten A (2000) Chimpanzee cognition and the question of mental re-representation. In: Sperber D (ed) Metarepresentation: a multidisciplinary perspective. Oxford University Press, Oxford, pp 139–167