

Attributing attention: the use of human-given cues by domestic horses (*Equus caballus*)

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Abstract Recent research has shown that domestic dogs are particularly good at determining the focus of human attention, often outperforming chimpanzees and hand-reared wolves. It has been suggested that the close evolutionary relationship between humans and dogs has led to the development of this ability; however, very few other domestic species have been studied. We tested the ability of 36 domestic horses to discriminate between an attentive and inattentive person in determining whom to approach for food. The cues provided were body orientation, head orientation or whether the experimenters' eyes were open or closed. A fourth, mixed condition was included where the attentive person stood with their body facing away from the subjects but their head turned towards the subject while the inattentive person stood with their body facing the subject but their head turned away. Horses chose the attentive person significantly more often using the body cue, head cue, and eye cue but not the mixed cue. This result suggests that domestic horses are highly sensitive to human attentional cues, including gaze. The possible role of evolutionary and environmental factors in the development of this ability is discussed.

Keywords Animal–human interaction · Social cognition · Domestication · Gaze · Begging task

Introduction

The ability to attribute attention to others would have obvious adaptive advantages, potentially allowing an animal to more efficiently detect the presence of predators and competitors, follow the gaze of others to significant events and locations, and to engage in more effective communication. There is currently much interest in discovering the prevalence of attention attribution skills across taxa, specifically in determining the cues employed by different species and the extent to which animals have an understanding of the mental states underlying attention. For domestic dogs (*Canis lupus familiaris*), humans represent significant social partners and dogs appear to be particularly adept at reading human cues and body language. Research has shown that dogs can use body, head and often eye cues to determine the attentional state of handlers across a variety of tasks such as obeying commands, fetching toys, locating hidden food and deciding whom to approach for food (Brauer et al. 2004; Call et al. 2003; Gácsi et al. 2004; Miklósi et al. 1998; Schwab and Huber 2006; Soproni et al. 2001, 2002; Virányi et al. 2004). Dogs also distinguish between situations in which a person is looking into space compared to when they are looking at something in particular—suggesting that they may have some appreciation of the communicative intent of gaze (Soproni et al. 2001; Virányi et al. 2004).

Perhaps surprisingly, findings from primates have been more mixed. Despite apes appearing to know what others can and cannot see and having a rudimentary understanding of the relationship between seeing and knowing (Bulloch et al. 2008; Hare et al. 2000, 2001), results from begging, gaze following and object-choice tasks suggest that untrained apes are less sensitive to eye cues than dogs and tend to rely on head and body cues (Kaminski et al.

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2004; Povinelli and Eddy 1996; Tomasello et al. 2007). Other studies of attention getting behaviour, gaze following and competitive food tasks suggest that some primates are capable of using eye cues in certain contexts (Ferrari et al. 2000; Flombaum and Santos 2005; Hostetter et al. 2007; Vick and Anderson 2003). Whether these apparently contradictory results are a methodological artefact or represent a genuine lack of sensitivity is currently unclear (Barth et al. 2005; Hare and Tomasello 2004; Hattori et al. 2007). However, what is clear is that dogs do show an ability to generalise and a level of flexibility across a variety of attention attribution tasks that has not to date been seen in other species including primates.

There are a number of possible explanations for this well-developed ability in dogs that are not mutually exclusive. It may be that domestic dogs have inherited this ability from wolves, that dogs learn to read human cues through enculturation, or that during the process of domestication, dogs have evolved such an ability through a process of selection and convergent evolution (Hare et al. 2002). Very few species have been domesticated, which suggests that there is something “special” about those that have, however, research comparing hand-reared wolf and dogs puppies have produced mixed results. Some studies have found wolves (*Canis lupus*) to be less able to use human cues than dogs, less able to use eye contact and to solicit joint attention (Hare et al. 2002; Miklósi et al. 2003; Virányi et al. 2008) suggesting that the dogs have not inherited their human-reading abilities from their ancestors. Conversely, one recent study found wolves to be more skilled at using human cues than dogs and attributed the poor performance of wolves in previous studies to the test environment (Udell et al. 2008). While intense enculturation and training appears to improve the ability of some species to read human cues including apes (Itakura et al. 1999; Povinelli and Eddy 1996), dolphins (Pack and Herman 2004; Tschudin et al. 2001), seals (Scheumann and Call 2004; Shapiro et al. 2003), ravens (Schloegl et al. 2008) and parrots (Giret et al. 2008), in dogs this skill is present very early in development and does not appear to improve significantly with age (Agnetta et al. 2000; Gácsi et al. 2008; Riedel et al. 2008).

