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Social cognition in the domestic dog: behaviour of spectators towards participants in interspecific games

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Social cognition, in particular the derivation of social information from observation of interactions between members of a social group, has been widely investigated in primates, but it has received little attention in other social mammals, although it has been anecdotally reported in the domestic dog, *Canis familiaris*. We recorded the behaviour of dogs ('spectators') that had observed controlled interactions between a human and a dog (the 'demonstrator') competing for an object, and that were subsequently allowed to interact freely with both participants. When the competitions were playful, as indicated by signals performed by the human, the spectator was more likely to approach the winner first and/or more rapidly, suggesting that winners of games are perceived as desirable social partners. When the human did not perform play signals, changing the social context from play to contest over a resource, spectators were slower to approach either of the participants, suggesting that participants in contests were less desirable as social partners than participants in games. If the dog was prevented from seeing the game, it still reacted differently to the winner and the loser, but its behaviour was not the same as after games that it had seen. We conclude that spectator dogs gain information from the players' subsequent behaviour as well as from direct observation of the game.

Social cognition, that is, cognitive processes that operate on information derived from, or relevant to, other animals, has been widely investigated in primates (e.g. Heyes 1994; Tomasello 2000). However, other taxa received less attention (Harcourt 1992) until consideration of the effect of social interactions upon welfare stimulated research into the sociocognitive abilities of domestic pigs, *Sus scrofa* (Held et al. 2001) and other species (Nicol 1996). Some evidence suggests that social species among the Carnivora have sophisticated sociocognitive abilities, and that the correlation between social skills and the volume of the neocortex, first established for primates, may also apply to the Carnivora and possibly other mammalian taxa (Dunbar 2000). Long-term alliances are an integral part of the social system of lions, *Panthera leo* (Heinsohn & Packer 1995), and there is evidence for coalition formation between clan members in spotted hyenas, *Crocuta crocuta* (Zabel et al. 1992). It is widely assumed that the wolf, *Canis lupus*, is capable of relatively sophisticated social cognition, although direct evidence is equivocal (e.g. Fentress et al. 1987) and experimental evidence is lacking (Tomasello 2000). The domestic dog, *Canis familiaris*, appears to have substantial cognitive abilities, harnessed by humans for such functions as guiding (Naderi et al. 2001) and sheep herding (McConnell & Baylis 1985), but scientific studies of these are relatively rare.

Primatologists, commonly acknowledge that the behaviour of animal A towards animal B can be influenced by A's prior observations of social interactions between B and other conspecifics (de Waal 1982; Heyes 1994). This has been demonstrated both in the field and experimentally. For example, third-party chimpanzees, *Pan troglodytes*, have been observed to console a conspecific attacked in a fight and to mediate reconciliation between opponents (de Waal & van Roosmalen 1979). Male hamadryas baboons, *Papio hamadryas*, are less likely to challenge a resident male who is highly preferred by his female partner (Bachmann & Kummer 1980), and pigtailed macaques, *Macaca nemestrina* (Judge 1982) and olive baboons, *Papio anubis* (Smutts 1985) more frequently attack a bystander that is a close relative or affiliative partner of their aggressor. Examples of social cognition have also been seen in other taxa such as domestic chickens, *Gallus gallus*

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domesticus (Hogue et al. 1996) and Siamese fighting fish, *Betta splendens* (Herb et al. 2003). Social cognition is also implicit in demonstrations of 'eavesdropping', defined as the extraction of social information by a third party from signalling interactions between conspecifics (McGregor & Peake 2000).

In the popular literature, it is often assumed that domestic dogs are also capable of relatively sophisticated social cognition (e.g. Anderson & Foster 1988). Similar assumptions are frequently implied by behavioural biologists, e.g. 'The healthy dog who limps in order to attract attention is known to us all' (Harcourt 1992, page 454). Behavioural counsellors warn that, in multidog households, the nature of interactions between a dog and its owner can affect both the relationship between the owner and an onlooking dog (Messent 1979) and the relationship between the two dogs (Anderson & Foster 1988; O'Farrell 1992). Evidence has begun to accumulate that dogs are particularly sensitive to social cues provided by humans, such as using cues from human gaze (Agnetta et al. 2000; McKinley & Sambrook 2000; Call et al. 2003) and pointing (McKinley & Sambrook 2000), using cues from humans to solve a detour task (Pongrácz et al. 2001), and 'intentional showing', in which the dog appears to indicate the location of a hidden object by rapidly alternating between looking at the object and at its owner (Miklósi et al. 2000). However, canine social cognition involving third-party relationships has not been examined experimentally, despite the relative degree of control that can be achieved when one of the social partners is a human.

We examined whether dogs are affected by the interactions that they observe between a conspecific and a human, looking specifically at dog–human games as a source of social information. The outcome of tug-of-war games (i.e. winning or losing) played by a dog and a human affects the subsequent behaviour of the dog towards that person, and dogs use information from such games to alter their behaviour towards their play partner (Rooney & Bradshaw 2002). Dogs also alter the way in which they interact with humans depending on whether the person performs play signals (Rooney et al. 2001). We therefore conducted two experiments using combinations of winning versus losing and signalling versus not signalling, in otherwise identical interactions between a dog and a person, to examine whether dogs that observed these interactions subsequently behaved differently towards the two participants.

