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ORIGINAL PAPER

Evidence of heterospecific referential communication from domestic horses (*Equus caballus*) to humans

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Abstract Referential communication occurs when a sender elaborates its gestures to direct the attention of a recipient to its role in pursuit of the desired goal, e.g. by pointing or showing an object, thereby informing the recipient what it wants. If the gesture is successful, the sender and the recipient focus their attention simultaneously on a third entity, the target. Here we investigated the ability of domestic horses (*Equus caballus*) to communicate referentially with a human observer about the location of a desired target, a bucket of food out of reach. In order to test six operational criteria of referential communication, we manipulated the recipient's (experimenter) attentional state in four experimental conditions: frontally oriented, backward oriented, walking away from the arena and frontally oriented with other helpers present in the arena. The rate of gaze alternation was higher in the frontally oriented condition than in all the others. The horses appeared to use both indicative (pointing) and non-indicative (nods and shakes) head gestures in the relevant test conditions. Horses also elaborated their communication by switching from a visual to a tactile signal and demonstrated perseverance in their communication. The results of the tests revealed that horses used referential gestures to manipulate the attention of a human recipient so to obtain an unreachable resource. These are the first such findings in an ungulate species.

Keywords Domestic horse · Referential communication · Human–animal communication · Intentional communication · Referential gesture

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Introduction

Deictic (or referential) gestures are mechanically ineffective body movements made to elicit specific behaviours on a recipient, repeated until the effect is obtained or failure is clearly indicated (Bates et al. 1975; Hobaiter and Byrne 2011). In referential communication, the sender elaborates its gestures to direct the attention of the recipient to its role in pursuit of the desired goal, e.g. by pointing or showing an object, thereby informing the recipient what it wants (Warneken et al. 2006). Because it reflects the construction of a mental action plan from the sender, this type of communicative gesture is considered a prerequisite for mind reading (Tomasello et al. 2005). If the gesture is successful, the sender and the recipient focus their attention simultaneously to a third entity, the target. Such shared attention should not be confused with simultaneous attention, where the attention of two individuals is drawn to the same stimulus by the stimulus itself, such as an unexpected sound (Tomasello 1995).

In contrast to gestures tuned to the mere presence or absence of an audience, referential gestures are displayed in accordance with the audience's attentiveness. For example, when choosing between an acoustic signal and a 'visual' gesture, the sender will choose the latter only if the audience is already visually attending to the signaller. If the audience is not visually attentive, the sender needs to perform some attention-getting behaviours, such as vocalizations or non-indicative gestures. The meaning of these behaviours is not codified in the gesture itself, but rather derives from some accompanying behaviour (Call and Tomasello 2007). Examples of such 'indicative behaviours' are alternate gazing and/or pointing, indicating the location of the desired target (Leavens et al. 2005).

At around the age of 9–12 months, human infants start to use gestures to coordinate attention towards a social partner and a distal object by using indicative behaviours such as pointing, showing or offering (Bates et al. 1979). In comparison, examples of referential gestures in non-human species have been relatively scarce until recently, with evidence from different taxa accumulating in the last decade (reviewed in Pika 2012). Species for which signals have been described that may possess some if not all of the attributes of a referential gesture include non-human primates (chimpanzees, Pika and Mitani 2006; Roberts et al. 2014; orangutans, Cartmill and Byrne 2007; baboons, Bourjade et al. 2014; rhesus macaques, Canteloup et al. 2015); dogs (Miklósi et al. 2000; Gaunet and Deputte 2011; Savalli et al. 2014); dolphins (Xitco et al. 2004); ravens (Pika and Bugnyar 2011) and fish (groupers and coral trout, Vail et al. 2013). For example, Roberts et al. (2014) found that chimpanzees use both indicative (pointing with the hand) and non-indicative (bobbing with the head) gestures to direct an experimenter in a search for hidden food. Dolphins convey the attention of a recipient to a food target by maintaining the alignment of their bodies with it while alternating gaze between the target and the recipient (Xitco et al. 2004).