This suggests that the process of domestication, a major part of which involves the adaptation to humans and their environment, may have selected for an ability to read human cues in dogs at least (Andersen et al. 2006; Hare et al. 2002).

Studies of other domesticated species indicate that the adaptive changes undergone by dogs during domestication may not have made them uniquely skilled at reading human behaviour. Cats can also use human pointing cues in an object-choice task and goats, believed to have been the second species to be domesticated but not having such a

close relationship with man as dogs, are able to use pointing and tapping cues, but could not use head direction and gaze alone (Kaminski et al. 2005; Miklósi et al. 2005). The goats tested in the study by Kaminski et al (2005) were kept in a zoo and had little human contact and so lacked the intense enculturation that domestic dogs undergo. As with dogs, this ability to use human pointing gestures did not improve with age and did not improve during the trials, also suggesting that this ability was not learnt during the test or over the subject’s lifetime.

In our study, we set out to test the ability to read human cues to attention in another domestic species, the horse. Horses were the last of the five main livestock mammals (goats, sheep, cattle, pigs and horses) to be domesticated around 3500 BCE and as such may be the species that has undergone the least manipulation during domestication (Clutton-Brock 1999; Outram et al. 2009). The relationship between human and horse represents an intermediate level between dogs that live in human homes, often separated from conspecifics, and farm animals, bred for production, that do not usually have such a close relationship with humans. As a species, horses primarily communicate visually, with body language and very small movements of the head, ears and eyes used as communicative signals (Waring 2003), although vocal signals also play an important role in social communication (Proops et al. 2009). Wild equids are also used to living in heterospecific groups and make use of the signals of other species to detect predators (Goodwin 2002). Each of these factors: the possible pre-existing propensity to use fine head cues, the use of signals from other species, domestication involving a close relationship to man and intense enculturation during their lifetime may well have (to varying degrees), led horses to develop an enhanced ability to read human cues to attention.

However, despite the famous case of Clever Hans demonstrating the extent to which horses are capable of detecting very subtle human gestural cues, surprisingly little research has been conducted into this ability in horses (Pfungst 1965). One pilot study using four horses showed that two were capable of using tapping and one of using pointing gestures to locate hidden food (McKinley and Sambrook 2000) and more recent research has confirmed that horses are able to use a variety of pointing gestures in this situation (Maros et al. 2008). Our study aims to provide a direct examination of the ability of horses to attribute attention to humans by assessing whether they are capable of using body, head and eye cues to attention in a begging task. We used this standard paradigm because it represents a naturalistic situation that does not require extensive training to perform and we tested subjects on single trials for each cue to prevent any learning during the study.

Materials and methods

Study animals

A total of 52 horses began the preliminary tests for the experiment and of these, 36 subjects were included in the final analysis. Twelve subjects were from Woodingdean livery yard, Brighton, UK and 24 from the Sussex Horse Rescue Trust, Uckfield, UK. Ages ranged from 10 months to 38 years (mean 13.70 ± 1.61), and included 19 gelded males and 17 females. At both sites subjects live outside all year round. The horses from Woodingdean yard are privately owned and are brought in from the herd regularly for feeding; some of them are ridden. The horses at the Sussex Horse Rescue Trust are checked once a day but remain with the herd most of the time. As such, the privately owned horses had more exposure to humans at the time of the study, although the extent of prior human enculturation was unknown for many of the subjects. Subjects had no known eyesight problems and were comfortable with being handled.

Warm-up phase with attentive experimenters

The test area and test trial procedure can be seen in Fig. 1.