In general, we predicted that changing the context from play to contest, by omitting play signals, would affect the behaviour of the second dog towards both participants. Furthermore, we predicted that being able or unable to see the social context (i.e. the game) from which the behaviour of one dog arises would affect the way in which a second dog reacts to both of the participants. To control the content and context of the interactions as far as possible while avoiding unnecessary artificiality, we arranged for dogs ('spectators') to observe interactions between other dogs ('demonstrators') and humans, varying the behaviour of the humans and the extent to which the spectator dogs could observe the interactions.

In experiment 1, we observed whether the behaviour of spectator dogs depended on the content and outcome of interspecific interactions that they had recently observed. Two of these interactions were games of tug of war, in which the human participant performed signals that are effective indicators of a playful context (Rooney et al. 2001). These games were predicted to alter the value of the winner as a potential social partner, which the spectator should express in its subsequent behaviour towards the participants. Accordingly, the human handler either allowed the demonstrator dog to win repeatedly during the game that the spectator observed, or prevented the demonstrator dog from winning. The third type of interaction, petting, was predicted to contain little status-related social information, and therefore acted as a control. In experiment 2, we omitted play signals from some of the observed interactions; we predicted that this would alter those interactions' social meaning from play to contest for a resource (Rooney et al. 2001) and result in changes in the spectator's subsequent behaviour. We also prevented the spectator dog from observing some of the interactions between the demonstrator dog and the human to examine effects on the spectator's subsequent behaviour caused by differences in the demonstrator dog's behaviour after (as distinct from during) that interaction.

EXPERIMENT 1

Methods

Dogs

The spectator dogs were 18 labrador retrievers (5 males, 13 females), two springer spaniels (both female) and one golden retriever (female), aged 6.5–85 months (mean = 25 months). Each spectator dog was paired with a demonstrator dog, which was either its kennel mate or a regular exercise companion, for the duration of the experiment. Fourteen of the demonstrator dogs were also used as spectators. All dogs were housed in pairs at the Waltham Centre for Pet Nutrition, U.K., were used primarily for nutrition studies and had received extensive daily contact with people since birth (for further details of housing and husbandry, see Loveridge 1998).

Procedure

Trials took place in a rectangular room (7.5 × 1.4 m). The dogs entered from a door at one end of the room. At the opposite end there was a chair, with a line 50 cm distant marked on the floor. The room was unfamiliar to the dogs, but they had experienced similar rooms previously. Trials were carried out by an experimenter (N.J.R.: female, aged 23 years) and a handler (female, aged 24 years), both of whom were unfamiliar to the dogs. Each spectator was tested three times on different days, a maximum of three days apart, at approximately the same time of day. A minimum of 2 days elapsed between sessions in which the roles of spectator and demonstrator were reversed. All sessions were composed of three stages (acclimatization, demonstration and experimental recording) and followed the same format. For the acclimatization stage, the spectator and demonstrator dogs were collected from their kennels, one by the experimenter and one by the handler, leashed and walked to the experimental room. There they were unleashed and allowed to roam freely for 2 min in the presence of the handler and the experimenter. The humans did not instigate interactions with the dogs, but if the dogs approached they received moderate petting. For the demonstration stage two video cameras (Philips Explorer VKR6850 and Panasonic WV-CL502), which in combination filmed the entire floor area of the room, were activated. The experimenter led the spectator dog (the subject) to the door end of the room, instructed it to sit and gently restrained it in a position facing the handler, who then interacted with the demonstrator dog for 2 min. The interaction between the handler and the demonstrator dog varied according to three experimental treatments.

(1) Petting: this was a control treatment. The handler remained seated on the chair. She stroked and spoke gently to the demonstrator dog.

(2) Human-win tug of war: the handler played with the demonstrator dog. The game centred around a Ragger toy (Petlove Ltd, Petsmart, Southampton, U.K.; a 30-cm-long piece of rope knotted at each end which can simultaneously be held by two players), and was composed mainly of tug of war (defined as two partners simultaneously pulling on a single object, each apparently aiming to gain sole possession) but chase (defined as partners reciprocally running after and away from one another) was also included if necessary to maintain the dog's interest. Play-eliciting signals, consisting of the bow and lunge composite signals (Rooney et al. 2001) were delivered by the handler at a mean rate of eight per session (minimum of four per session). In the bow, the handler mimicked a canid play bow and simultaneously patted the floor, and in the lunge the handler shuffled her feet and then lunged towards the dog. The handler also gave frequent play-eliciting vocalizations (Rooney et al. 2001). All dogs played for at least 90 s of the 2 min. The handler retained possession of the toy in the majority ($\geq$80%) of competitions and at the end of the play session. She then gave the toy to the experimenter who placed it outside the room. The handler led the dog back to the starting position and sat on the chair with the dog beside her.