So far, among domesticated species, only dogs have been used as a model of referential communication (Hare et al. 1998; Miklósi et al. 2000; Gaunet 2010; Gaunet and Deputte 2011; Savalli et al. 2014). In the experimental setups so far used, the ability of dogs to communicate with a human observer about the location of an unreachable reward (toy or food) was tested. Hare et al. (1998) were the first to adapt experimental settings used to test primate-human referential communication to dog–human dyads. They found that dogs used gazes and vocalizations socially, i.e. less frequently in the absence of a human recipient. Subsequent experiments showed that dogs use alternate gazing when communicating the location of a hidden target (Miklósi et al. 2000; Gaunet and Deputte 2011), and even adjust their own position in space to gaze at their owner according to the direction of the owner's gaze (Gaunet and Deputte 2011). When dogs obtained a different target to the requested one, they showed persistence, i.e. repeated gazes and vocalizations until they obtained the correct target, but did not elaborate their requests; e.g. no new behavioural technique emerged (Gaunet 2010). Recently, Savalli et al. (2014) found evidence that dogs communicate referentially with humans according to all operational criteria described by Leavens (2004): they use gaze alternation between a subject and a target, accompanied by attention-getting behaviours, such as vocalizations, that are modulated according to the attentional state and presence of the recipient. Dogs remained persistent in their communicative attempts and elaborated them if unsuccessful, i.e. if dogs did not obtain the full amount of food requested.

Primates, canines, dolphins and ravens live in complex social societies. It has been suggested that referential gesturing is an extremely rare form of communication (Tomasello et al. 2005), one that most likely evolved in species with highly complex social systems such as fission–fusion societies, where the negotiation of interactions and the use of visual social signals plays a fundamental role (Emery 2000; Pika 2012). Here we investigated the ability of referential communication in a highly social species that has so far not been studied for this skill: the domestic horse (*Equus caballus*). Horses live in fission–fusion societies (Rubenstein and Wrangham 1986) and are prey animals, for which concerting group actions and the associated communicative skills are of primary importance for survival. These animals communicate primarily visually, through fine-tuned body postures and ear, eye and head movements (Waring 2003; Wathan and McComb 2014). Given their social and cognitive skills, horses may be able to use referential communication at the intraspecific level. Nevertheless, unlike most species mentioned above, the horse is a domesticated species and it provides, in addition to dogs, a good model for studying interspecies communication, in particular animal–human communication. Therefore, we tested the ability of horses to communicate referentially with humans at the interspecific level. Research has already shown that horses understand human attentional cues (such as body and head orientation, eyes opened/closed, Proops and McComb 2010), permanent pointing (Maros et al. 2008) and, to some extent, gazing (Krueger et al. 2011), but research on how horses may use indicative behaviours to communicate with humans is lacking.

The aim of this study was to test the ability of domestic horses to communicate referentially with a human about the location of a desired target, a bucket of food, visible but out of reach. By varying the attentional states of the experimenter, we tested whether the horses would understand the difference among them and act accordingly. Like in many previous studies (Hare et al. 1998; Miklósi et al. 2000; Xitco et al. 2004; Gaunet and Deputte 2011; Savalli et al. 2014) a within-subject design was employed. We aimed to empirically answer the following questions according to the six operational criteria for intentional communication first described by Bates et al. (1975) in humans, and then adapted by Leavens (2004) to non-human animals: (1) Are the horses using gaze alternations, i.e. successive visual orientation between the communicative partner and the target? (2) Do the horses deploy attention-getting behaviours, head jerks, nods and shakes? (3) Are the signals used socially, i.e. is a recipient required to exhibit the behaviour? (4) Does the attentional status of the communicative partner (the human) influence the propensity of the sender (the horse) to exhibit the communicative gestures? (5) Is the communication persistent, i.e. does the signaller (the horse) repeat its signals in relation to different attentional and/or comprehension states of the recipient (the human), until the goal is obtained? (6) Is there elaboration of communicative gestures and related behaviours following persistent and ineffective signalling, such as changing the communicative channel?

Our main prediction was that horses use alternated gazes between the target and a human to convey their attention towards the desired object, thus activating attention-sharing mechanisms. This would be done by attracting the attention of the human with gazes or head gestures or by pointing at the target, modulating signalling according to her attentional state or the presence. We thus expect the highest rate of gaze alternation and attention-getting behaviours when the human (the experimenter or other humans present) is attentive towards the horse, and the lowest rate when her attention is elsewhere or she is absent. We predicted that horses were persistent in their communicative efforts, thus repeating their request after a period of absence of the human. Finally, we expected elaboration from horses in terms of switching from a visual to a tactile communicative channel if visual signalling turns out to be ineffective, i.e. walking back to the human and prompting action via physical contact with her.

If horses were found able to communicate referentially with a human observer, we propose that they acquired this skill individually during repeated interactions with conspecifics, being gradually reinforced with more and more subtle signals, and then adapted their signalling to interspecific communication with humans, where instead they needed to signal with more evident cues. This is similar to what is hypothesized in non-human primates, where referential gestures seem to arise from a ritualization of actions during interactions at the individual level (Tomasello et al. 1993; Tomasello 2006).