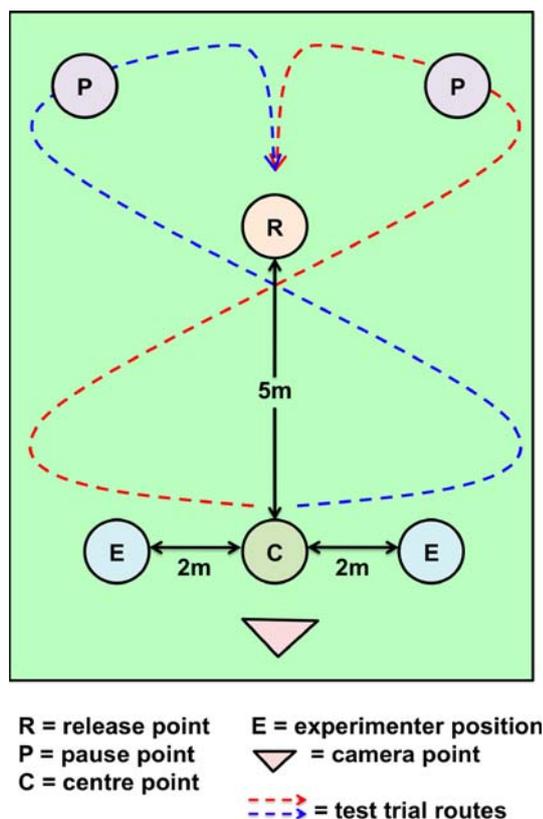


Fig. 1 Diagram of the experimental set-up and test trial procedure

Twenty-four subjects were given an introductory warm-up phase in which experimenters were facing forwards when giving a reward. This phase began with the subject being held at the release point while the experimenters (A and B) approached the horse from the centre point with their hands outstretched and gave the subject a food reward (commercial horse treats). The experimenters then withdrew to the centre line at point C and the handler (an experimenter familiar to the horses) led the horse to point C to receive another food reward from both experimenters. To prevent the horses developing a preference for one of the experimenters, the reward was administered jointly by crossing over their arms and holding out their hands together with a treat in the middle of both of their hands. The experimenters also swapped sides between each trial. The response of the horse was gradually shaped so that within a maximum of 10 warm-up trials, the horses were released at point R and would approach the experimenters at point C to receive a reward. Of the 32 subjects that began the test, 4 failed to complete the warm-up phase.

Warm-up phase with inattentive experimenters

Additional trials were run with 12 subjects. Here subjects were presented with a warm-up phase in which the experimenters were not attentive to the subjects and adopted body postures that were not repeated in the test trials. In this phase, the experimenters stood at 90° from the subject facing each other with their hands outstretched together and a reward held in their hands. The horse was led to the experimenters. Again the response of the horse was gradually shaped so that within a maximum of 10 warm-up trials the horses were released at point R and would approach the experimenters at point C to receive a reward. In these trials, there was no possibility that the horses could be conditioned to cues during the warm-up phase that were later presented in the test trials. Of the 20 subjects that began the test, 6 failed to complete the warm-up phase.

Test trials

The test phase was the same for all 36 subjects. Four cued trials were given to each subject in a counterbalanced order with a reinforcement trial between each test trial. After the warm-up phase, experimenters A and B took up their positions at the points marked E in Fig. 1. For each trial, one experimenter was inattentive and the other was attentive. The side of the attentive person, the identity of the attentive person and the side the experimenters stood on was counterbalanced across trials. No reward was given during test trials. After each test trial, there was a reinforced trial to maintain the motivation of the subjects. In

these trials, experimenters A and B returned to point C and adopted the position the subjects had been presented with in the warm-up phase. Subjects were released at point R to approach the experimenters and receive a treat. Subjects were then lead in a figure of eight around the test area, either to the left or the right and then held at point P for 30 s facing away from the centre point before beginning the next trial (Fig. 1). Pilot trials showed that these measures considerably reduced perseveration rates. If horses failed to respond to a cue, another reinforcement trial was given and the test trial then repeated. Test trials were repeated a maximum of three times before moving on to the next cue and recording a “no response” score for that cue type.

Four cues to attention were tested. Both experimenters adopted neutral facial expressions throughout the trials. The attentive person stood facing forwards and maintained eye contact with the subject as they approached, keeping their head motionless. The inattentive person either stood with their body turned 180° away from the subject (body orientation condition), stood with their body forwards but their head turned away (head orientation condition) or stood with their body and head forwards but with their eyes closed (eyes closed condition). A fourth, mixed condition was included where the attentive person stood with their body turned away from the subjects but their head turned towards the subject while the inattentive person stood with their body forwards but their head turned away (Fig. 2). A male and female experimenter took part in the trials where

an inattentive posture was adopted during the warm-up phase and two other male experimenters took part in the trials where an inattentive posture was adopted during the warm-up phase; the handler was the same for all trials.