(3) Dog-win tug of war: the handler played tug of war as described above, but this time the demonstrator dog was allowed to win as many of the competitions as possible, and always won more than half. All dogs played for at least 90 s of the 2 min. The demonstrator dog retained the Ragger at the end of the session, after which the experimenter retrieved it and placed it outside the room. The handler returned to the chair with the demonstrator alongside her.

All subjects experienced all three treatments. The petting treatment always occurred first. The subsequent order of dog-win and human-win treatments was randomized and balanced within the sample.

Immediately after the demonstration stage, we carried out the experimental stage. The experimenter released the spectator dog and then left the room. The handler then released the demonstrator dog and remained seated on the chair. The dogs were free to interact and move around the room. If the spectator dog approached the handler, it received moderate petting, but the demonstrator dog was ignored. If either dog jumped or climbed upon the handler or chair, they were gently pushed down. After 2 min, filming was terminated. The experimenter returned, leashed the dogs and returned them to their kennels.

From the film, we recorded the behaviour of the spectator dog, towards both the handler and the demonstrator dog, during the experimental stage, with the Observer data-recording system (Noldus Information Technology b.v., Wageningen, Netherlands). Variables describing initial approaches required detailed repetitive observations and so were recorded manually. We measured eight variables (Table 1).

Statistical analysis

The first approaches of the spectator, to either handler or demonstrator dog, were compared between all conditions with Cochran's Q test and between pairs of conditions by McNemar tests based on the binomial distribution (SPSS version, 11 SPSS Inc., Chicago, IL, U.S.A.; Siegel & Castellan 1988). Scales were analysed untransformed; variables describing times, frequencies and gait were transformed by log $(x + 1)$ to improve normality, and both were analysed by repeated measures ANOVA and paired t tests. All P values are two tailed.

Results

Whether the spectator first approached the human or the demonstrator dog was significantly affected by treatment Cochran's $Q_2 = 8.86$, $P = 0.01$). After the control treatment (petting), there was a nonsignficiant tendency

Table 1. Behavioural variables measured for the spectator dog during the experimental recording stage

Variable	Description
First approach	Individual that spectator approached first to within 50 cm (0: dog; 1: human)
Behaviour towards demonstrator dog	
Latency of approach	Time (s) from release to spectator's first oriented approach to within 50 cm of demonstrator dog
Gait of approach	Gait of spectator's first approach to demonstrator dog: 0: no approach; 1: stand; 2: walk; 3: trot; 4: run; 5: bound
Approach frequency	Number of times spectator approached to within 50 cm of demonstrator dog
Displacement frequency	Number of times spectator displaced demonstrator dog from position near handler
Behaviour towards human handler	
Latency of approach	Time (s) from release to spectator's first oriented approach to within 50 cm of handler
Gait of approach	Gait of spectator's first approach to handler (scale as for approach to dog)
Approach frequency	Number of times spectator approached to within 50 cm of handler

for the spectator dogs to approach the demonstrator dog first (12 dogs), rather than the handler (9 dogs; chi-square test: $\chi^2_1 = 0.43$, $P = 0.51$). There was no significant difference between approaches to demonstrators and humans after games won by dogs (11 versus 10, respectively; McNemar test: $P = 1.0$). After games won by the handler, however, 15 of 21 dogs approached the handler first (McNemar test: $P = 0.03$).

The gait with which the spectator approached the demonstrator dog differed significantly between treatments (repeated measures ANOVA: $F_{2,40} = 5.55$, $P < 0.01$), as did the latency to approach the handler ($F_{2,40} = 3.41$, $P < 0.05$). Spectators approached demonstrator dogs faster after games that demonstrators had won (mean score $\pm$ SE $= 2.54 \pm 0.24$) than after games won by the handler (1.93 ± 0.18; paired t test: $t_{20} = 2.96$, $P = 0.007$) or after the control condition (1.66 ± 0.28; paired t test: $t_{20} = 3.62$, $P = 0.002$). The latency to approach the handler was shorter after games won by the handler (5.41 ± 1.63 s) than after games won by demonstrator dogs (23.57 ± 9.73 s; $t_{20} = 2.50$, $P = 0.02$) with the control intermediate (14.87 ± 5.45 s; comparing control and dog-win conditions: paired t test: $t_{20} = 1.93$, $P = 0.07$). All other variables (Table 1) were unaffected by treatment.

Discussion

The behaviour of the spectator dog varied depending on whether it had observed a tug-of-war game won by a dog or by a human. Spectators were more likely to approach the handler, and approached sooner, after the handler had won the game, and approached the demonstrator dog with a faster gait after it had won. The specific variables that were affected are probably due to the method used. The human remained in a fixed, seated position, so latency is a good indication of the spectator's motivation to reach her. However, the demonstrator dog was free to move around the room; the spectator's approach latency would thus be affected by the demonstrator's position, so gait is a better indication of the spectator's motivation to reach the dog. These results therefore support the hypothesis that spectator dogs can distinguish between winners and losers of a dog–human tug-of-war game; they appeared to be more motivated to approach an individual that had won a game than one that had lost.