Materials and methods

Subjects

In total, 14 horses participated (mean age 10.9 ± 4.6; 8 geldings, 6 females; mixed breeds), hosted at EquiLuna A.S.D (Italy), Study Center for Ethical Equitation. All horses lived in the same social group in a paddock of 6000 m^2, allowing natural social interactions, and were regularly involved in riding activities with humans. They were trained under the principles of the so-called natural horsemanship training (NHT), which are believed to provide a better experience compared to traditional training for horses and also to build better relationships between the horse and the trainer (for a review, see Birke 2007). They were provided with grass, hay and water ad libitum.

Experimental setting

We tested the horses in a familiar environment (refer to Schwab and Huber 2006) to avoid unnatural behavioural responses or stress induced by testing in novel settings. During tests, horses were able to see their conspecifics, confined at a distance of about 30 m. Occasionally, and due to the schedule of equestrian activities, conspecifics were at a closer distance and able to see the experimental area and the procedure, but physical contact was still not possible. Both the experimenter (RM) and the helpers involved in the tests were familiar to the horses.

The experiment was conducted in a fenced arena (size 64 sqm). Two food buckets without lids were placed behind gates in equal distances from a release point, 16 m from each other (Fig. 1). Carrots, apples or oat were randomly used to fill both buckets, each with a different bait. We used two buckets instead of one because we did not know the individual food preferences of the horses and

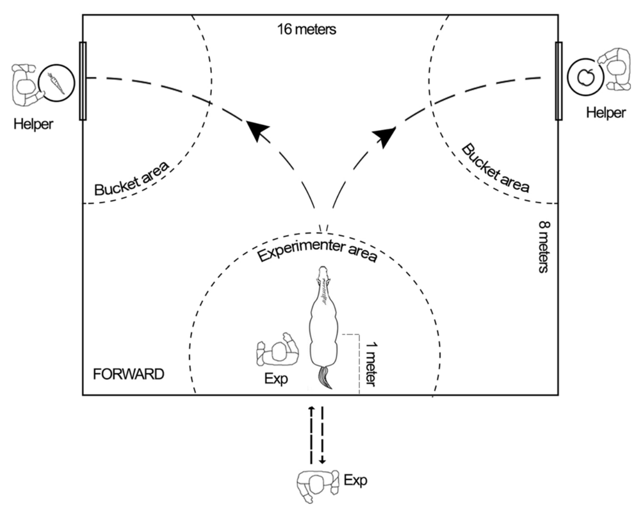

Fig. 1 Sketch of the experimental procedure from above. A horse is depicted at the release point. Human pictures resemble the position of the experimenter and the helpers, if present. The Bucket and the Experimenter Area had a radius of one horse body length. The *dotted straight line* outside the test area in the bottom of the figure indicates the direction taken by the experimenter when walking out and coming back to the test area during the condition 'Walk-away'. *Exp* experimenter

wanted to maintain their attention by providing in each session at least one preferred reward. During training and tests, only the experimenter (RM) and an assistant with a video camera were present, with the exception of one experimental condition ('Many') in which two helpers were included. The assistant with the video camera was shielded behind a panel and was visible to the horse only at the beginning of the test session during hiding, but not during the tests.

Experimental conditions

We designed four experimental conditions (Online Resource 1), consisting of 3 trials each, totalling 12 trials for each horse. The sequence of trials was determined in a pseudo-random manner, i.e. avoiding that the same condition was administered in two consecutive trials. Each horse participated in only one trial per day. Each trial lasted for about 1 min (57 ± 7 s). The duration of trials varied because the number of seconds that the experimenter took to walk 100 m away from the arena was not always the same (condition 'Walk-away'), or because on some occasions the horse would walk back to the experimenter.

During each trial, the experimenter guided the horse on the leash into the arena by entering randomly from the left or the right side (Fig. 1). As soon as they reached the gate on the opposite side of the arena, the experimenter crossed the gate and showed the filled bucket to the horse, then she led it to the other bucket and did the same. She handled the horse to the release point (see Fig. 1), made it turn towards the centre of the arena and placed herself at its left or right side at random. She then released the horse, and it would walk to the gate in front of the chosen reward. The conditions were set as follows:

- **Forward:** The experimenter was frontally oriented towards the centre of the arena, i.e. looking at a point equally distanced from the two gates.
- **Backward:** The experimenter faced away from the gates, i.e. her back was oriented to the centre of the arena. Being turned is identified as a state of inattention by many species, the horse included (Krueger et al. 2011). The 'Forward' and 'Backward' conditions were similar to those used in Hare et al. (1998) and Savalli et al. (2014), but we prolonged the 'Backward' for up to 3 additional min (Backward_prolonged) to investigate elaborated communication. For the analyses, Backward_prolonged was considered separately from the original Backward condition.