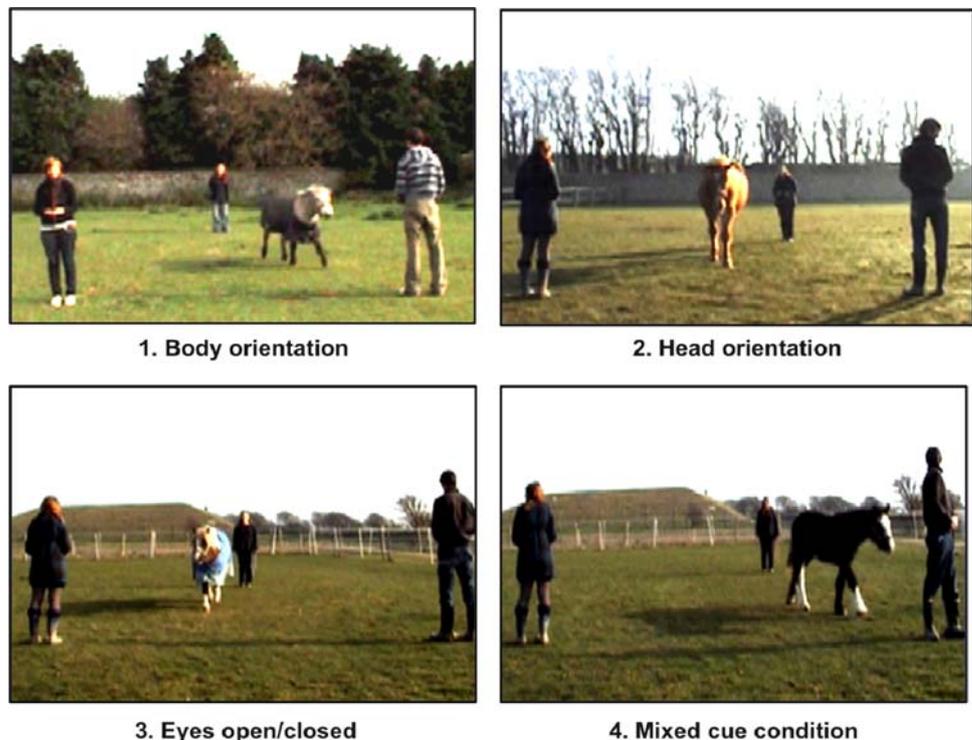
Psychophysical and anatomical estimates of visual acuity in the horizontal streak of the horse retina where ganglion density is highest have provided acuity estimates that range from 16.5 cycles per degree (CPD) to 30.8 CPD (Harman et al. 1999; Timney and Keil 1992). If we take the estimate of visual acuity to be around 23 CPD, this means horses’ acuity is about 20/33 compared to humans, so detail a human can see at 8.3 m, a horse can see at 5 m, suggesting that subjects would be able to detect the difference between open and closed eyes at 5 m. This would be consistent with their use of fine head and body movements as a method of communication between conspecifics.

Of the 42 subjects that progressed to the test trials, 6 showed a side bias by choosing the left or right side for all trials (4 subjects exposed to the attentive warm-up phase and 2 exposed to the inattentive warm-up phase) and so their results were excluded from the analysis. Of the 36 subjects that were included in the analysis, 2 subjects failed to choose an experimenter for three consecutive mixed cue trials and so were given a “no response” score for that cue type.

Behavioural and statistical analysis

Trials were recorded using a Sony digital handycam DCR-TRV19E video recorder and were converted to .mov files

Fig. 2 Still images of the four experimental conditions



and analysed frame by frame (frame = 0.04 s) on a Mac G4 powerbook using Gamebreaker 5.1 video analysis software [31]. The main behaviour studied was whether the subjects correctly chose the attentive person over the inattentive person when determining whom to approach to receive food. A choice was defined as correct if the subject approached and stood within 1 m of the attentive experimenter within 60 s of being released. The number of subjects correctly choosing the attentive person for each trial type was analysed using binomial tests. Fisher's exact tests were used to compare the accuracy of responses to each cue for subjects given the two different warm-up phases. Overall side and experimenter preferences were assessed using binomial tests. The total number of correct scores was calculated for each subject and effects of sex and age were analysed using a Mann–Whitney *U* test and a Spearman's ρ correlation, respectively. We also predicted that there may have been a difference between the subjects from the livery yard that had regular interactions with humans and the animals at the horse sanctuary who currently had less exposure to humans on a day to day basis, and may have had more negative experiences with humans prior to arriving at the sanctuary. This possible effect was also analysed using a Mann–Whitney *U* test.