The finding that the winner of the game was more attractive to the spectator than the loser shows an opposite trend to the results of studies of 'eavesdropping' in a range of species. For example, Siamese fighting fish spectators were more likely to start interactions with individuals that they had seen losing than with those that they had seen winning (Oliveira et al. 1998). We suggest that this difference in spectator behaviour is a result of the context, which in our experiment was playful, compared to signalling between rivals and agonistic encounters observed in other studies. Previous studies of dog play have shown that the outcome of playful tug-of-war games does not have dominance-related consequences for the players (Rooney & Bradshaw 2002, 2003). We therefore repeated the experiment, but included two treatments in which play signals were omitted, to investigate the importance of social context to the behaviour of spectators.

Spectators showed a difference in behaviour depending on whether they had observed the human or the dog win the game; however, it was not possible to determine whether the spectator dogs were reacting to the outcome of the game that they had observed or to cues from the demonstrator dog after the game had ended. Demonstrator dogs might have been more active and willing to play again after they had been allowed to win, as predicted from an earlier study (Rooney & Bradshaw 2002), and thereby they may have directly triggered social play in some spectators. We therefore recorded the behaviour of the demonstrator dog up to its approach to the spectator, and included two treatments in which the spectator dog did not view the game itself (i.e. was prevented from watching).

EXPERIMENT 2

Methods

Dogs

The spectator dogs were 22 labrador retrievers (3 males, 19 females), ranging in age from 15 to 138 months (mean = 59 months); four of these had been spectators in experiment 1 which had taken place 2 years before; otherwise all dogs were unfamiliar with both the handler and the experimenter. The 11 demonstrator dogs were also labrador retrievers, all of which were reported by dog-care staff to play tug of war enthusiastically. Each demonstrator partnered two spectators. In all cases, demonstrator and spectator were familiar, as they had been regularly exercised together. Housing and husbandry were the same as in experiment 1.

Procedure

Trials took place in an octagonal room (approximately 7×3.5 m). The room was surrounded on six sides by storage rooms, each of which had a half-glazed wooden door. Doors on the remaining two sides were the entry and exit routes. One of the storage room doors was removed and a wire holding cage (1.2×0.75) was fixed in the opening such that the cage could be entered from the experimental room, and once inside a dog could see the whole of the experimental room. Two video cameras (Philips Explorer VKR6850 and Sony Video 8 CCD-TR370E) were mounted on tripods in two of the adjoining rooms, such that the entire room could be filmed. A chair was placed at one end of the room opposite to, and facing, the cage, with a line 50 cm distant marked on the floor. The room was unfamiliar to the dogs, so during the week preceding the experiment, all spectators and demonstrators were individually walked through and exercised in the room on at least five occasions. Spectators were also acclimatized to the cage.

Each subject was tested six times on consecutive days at approximately the same time of day. Demonstrators took part in two sessions per day (one with each spectator partner) which were separated by at least 4 h. Trials were carried out by an experimenter (male, aged 21 years) and a handler (N.J.R.: female, aged 25 years), and were composed of three stages: acclimatization, demonstration and experimental recording. Acclimatization was identical to that in experiment 1. In the demonstration stage, the cameras were activated. The experimenter then led the spectator dog (the subject) to the cage and encouraged it to enter. The cage door was shut and, in unseen sessions, a wooden board was placed over the door. The handler then engaged in a tug-of-war game with the demonstrator dog for 2 min, as described for experiment 1. The treatment took one of the following six forms.

(1) Signalled (seen) human-win: the handler played with the dog while, the spectator dog was in the cage with no barrier present, and delivered the bow and lunge composite signals (as in experiment 1) and frequent play-eliciting vocalizations ($\overline{X} \pm$ SE frequency $= 65 \pm 1.1$ per session). The handler retained possession of the toy (Ragger as in experiment 1) in the majority ($\geq$80%) of competitions and at the end of the play session. She then gave the toy to the experimenter who placed it outside the room. The handler led the demonstrator dog back to the starting position and sat on the chair with the dog beside her.

(2) Signalled (seen) dog-win: the handler played tug-of-war, while the spectator dog was in the cage with no barrier present, as described above, but the demonstrator dog was allowed to win most ($\geq$80%) of the competitions. The demonstrator dog retained the toy at the end of the session, after which the experimenter retrieved it and placed it outside the room. The handler returned to the chair with the demonstrator alongside her.

(3−4) Unsignalled (seen) human-win, unsignalled (seen) dog-win: the procedures were the same as for signalled human-win and signalled dog-win, respectively, but the handler performed no play signals or vocalizations. It was impossible to prevent the demonstrator dogs from performing play signals, and many of them did.