In these two conditions, after releasing the horse, the experimenter kept her eyes open and looked at it as soon as it caught her attention, e.g. when the horse made noises, pulled the tape on the gate or looked back at her. As soon as the horse stopped these behaviours for 2 s, the experimenter looked again straight to the centre of the arena. She opened the gate to the bucket after the set time, regardless of the horse's attention, or sooner if the horse walked back into the experimenter's area (Fig. 1). The experimenter did not open the gate after the communicative attempts of the horses because we did not want to decide a priori which was the 'right' communication to have the gate opened, but instead wanted the horses to choose what to do. We therefore fixed a certain time (about 57 s) after which the experimenter opened the gate.

The other two experimental conditions were:

- **Many**: Behind each of the two buckets, a helper was facing towards the arena. During the test, as soon as the horse approached the gate while led by the experimenter, the helpers showed the rewarded bucket to the horse. The helpers were asked to alternate looks between the horse and the bucket. If the horse approached a bucket and waited in front of the gate, the helper behind that gate opened it after 50 s. If the horse gazed back at the experimenter, she would open the gate instead of the helper. This was done to assure the horse that in the presence of the helpers, communication with the experimenter was still effective. This is a completely novel condition, not administered in any previous experiments.
- **Walk-away**: The experimenter left the arena at the rear side and walked away as indicated in Fig. 1. This condition is similar to that used by Miklósi et al. (2000), Xitco et al. (2004), Gaunet and Deputte (2011) and Savalli et al. (2014), but in order to test whether horses were persistent in their request, we modified this condition by allowing the horse to observe the human walking away from the test area (about 100 m along a straight line) and returning after 60 s. For the analyses, we considered the walking away and the returning phases as two separate conditions: Walk-away and Returning.

Training phase

The aim of the training was to familiarize the horse to the procedure, namely to approach the bucket as soon as it was baited and to wait for the experimenter to open the gate, and to habituate to the experimental area. During the training, the experimenter guided the subject on the leash into the arena as she did during the test phase. The experimenter remained still and oriented to the centre of the arena until the horse reached the gate. Then she followed and opened the gate to provide access to the baited bucket. The waiting time from when the horse stopped in front of the gate and the experimenter opened the gate was increased stepwise from 5 to 10, 20 and finally 30 s. This was done because we did not want to inadvertently reinforce communicative behaviours of the horse. For example, the horse might have turned back as soon as it arrived at the gate (as often happened): if we just opened the gate, we would have reinforced the behaviour. Instead, fixed durations allowed for a random combination with communicative attempts.

The training occurred for each horse before testing, until it reached a bucket 5 consecutive times (once per day in consecutive days) after being released. If the horse did not approach a bucket after being released, it was prompted to move (by swinging a rope close to the horse, without touching it). If it did not move or if it showed no interest in the rewards 5 consecutive times, it was excluded from the sample.

Data collection and analyses

All trials were recorded with a video camera (Sony HDR-CX220). A selection of behaviours (see ethogram in Table 1; for video examples of the coded behaviours see Online Resource 2) was continuously registered from the video using Solomon Coder beta 12.09.04 (http://solomoncoder.com). As for the behaviour 'Gaze to the experimenter', we considered a head rotation of 90 degrees to maintain a conservative criterion of gazing at the recipient (see Table 1 and Fig. 2a) (although Xitco et al. 2004 adopted 45 degree criterion with dolphins). Because the orientation of ears is considered to indicate the horse's focus of attention for conspecifics (Wathan and McComb 2014), we did not consider the mere orientation of the head towards the bucket as a gaze. Instead, we scored a gaze to the bucket only when it was accompanied by active pointing, i.e. when head direction combined with the orientation of at least one ear towards the bucket (see Table 1; Fig. 2b).

The experimenter did all video analysis. A person unfamiliar to the experiment analysed 10 % of the videos to ensure validity of coding. There was good correlation between the experimenter and naïve coder for all three important variables (pointing to the bucket, head gestures and gazing at the experimenter: $r > 0.75$, $p < 0.001$).

We verified each operational criteria according to the methods explained in Table 2. Because the duration of the trials varied, absolute frequencies and durations were divided by each trial's total duration. The data were analysed nonparametrically because it did not fulfil the criteria for parametric analysis. We compared the nonparametric conditions with Friedman tests, and if the tests turned out significant, pairwise comparisons of significant variables were performed using Wilcoxon (criteria #1 to #5). Differences in proportions were tested by means of the