In addition to assessing whether subjects were able to make the correct choice of whom to approach for food, we also recorded the time it took for horses to make a response. Response times were defined as the time between the release of the subject and the time at which the horse stopped moving and was within 1 m of either of the experimenters. Reaction time data were positively skewed and so were \log_{10} transformed. The effects of trial type and response accuracy (correct/incorrect) were analysed as fixed factors in a linear mixed model with a scaled identity covariance structure. The model was run using a maximum likelihood estimation.

Results

The number of correct responses given to each cue by the subjects exposed to attentive experimenters compared to the inattentive experimenters in the warm-up phase, was not statistically different (Table 1). This demonstrates that the horses' responses during the test trials were not conditioned by specific cues that were given during the warm-up phase. Results from the two groups were therefore pooled for further analysis.

Main effect

Results show that the horses chose the attentive person significantly more often than the inattentive person using

Table 1 Comparison of accuracy rates for subjects given the warm-up trials in which experimenters were attentive compared to inattentive

| Cue | Attentive warm up | Inattentive warm up | FET (<i>P</i>) |
|-------|-------------------|---------------------|------------------|
| Body | 19/24 79% | 9/12 75% | >0.99 |
| Head | 17/24 71% | 8/12 67% | >0.99 |
| Eyes | 19/24 79% | 9/12 75% | >0.99 |
| Mixed | 13/22 59% | 5/12 42% | 0.48 |

Results of Fisher's Exact Tests (FET) comparing the difference between the two results are shown

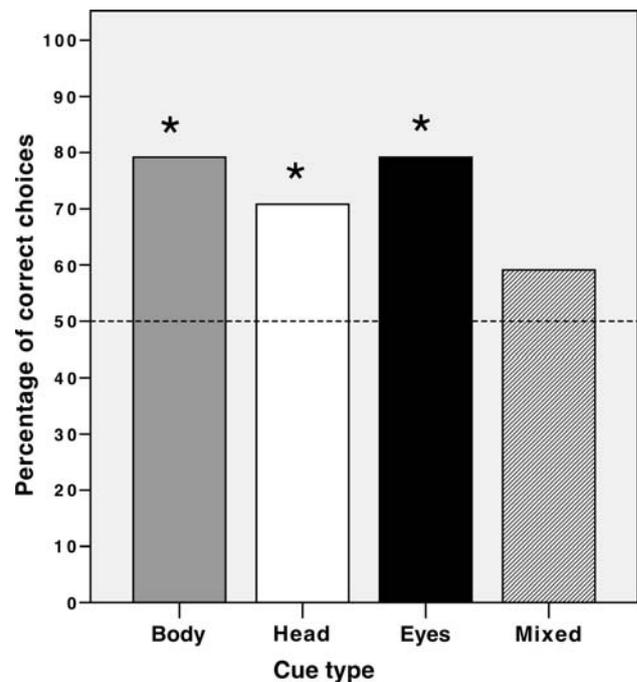


Fig. 3 Percentage of horses correctly choosing the attentive person for each cue type. * $P < 0.05$ (binomial probabilities, two-tailed predictions)

the body cue ($n = 36$, $K = 28$, $P = 0.001$), the head cue ($n = 36$, $K = 25$, $P = 0.029$) and the eye cue ($n = 36$, $K = 28$, $P = 0.001$) but not the mixed cue ($n = 34$, $K = 18$, $P = 0.864$) (Fig. 3).

Total scores were not correlated with age ($r_s = -0.048$, $P = 0.780$). Overall, females performed significantly better than males ($U = 93.0$, $P = 0.016$) although both groups had a median score of 3. There was no difference between overall scores for subjects from the two locations ($U = 103.0$, $P = 0.129$). In addition, there were no overall side ($n = 142$, $K = 76$, $P = 0.450$) or experimenter biases across subjects (trials with attentive experimenters during warm-up phase $n = 94$, $K = 51$, $P = 0.470$; trials with inattentive experimenters during warm-up phase $n = 48$, $K = 28$, $P = 0.312$).