(5−6) Signalled (unseen) human-win, signalled (unseen) dog-win: the handler played with the dog as for signalled human-win and signalled dog-win, respectively. After the spectator entered the cage, the experimenter placed a wooden barrier in front of the cage door. The dog was unable to see the experimental room although its hearing was unobstructed. After the game, the handler led the demonstrator dog back to the starting position and sat on the chair with the dog beside her. The experimenter then removed the barrier.

Each subject experienced all six treatments. The order was randomized according to a Graeco Latin Square design (Cochran & Cox 1957) in such a way that dog-win and human-win sessions alternated. To start the experimental stage, the experimenter opened the cage, released the spectator, and then left the experimental room. The remainder of the procedure was the same as in experiment 1.

For the spectator dog, analysis was identical to that in experiment 1. The behaviour of the demonstrator was also recorded during the demonstration phase (proportion of wins by the dog) and up to the first approach to the spectator (Table 2). Thereafter, the behaviour of the demonstrator and the spectator was largely interactive and therefore difficult to dissociate; hence, only the spectator's behaviour was recorded.

Table 2. Behavioural variables measured for the demonstrator dog in experiment 2 during the experimental recording stage

Variable	Description
Gaze	Before release, dog looked exclusively at the handler (0), the spectator dog (1) or both (0.5)
Latency to leave handler	Time (s) from release to demonstrator dog leaving handler
Initial ear position	Ear position of demonstrator dog immediately before release (0: low; 1: relaxed; 2: pricked)
Initial tail position	Tail position of demonstrator dog immediately before release (1; 5: high)
Behaviour towards spectator dog	
Latency to approach	Time (s) from release to demonstrator's first oriented approach to within 50 cm of spectator dog
Gait of approach	Gait of demonstrator's first approach to spectator dog: 0: no approach; 1: stand; 2: walk; 3: trot; 4: run; 5: bound
Approach ear position	Ear position of demonstrator dog during approach to spectator (0: low; 1: relaxed; 2: pricked)
Approach tail position	Tail position of demonstrator dog during approach to spectator (1: low; 5: high)

Statistical analysis

Demonstrator behaviour. The proportions of wins, latencies and the gait variable were log transformed before analysis by repeated measures ANOVA. For gaze and for ear and tail positions, which could not be made normal by transformation, differences between all six conditions were initially compared by Friedman ANOVA. If results approached significance, we calculated means for each of the conditions for each of the demonstrator dogs; these means were approximately normally distributed and were analysed by ANOVA.

Spectator behaviour. The first approaches of the spectator, to either the human handler or the demonstrator dog, were initially compared between all six conditions by Cochran's *Q* test (SPSS version 11). Pairwise comparisons were then made by McNemar tests within dog-win and human-win sessions of the same type (signalled, unsignalled and unseen) and between different types with the same winner (signalled versus unsignalled, signalled versus unseen).

Frequencies, latencies and gait were transformed by log $(x + 1)$ to improve normality. Paired *t* tests and two-way repeated measures ANOVA were then used to compare each variable in the same combinations as for the first approaches. All *P* values are two tailed.

Results

Demonstrator behaviour

In the dog-win condition, the dogs won an average of 96.7% of competitions; in the human-win condition, dogs won 4.3%. The proportion of wins was unaffected by treatment (i.e. whether the play was signalled or whether the spectator was visible; ANOVA: treatment: $F_{2,20} = 0.48$, $P = 0.63$; treatment * winner interaction: $F_{2,20} = 0.46$, $P = 0.64$). No other behaviour pattern measured (Table 2) was significantly affected by whether the demonstrator dog had been allowed to win or made to lose the preceding game ($\alpha = 0.05$). There were also no significant differences between the signalled and unsignalled treatments (Table 3). In the unseen treatment, following the moment when the spectator was revealed to the demonstrator after the game, the demonstrators' behaviour was initially different to that in the 'seen' treatments (Table 3). They were more likely to look at the spectator before release and to have pricked ears; they left the handler more quickly after release, and were quicker to approach the spectator, although gait of approach was unaffected. Tail position was unaffected, and ear positions had returned to normal by the time they had approached the spectator dog an average of 3 s later. The only detectable effect of condition on the behaviour of the demonstrator was therefore the sudden 'appearance' of the spectator, and this appeared to be transitory.

Spectator behaviour

Whether the spectator first approached the human or the demonstrator dog was significantly affected by treatment (Cochran's $Q_5 = 12.8$, $P = 0.03$; Table 4).

Signalled (seen) sessions. The proportions of spectator dogs approaching the handler and the demonstrator dog first were similar to those in the corresponding treatments in experiment 1, but in experiment 2 this difference was not significant (McNemar test: $P = 0.15$; Table 4). Again as found in experiment 1, spectator dogs approached demonstrator dogs faster when the demonstrator dog had won than when it had lost (wins: $\overline{X} \pm SE = 2.64 \pm 0.23$; losses: 1.91 ± 0.22; paired t test: $t_{21} = 3.17$, $P = 0.005$).