Table 1 Definitions of variables

Variable	Definition
Gaze at the experimenter	Either the horse's forehead was oriented towards the experimenter, e.g. when it orients its body towards the experimenter, or the horse turned its head by 90 degrees laterally or more back (away from the anterior–posterior axis)
Point at the bucket	The subject's neck was stretched towards the gate or the bucket, or its head and at least one ear were oriented towards the gate or the bucket, or subject's neck was not stretched but its chin was beyond the gate
Gaze alternation	A gaze at the experimenter was followed by pointing at the bucket within two seconds or vice versa
Head gesture	Movement of the head along the sagittal plane as in head nods or the transversal plane as in head shakes. Head gestures differed from normal movements of the head in their timing (very quick or very slow)
Latency	Time span between the release of the subject and a walk (all four hooves were moved in sequence) towards the experimenter

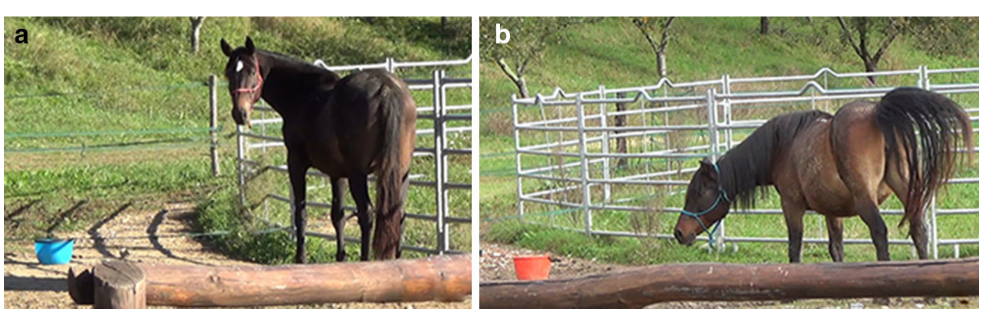

Fig. 2 Pictures of two coded behaviours: **a** gaze to the experimenter and **b** point at the bucket. Descriptions of the behaviours are available in Table 1

Table 2 For each operational criteria, we defined a set of research questions. To answer these questions, we compared the frequency, duration and/or proportion of the coded behaviours between experimental conditions

Operational criteria	Research question: did horses…?	Experimental condition	Behaviour
#1: Subjects use gaze alternation	…use gaze alternation in absence of visual contact with the human?	Forward versus Backward	f_i (gaze alternation)
	…use gaze alternation with the human experimenter when more appropriate helpers were present?	Forward versus Many	
	…use gaze alternation in absence of the human?	Forward versus Walk-away	
	…use gaze alternation when visual contact with the human is re-established?	Forward versus Returning	
#2: Subjects use visual attention-getting behaviours	…use visual attention-getting behaviours in absence of visual contact with the human?	Forward versus Backward	f_i (gazes towards the experimenter, head gestures, pointing at the buckets)
	…use visual attention-getting behaviours both with the human experimenter and the helpers?	Forward versus Many	
	…use visual attention-getting behaviours in absence of the human?	Forward versus Walk-away	
	…gaze longer to a human leaving the arena than when she or the helpers remain in the arena?	Walk-away versus Forward Walk-away versus Many	Duration of gazes towards the experimenter
#3: Gaze alternation is used socially	…use gaze alternation in absence of the human?	Forward versus Walk-away	f_i (gaze alternation)
#4: Gaze alternation is modulated according to the attentional state of the experimenter	…alternate their gaze with the human even if visual contact was absent?	Forward versus Backward	f_i (gaze alternation)
	…alternate their gaze with the human even if the helpers were more attentive to the subject?	Forward versus Many	
#5: Subjects are persistent in their communication with the recipient	…re-start using gaze alternation with the human when she was coming back after leaving?	Walk-away versus Returning	f_i (gaze alternation)
#6: Subjects elaborate the communicative signal by switching communication from the visual to the tactile channel	…walk back to the experimenter when visual communicative attempts were not successful?	Forward versus Backward Forward versus Backward_prolonged	% (subjects walked back to the experimenter and established a physical contact with her)

f_i frequency. For definitions of the coded behaviours, see Table 1

McNemar's test (criterion #6). These tests were performed with GNU PSPP version 0.8.4 software (Free Software Foundation, http://www.gnu.org/software/pspp). All tests were two-tailed with an alpha level of 0.05.

To evaluate whether there was a learning effect across conditions, the first and the last trial of all the conditions, and the first and the last trial regardless of condition, were compared for 4 relevant behaviours (gaze alternation, gaze at the experimenter, point at the buck and head gestures), using a two-sample Wilcoxon signed-rank test.

Results

From 18 horses, only 4 failed and were excluded. Failure was considered to have occurred when the horse remained close to the experimenter even after release (3 subjects) or did not move into the bucket's area (1 subject). This last horse was not interested in the food and spent all the training time close to the fence of the arena and oriented towards its conspecifics.