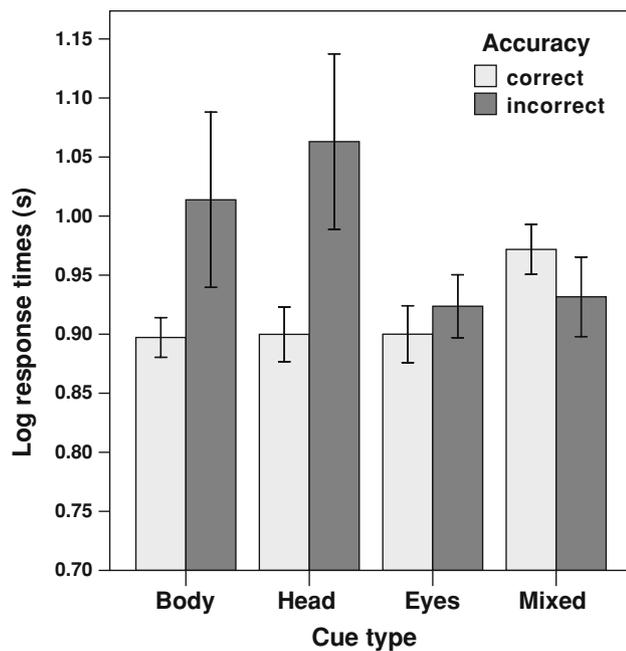


Fig. 4 Mean response times for correct and incorrect choices for each cue type

Response times

Overall response times were longer for incorrect compared to correct trials ($F_{1,141} = 7.403$, $P = 0.007$) although there was no significant main effect of cue type on response times ($F_{3,141} = 1.356$, $P = 0.259$). The interaction effect of cue type and accuracy on response times was significant ($F_{3,141} = 3.951$, $P = 0.010$). More specifically, response times tended to be slower when horses were making the wrong choice on the basis of body and head cues but not when choosing on the basis of eye and mixed cues (Fig. 4).

Discussion

These results show that horses are highly skilled at reading human cues to attention and are capable of using subtle eye cues (possibly by detecting fine movement of the eyes) as well as “grosser” cues such as body and head orientation to select the more attentive of two people. The level of accuracy was similar across the body, head and eye cue trials, suggesting subjects were equally able to utilise each cue. However, reaction times reveal that subjects took longer to reach a decision when making an incorrect choice (approaching the inattentive person) on the basis of head and body cues, indicating that they were less sure of their decision on these occasions. Conversely, when using the

finer scale eye cue there was no difference in decision times for correct and incorrect choices so subjects did not appear to have an underlying awareness of whether they were making the wrong choice. Thus horses may process these cues in different ways.

The differences in reaction times for incorrect compared to correct choices for the body and head cues also indicate that the horses may have been discriminating between attentive and inattentive experimenters to a higher degree than is apparent in their choice of person alone. In a similar way, although dogs do not show a strong preference towards fetching a toy to owners when their eyes are visible compared to when their eyes are obscured with a blindfold, they do approach more hesitantly (Gácsi et al. 2004). Primate studies have also pointed to a discrepancy between the accuracy of the overt response to cues and more unconscious measures of responding such as looking time (Hattori et al. 2007). In our study, subtle behaviour (hesitancy) revealed greater discrimination between cues than more overt responding.

It is also worth noting that four of the eight subjects which approached the inattentive person given the body cue moved round to the front of the person possibly to enter the experimenter’s field of vision. Horses also used tactile gestures such as nudging the experimenters when they were not rewarded. This suggests that even when they chose the inattentive person they may have been using strategies to gain their attention. Recent research confirms that horses, like primates, can adjust the mode of their communication based on the attentiveness of their handler (Hostetter et al. 2001; Leavens et al. 2004; Takimoto and Fujita 2008).

Subjects did not preferentially choose the experimenter facing them during the mixed cue trials. There are two ways to interpret this finding: either they do not have a hierarchical interpretation of attention cues and fail to appreciate that eye (and head) cues are more salient than body cues, or they may interpret the turned body as a signal that the experimenter does not intend to cooperate with them. This second interpretation was put forward as a possible explanation of similar findings in apes (Kaminski et al. 2004). In this way, failure to approach the person facing forwards but with their body turned away, may not represent a failure to attribute attention but instead, an active attribution that the turned back signals a lack of intention or ability to provide food. This current study cannot distinguish between these two possible explanations and, indeed there is still debate as to whether humans process body, face and eye cues hierarchically or in parallel (Gácsi et al. 2004).