Table 3. Effects of treatment on the behaviour of demonstrator dogs in experiment 2 during the experimental recording stage

			Treatment		
Variable	$F_{2,20}$	P	Signalled	Unsignalled	Unseen
Gaze	10.5	0.001	0.46[a]	0.44[a]	0.79[b]
Latency to leave handler	4.57	0.02	2.28[a]	2.92[a]	1.06[b]
Initial ear position	4.34	0.03	1.06[a]	1.09[a]	1.33[b]
Initial tail position	Friedman	0.75	2.93[a]	2.93[a]	2.87[a]
Latency to approach	7.24	0.004	5.70[a]	5.68[a]	3.03[b]
Gait of approach	1.64	0.22	1.11[a]	1.21[a]	1.49[a]
Approach ear position	Friedman	0.16	1.09[a]	1.22[a]	1.17[a]
Approach tail position	Friedman	0.37	3.19[a]	3.27[a]	3.21[a]

For units of each variable, see Table 2. For non-normally distributed variables, P values from Friedman tests are given. Means within a row followed by the same superscript letter are not significantly different (ANOVA: $P < 0.05$).

Table 4. Numbers of spectator dogs in experiment 2 making first approaches to the demonstrator dog and the handler

Spectator/game condition	Winner	Approach demonstrator	Approach handler
Signalled (seen)	Human	7	15
	Dog	10	12
Unsignalled (seen)	Human	11	11
	Dog	9	13
Signalled (unseen)	Human	11	11
	Dog	17	5

Unsignalled (seen) sessions. When the spectators had watched unsignalled sessions, there was no difference between whether they approached the handler or the demonstrator dog first compared to signalled (seen) trials (McNemar tests: human-win: $P = 0.29$; dog-win: $P = 1.0$; Table 4). However, the absence of signals had a significant main effect on two variables, the gait of the approach to the handler (main effect in two-way ANOVA: $F_{1,21} = 4.25$, $P < 0.05$) and the frequency of approaches to the demonstrator ($F_{1,21} = 5.40$, $P < 0.05$); both were lower after trials in which no play signals were delivered. There was also a significant interaction between winner and signal presence on the gait of approach to the demonstrator dog ($F_{1,21} = 8.50$, $P = 0.01$; Fig. 1). After sessions in which the demonstrator dog had won, spectators approached the dog with a faster gait when signals were incorporated in the session than when they were not (paired t test: $t_{21} = 2.34$, $P = 0.03$). The omission of play signals by the handler, which we predicted should have indicated to the demonstrator dog that the interaction was 'serious', and not playful, therefore appears to have made both

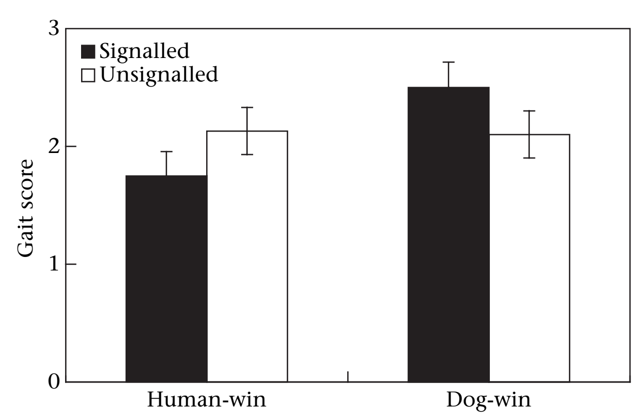

Figure 1. Mean ± SE score for the gait of approach of the spectator dog to the demonstrator dog (back-transformed from log-transformed data), comparing trials in which the spectator dog had observed signalled and unsignalled games. 0: No approach; 1: stand; 2: walk; 3: trot.

the handler and the demonstrator less attractive as social partners, but a winning dog was approached more warily than a loser.

Signalled (unseen) sessions. Preventing the spectator dog from seeing games won by dogs had a substantial overall effect on its first approach. Compared to signalled (seen) games, eight spectators switched from approaching the human first to approaching the dog first, and only one made the opposite switch (McNemar test: $P = 0.03$). After games won by humans, seven spectators switched from approaching the human first to approaching the demonstrator, but three made the opposite switch (McNemar test: $P = 0.34$). The overall increase in first approaches to the demonstrator (28 in unseen games, 17 in seen games) is likely to be related to the difference in the demonstrator behaviour recorded; in unseen trials, the demonstrator was initially more reactive, which may have drawn the attention of the spectator.

However, after unseen trials, the spectators' behaviour differed depending on whether the human or the dog had won the game, even though they had not seen the game itself, and there was no discernible difference in the behaviour of the demonstrator immediately after the game. When the spectator dogs were unable to see the games won by the handlers, half approached the handler first and half approached the demonstrator dog first. After games won by the demonstrators, this proportion was significantly different (McNemar test: $P = 0.03$); 17 approached the demonstrator first and five the handler first. Displacing the demonstrator from the person indicates a dog's motivation to reach the person, so the increased number of displacements after a human win is likely to indicate increased attraction to a winning human. More first and total approaches to a dog that won similarly indicate attraction to a winning dog.