No learning effect was found for the variables tested between the first and the last trial of each condition (additional data are given in Online Resource 3). There was a significant difference across conditions in the relative frequency of gaze alternations ($X^2 = 18.54$, $p < 0.001$), gazes at the experimenter ($X^2 = 13.49$, $p < 0.01$), head gestures ($X^2 = 13.37$, $p < 0.01$) and pointing at the bucket ($X^2 = 11.29$, $p < 0.01$), and in the relative duration of gazes at the experimenter ($X^2 = 14.71$, $p < 0.001$). Horses did not walk to the gate where they came in ($z = -0.14$, $p = 0.89$), rather walked to gate where oats were provided ($z = -3.00$, $p < 0.01$), thus showing a preference for this reward.

Post hoc analysis revealed that horses alternated gazes between the target and the experimenter significantly more often in the Forward than in the Walk-away ($z = -2.48$, $p < 0.01$), the Backward ($z = -2.92$, $p < 0.01$) and the Many condition ($z = -3.08$, $p < 0.01$) (Fig. 3). In the Returning condition horses showed gaze alternations at a rate similar to the Forward condition ($z = -0.41$, $p = 0.68$), but significantly more often than in the Walk-away condition ($z = -2.47$, $p < 0.01$).

Gazes at the experimenter were significantly more frequent in the Forward than the Backward ($z = -2.45$, $p < 0.01$) and the Many ($z = -3.23$, $p < 0.001$) but not the Walk-away condition ($z = -1.35$, $p = 0.18$). The average duration of gazes at the experimenter during the Walk-away condition was significantly longer than the Forward ($z = -2.57$, $p < 0.01$) and the Many condition ($z = -2.79$, $p < 0.01$), but similar to the Backward condition ($z = -1.71$, $p = 0.09$).

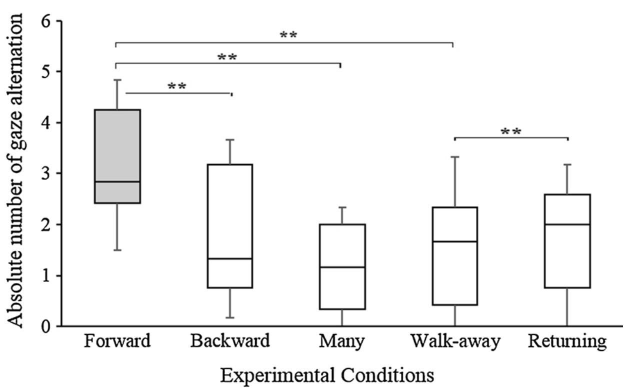

Fig. 3 Medians of the absolute numbers of gaze alternation between the experimenter and the target. Labels on the *x*-axis indicate the different experimental conditions. *The box* of the Forward condition is grey because it represents the baseline condition. Whiskers extend to the 25 and 75 % quartile and exclude outliers; with $*P \leq 0.05$, $**P \leq 0.01$

Horses pointed more often at the bucket or produced more head gestures in the Forward condition compared to either the Backward (point at the bucket: $z = -3.30$, $p < 0.001$; head gesture: $z = -2.62$, $p < 0.01$) or the Walk-away condition (point at the bucket: $z = -2.20$, $p < 0.02$; head gesture: $z = -3.30$, $p < 0.001$). Instead, the rate of pointing or head gesturing was similar between the Forward and the Many condition (point at the bucket: $z = -1.64$, $p = 0.11$; head gesture: $z = -0.50$, $p = 0.59$) (Fig. 4).

Only during the Forward and the Backward conditions did some horses walk away from the bucket's area in the direction of the experimenter. In the Forward condition, this was done by four out of 14 horses (28.6 %), after a latency of 35 ± 16 s. In the Backward condition, seven out of 14 horses (50 %) walked back to the experimenter, after a latency of 40 ± 10 s. During the Backward condition, five out of seven horses established physical contact with her. Four horses walked back to the experimenter in both the Forward and Backward condition, but only three during the Backward condition alone ($X^2 = 1.33$, df = 1, $p = 0.25$, McNemar's test). During the Backward_prolonged condition, ten out of 14 (71.4 %) horses walked back to the experimenter, after a latency of 82 ± 31 s. Nine of these 10 horses established physical contact with her. With respect to the Forward condition, seven more horses walked back to the experimenter's area during the Backward_prolonged condition ($X^2 = 5.14$, df = 1, $p < 0.05$, McNemar's test).