Another interesting result was that females were more likely to choose the attentive experimenter than males. In free-ranging horse societies, older mares are often

instrumental in maintaining social cohesion within the group and determining their daily movement; long-lasting bonds between female horses are commonplace and in this sense horse societies have been described as matriarchal (Goodwin 1999; Jensen 2002; Wells and Goldschmidt-Rothschild 1979). This result would suggest that females may possess enhanced social discriminative abilities as has been reported in other matriarchal societies (McComb et al. 2000, 2001). However, recent research has not shown domestic female horses to be more skilled than males at recognising close associates (Proops et al. 2009), neither has this sex difference been reported in previous studies of human attention attribution conducted with other species. Further research with a larger sample size would be required to investigate these preliminary findings.

Overall, subjects were able to use body, head and eye cues in our begging task, indicating that horses may well be as skilled as dogs and more skilled than all but the most intensely enculturated and trained apes at this specific task. In this study, horses were presented with one trial per cue, therefore, subjects did not have the opportunity to learn to discriminate cues during the task. This factor combined with the finding that horses were as accurate at attributing attention given a warm-up phase with inattentive compared to attentive experimenters, suggests our experiment provides a test of their pre-existing knowledge about human attentional states. Taken together with other findings indicating that horses are able to use complex human cues in object-choice tasks, these results point towards an enhanced ability to read human cues in domestic horses. In the same way that there are three explanations for enhanced abilities to read human communicative cues in dogs, there are also three main explanations for this skill in horses. Domestic horses may have learnt these abilities through intense enculturation throughout their lifetimes or, through the process of domestication, evolved a particular sensitivity to human communicative cues, or inherited a general skill for the discrimination of social cues from their wild ancestors.

The absence of a correlation between age and ability in our experiments and the accurate performance of a 10-month-old foal (and other youngsters) in the study suggests that the social sensitivity observed may have a strong genetic component and/or is learnt very early in development. Further research specifically looking at the ontogeny of this ability in foals (akin to previous studies of puppies) would help to elucidate more clearly the role of genes and environment in its development. Similarly, comparisons between adult subjects with different training/human exposure histories would also be of benefit. “Natural horsemanship” training techniques, typified by trying to take into account natural horse behaviour during training and also with a strong emphasis on ground work, appears to

produce adult horses better able to use human cues such as pointing in an object-choice task (Bartosova et al. 2008; McKinley and Sambrook 2000). Whether training plays a role in development of attention attribution skills is unclear. We found no difference between subjects based on their current level of human interaction, however, as is often the case with studies of adult horses, it was not possible to obtain full life histories for many of the subjects and so the effects of prior experience on their abilities could not be adequately assessed (Cooper 2007). It also remains to be seen whether domesticated horses perform better than their wild cousins or other equid species, when socialised to comparable levels. So far, this analysis of pre-existing phylogenetic skills via direct comparison between domesticated and wild species has only been conducted with dogs, wolves and domestic foxes.

By studying the ability of horses to attribute attention to people across a variety of tasks, we can determine the extent to which horses are able to use eye and body cues flexibly. Traditional animal management techniques often state that direct eye contact is seen by many species, including horses, as an aggressive act, although there has been very little empirical evidence to confirm this (Vervill and McDonnell 2008). In the same way that humans distinguish between a stare of aggression and a look of friendship, this current research suggests that horses will interpret eye contact as a friendly gesture in certain contexts. Future research investigating the cues and contexts in which horses interpret gaze as a positive or negative cue will help to determine the sensitivity and flexibility with which horses interpret human gaze. This may also help to clarify whether recognition of attentional states occurs as a strictly behavioural, discrimination learning process or whether the ability operates at a more cognitive, rule-based level.

In order to understand the evolution of social intelligence, the development of attention attribution skills and how they relate to other abilities such as theory of mind, it is necessary to test a wide variety of domestic and wild animals across a range of tasks. It is clear from our results that horses are highly sensitive to human gestural cues including gaze. Although the factors which give rise to this ability are likely to vary across taxa, the high numbers of correct responses on first trials, the lack of correlation between age and performance, and the accurate performance of some very young subjects in this study suggest that horses, like dogs, may have a pre-disposition to be highly sensitive to human attentional cues.

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