Two behavioural measures were significantly affected by the combination of visibility and winner: the gait of the approach to the demonstrator dog (interaction in two-way ANOVA: $F_{1,21} = 4.80$, $P < 0.05$; Fig. 2) and the frequency of displacement ($F_{1,21} = 7.91$, $P = 0.01$; Fig. 3). When the play session was won by the handler, the spectator dog approached the demonstrator dog significantly faster when it had been prevented from seeing the play session (paired t test: $t_{21} = 2.79$, $P = 0.01$); when the play session was won by the dog, there was no significant difference between conditions in gait speed ($t_{21} = 1.15$, $P = 0.26$; Fig. 2). When the play session was won by the dog, the spectator displaced the demonstrator from the handler significantly less frequently after signalled (unseen) sessions ($t_{21} = 2.27$, $P = 0.03$); when the handler won, there was no significant difference between conditions in frequency of displacement ($t_{21} = 1.32$, $P = 0.20$; Fig. 3).

In summary, the general effect of preventing the spectator from observing games was to increase the likelihood of the dog approaching the demonstrator first. However, the effect of preventing visual access depended on the winner of the game. Preventing spectators from observing games won by the dog led to more first approaches made to the demonstrator, but a lower probability that the spectator would displace the demonstrator dog from the handler. Preventing spectators from seeing games won by handlers increased the spectators' gait when they approached the demonstrator dog.

Discussion

The results of this experiment confirmed the findings of experiment 1, that spectators reacted differently to the winners and losers of games. In signalled games that dogs could see, they again showed an increased attraction towards the winner of the game. If the handler did not signal that the competitions were playful, she became less attractive as a partner for interaction with the spectator, whether or not she had won the game. A winning dog was approached more slowly than was a losing dog, when no signals were incorporated, again indicating a reduction in social attraction. Observations of the demonstrator's play behaviour showed that the interactions in signalled and unsignalled conditions were similar in content, which suggests that signalling a playful context is important in determining how dogs react to the winners and losers of social interactions.

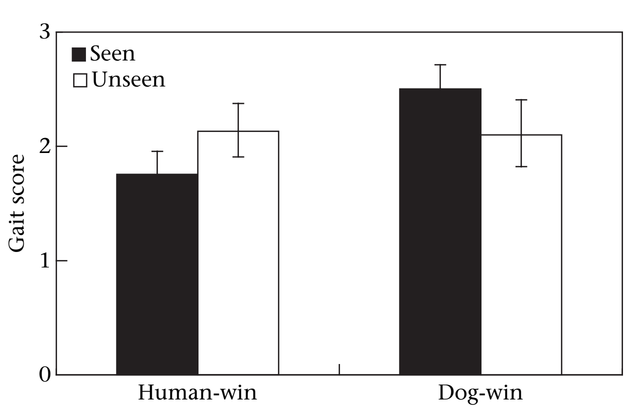

Figure 2. Mean ± SE score for the gait of approach of the spectator dog to the demonstrator dog after signalled games, comparing trials in which the spectator dog could and could not see the game. 0: No approach; 1: stand; 2: walk; 3: trot.

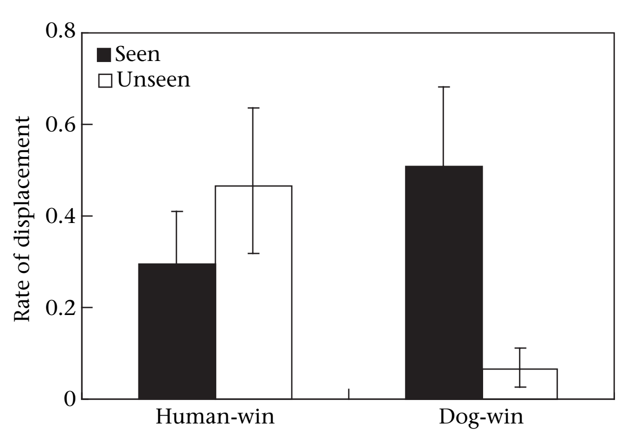

Figure 3. Mean ± SE rate (number/min) at which the spectator dog displaced the demonstrator dog from the handler (back-transformed from log-transformed data) after signalled games, comparing trials in which the spectator dog could and could not see the game.

The overall preference for winners when play signals were included could be because demonstrator dogs that had been allowed to win a signalled game showed more activity and willingness to play with a human, as predicted from the increase in 'playful attention seeking' promoted by winning games in a previous study (Rooney & Bradshaw 2002). However, we found no difference in the initial behaviour of demonstrators, so the effect of having engaged in unsignalled contests may be apparent in demonstrators' behaviour only after the spectators have begun to interact with them. Spectators may be attracted to winners because they prefer to form social coalitions with individuals seen to be successful in nonagonistic encounters, and are more wary of those that are seen to compete directly for resources. The results may also be interpreted as support for theories of the role of play behaviour, that playing with a stronger or more closely matched play partner provides more opportunity to practise important skills (Pellis & Pellis 1998) and to assess ability in a safe environment (Thompson 1998).