Discussion

The aim of this study was to test the ability of domestic horses to communicate referentially with humans about a desired, but inaccessible food. The question was whether

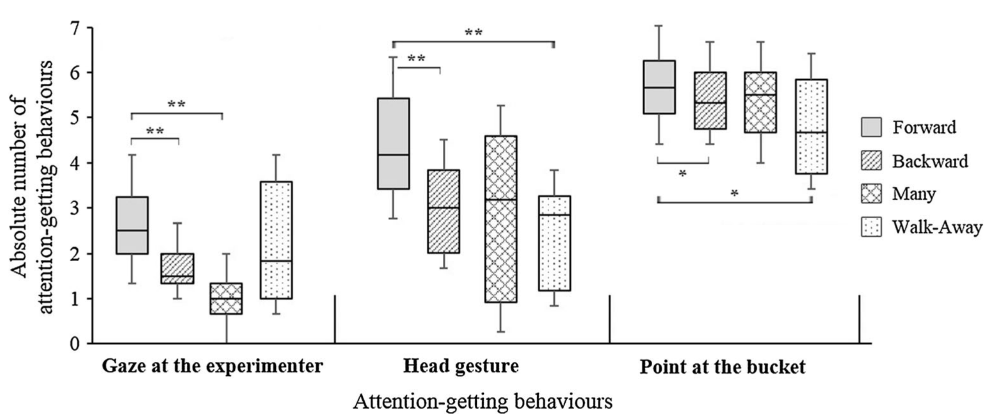

Fig. 4 Medians of the absolute numbers of attention-getting behaviours (gazes at the experimenter, head gestures, point at the bucket). *The legend* indicates the patterns associated with each experimental condition. Whiskers extend to the 25 and 75 % quartile and exclude outliers; with $*P \leq 0.05$, $**P \leq 0.01$

horses would try to achieve the goal by manipulating the attention of a human experimenter, which requires an understanding of the human's different attentional states. By applying well-established criteria for referential communication, we found evidence in support of referential communication. Horses used gaze alternation to coordinate attention with a human recipient in the direction of the desired target (operational criterion #1): the frequency of this behaviour was higher when the human was frontally oriented than when it was backward oriented, absent or when more appropriate helpers were present. Therefore, horses alternated their gaze depending on the presence (criterion #3) and attentional state of the human (criterion #4).

One may argue that gaze alternation is the outcome of associative learning and is not related to intentional communication. The horses involved in this study had lived their whole lives up to this point with humans and may have incidentally learned that turning the head back towards a human increases the chances of obtaining what they desire, without understanding the meaning of the gesture. This did not happen during our study, as evidenced by the results exploring possible learning effects. Even if the horses had learned this behaviour prior to the study, our data confirm that they were able to use this behaviour in a flexible way suggesting they comprehend its meaning. Horses behaved differently depending on the attentional state of the human experimenter: when her attention was elsewhere ('Backward' and 'Walk-away' conditions), the rate of gaze alternation decreased, suggesting that horses understood that turning the head back was a visual signal and thus needed the visual attention of the human experimenter. In a recent study, Bourjade et al. (2015) found that a similar rate of gaze alternation in trained and untrained baboons, which demonstrates that this behaviour was spontaneous and not incidentally learned from humans.

Still, one may argue that horses learned that their head needs to be turned in combination with a frontal position of the human, without really understanding the attentional state of the human. The use of attention-getting behaviours by horses may rule out this explanation (criterion #2). We took into account the direction of the horses' ears together with head orientation to infer the attention towards the target, or the use of head gestures like head nods and shakes as attention getters. According to our results, when the experimenter was backward oriented and when she was walking away from the arena, not only the rate of gaze alternation, but also that of head gestures and pointing dropped to chance level. That horses may have incidentally learned that both gaze alternation and attention-getting behaviours had to be used when the human was frontally oriented seems unlikely. During the condition 'Many', one helper was behind each bucket. These helpers, located closer to the bucket and with their attention focused alternatively at it and at the horse, would be perceived as more appropriate recipients than the more distant and not focused experimenter. In this condition, horses pointed at the bucket and gestured with the head, but did not use gaze alternation. This suggests that horses understood that the outcome of gaze alternation with the experimenter was for her to open the gate, whereas in this case the helper was closer to a chain of actions that might bring them to the baited bucket. This result furthermore suggests that horses comprehended the use of attention getters, which were needed because the helpers were inactive.

Horses pointed at the bucket and executed head gestures with the same frequency in both the 'Forward' and the 'Many' conditions, where helpers and the experimenter were frontally oriented. This supports the hypothesis that these two behaviours are used in conjunction with eye contact to prompt action of the recipient and/or to indicate the position of the desired target. This interpretation of head gestures in terms of communicative signals stands in contrast to the widespread view in the equestrian community who consider head gestures as mere signs of arousal or distress.