These results show that dogs can derive social information about third-party interactions from observing a game, but is this information derived solely from watching the game or from cues from the demonstrator dog afterwards? When the spectator dog was prevented from directly observing the game, some of the changes in behaviour observed could be attributed to changes in the behaviour of demonstrators, which were momentarily more attentive to the spectator when it approached. However, there were still differences in the way spectators behaved depending on whether the dog or the human had won the game. Thus, our measures were sufficiently sensitive to detect some differences in demonstrator behaviour, but evidently not all. The results also highlight how the behaviour of demonstrator and spectator are highly interactive, and neither one must be viewed in isolation. This is an important methodological consideration in future research.

The fact that spectators reacted differently to winners and losers of unseen games, even in their initial approach, suggests that they derived information regarding the outcome of the game from the demonstrator immediately upon presentation or release. One possible reason for this may be that demonstrator dogs that had been allowed to win a signalled game were more playful. However, we detected no consistent differences in the behaviour of demonstrators between unseen dog-win and human-win trials. We suggest that, under these artificial conditions in which a hidden dog is suddenly exposed after an interaction, the subtle signals that the demonstrator observes become increasingly salient. Thus, during seen dog–human games, the dog derives information throughout the game regarding both the winner and the context, but in unseen games, the postinteraction signals are the sole and therefore much more salient source of information. We suggest that these cues are subtle and that their identification requires additional study.

The interactive effects of visibility and winner upon the spectators' behaviour are difficult to interpret because the demonstrator's behaviour is clearly altered during the unseen condition. However, the different reactions of spectators to winners and losers that they have observed or been prevented from seeing play suggest that the spectators' behaviour is a result of both information obtained from observing the interaction and cues given by the demonstrator after the game.

We therefore conclude that dogs can derive socially relevant information from observing interactions between other dogs and people in which they have not themselves participated. Furthermore, they appear to use this information in complex ways. For example, they do not simply prefer winners to losers of competitions, but they also interpret the immediate behaviour of a conspecific depending upon whether they have been able to see the situation from which that behaviour had developed (as shown by the tendency to approach the dog first when the game had not been seen, and the human first when it had been) and the context in which the competition takes place.

GENERAL DISCUSSION

Evidence indicates that many dogs are capable of using cues provided by people to locate hidden objects (Adler & Adler 1977; Hare & Tomasello 1999; Agnetta et al. 2000; Miklósi et al. 2000; McKinley & Sambrook 2000). There is less direct evidence for social learning from other dogs (Slabbert & Rasa 1997; Hare & Tomasello 1999), but this discrepancy probably reflects the relative ease of controlling the behaviour of human versus canine participants in experiments, rather than a lack of ability of dogs to gather information from the behaviour of conspecifics. However, McKinley & Sambrook (2000) and Hare et al. (2002) suggested that dogs have been 'encultured' by domestication to facilitate learning about cues and signals produced by humans, although there appear to be limits to the plasticity of such learning, because some cues that owners repeatedly perform while attempting to initiate games with their dogs are much less successful than others (Rooney et al. 2001). In our study, the changes in the behaviour of dogs that observed play signals produced by humans in games with other dogs suggest that the interpretation of the outcome of a competition is modified by the context in which it is observed.

The changes in the spectators' behaviour when the human partner displayed no signals can be interpreted as evidence either that human signals were important per se to the spectator or that the spectator was focused primarily on the demonstrator dog's behaviour, which might have been more competitive (Rooney et al. 2001). If the spectators are reacting primarily to the human signals, this hypothesis suggests that the spectators were 'eavesdropping' (McGregor & Peake 2000), which would indicate the first demonstration of eavesdropping of play signals. Much of the literature on eavesdropping concerns male–male agonistic displays, such as the songs of common nightingales, *Luscinia megarhynchos* (Naguib & Todt 1997) and the visual displays of Siamese fighting fish (Oliveira et al. 1998). In Siamese fighting fish, spectators were more likely to start interactions with individuals they had seen losing than with those that they had seen winning; this is the opposite trend to the one that we observed, and it presumably reflects the difference in context, between rivals on the one hand and between playful members of a social group on the other. This interpretation is supported by the slower gait of approach to a winning than to a losing dog in the absence of signals.

This apparent ability to make distinctions between winners and losers and act upon them suggests that dogs have the cognitive ability to form coalitions based on observations of third-party interactions. Although such abilities are commonly found in primates, comparisons of neocortex size between primates and other orders have been used to suggest that some highly social members of the Carnivora, including the spotted hyaena and the ancestral species of the domestic dog, the wolf, have enlarged neocortices to enable the processing of social information such as 'mind reading' (Dunbar & Bever 1998). The ability of dogs to learn and respond to signals produced by humans, and the relative ease with which these interspecific social relationships can be manipulated experimentally (see also Miklósi et al. 2004), suggests that paradigms similar to the one we have used in these experiments may be a fruitful way of probing the social cognitive abilities of nonprimates.

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