Unexpectedly, the frequency of gazes (not of gaze alternation) at the experimenter walking away was similar to the baseline condition ('Forward'). This is the opposite of our prediction, but a careful consideration of the features of these gazes led us consider them to have a checking rather than a communicative function. In fact, horses did not look—as they did in the 'Forward' condition—at the bucket after gazing at the experimenter. Whereas gaze alternation, if performed together with attention-seeking behaviours and in the presence of a recipient, can be considered a referential gesture, gazes alone do not necessarily have communicative means. These gazes not only were performed without alternation towards the bucket, but also were not accompanied by other attention-getting behaviours, such as head gestures. The results on the rate of gazing are similar to those obtained in dolphins (Xitco et al. 2004) and in dogs (Savalli et al. 2014). In particular, if food was taken away from the testing room, dogs gazed at the exit door at the same rate as they did at the food when it was present. However, in the condition when the food was absent, dogs did not alternate their gaze between the exit door and the owner as frequently as they did between the food and the owner. Savalli and co-authors (2014) interpreted the rate of gazes at the exit door as a 'waiting' reaction, whereas gazes used during alternation were given a communicative meaning. We agree with them that some behaviours that are used as attention getters can change their function with conditions (see also Gaunet and Deputte 2011), so that when the possible helper is leaving, gazing could serve as checking/monitoring behaviour.

Further, in our experiment gazes at the experimenter walking away were on average longer than during the two conditions in which the experimenter was visually attentive ('Many' and 'Forward'). Longer gazes were interpreted as a violation of expectation in horses in both Proops et al. (2009) and Sankey et al. (2011), where horses gazed longer in the direction of a mismatched cue. The long gazes given by our horses may have been triggered likewise by violation of expectation if the horse was expecting the experimenter to remain in the arena as in the other conditions.

The last two criteria for intentional communication are persistence (#5) and elaboration (#6). Horses were persistent in their communicative effort: they diminished the frequency of gaze alternation while observing the experimenter walking away from the test area, but resumed alternating gazes between the experimenter and the target when the experimenter returned ('Returning' condition). The horses also elaborated their communicative strategy when first attempts failed, by entering the recipient's visual field or getting closer to her during 'Forward' and 'Backward' conditions, and switching their communicative channel from visual to tactile. Walking back to the experimenter and touching her is a behaviour known from earlier reports about horses in a human-given cue experiment (Proops and McComb 2010) and dogs during tests for referential communication (Savalli et al. 2014). Whereas we did not find significant differences between the number of horses that approached the experimenter in the two conditions, we found that most of the horses elaborated their communication during the additional time given when we compared the 'Forward' and the 'Backward_prolonged' condition (characterized by longer trials). It is not clear whether this difference arose because horses understood the different attentional state of the recipient or simply because trials were longer. Horses understand the asymmetry of the human's front and back side and often prefer facing a human when monitoring him (Sankey et al. 2011), so it is possible that they walked back to the experimenter more in the Backward_prolonged condition for this reason.

One hypothesis for the origin of referential gestures in non-human primates is that they arise from a ritualization of actions during interactions at the individual level (Tomasello et al. 1993, Tomasello 2006). Similarly, horses may individually learn that a gaze directed to a conspecific is reinforced with obtaining its attention and that a sequence of gazes to a conspecific followed by gazes to the target points the conspecific's attention to the target itself. We therefore consider intentional gaze alternation in horses to be a behaviour learned within their social environment rather than an innate behaviour. In species with protruded faces, such as horses, head orientation has always been considered a cue salient enough to indicate an interest towards a specific direction or item, without calling eye gaze into action (Emery 2000). This consideration may have led to an underestimation of horse's communicative skills, supported by the difficulty to detect gaze alternation when performed between conspecifics: horse's lateral vision covers about a 340° field view (Murphy et al. 2009), and a slight turn of the head may be sufficient to catch the attention of, for example, a conspecific in the rear.

So why in our experiment did horses use large-scale head movement to communicate with the human experimenter? Xitco et al. (2004) noted that dolphins, which also have lateral eyes, produced large-scale head movements in the direction of the experimenter that were not needed by these animals for their own perceptual benefit, because they could establish eye contact with an experimenter in the rear even with a slight turn of their head. In domestic settings, horses are completely dependent on humans and even accept the help of humans to complete a task (Lesimple et al. 2012). During its individual experience with humans, a horse may learn that we respond to eye contact when associated with head orientation and may adapt its communicative signals accordingly. In other words, the horse may learn that when it does not turn its head to the human recipient, its communicative efforts are not reinforced by obtaining the attention of the human. If so, the fact that horses turned their head back when alternating gaze with the human is another piece of evidence supporting the communicative meaning of this behaviour. If interspecific gaze alternation is instead a product domestication, it is an open question worthy of being investigated. In fact, a comparison between prehistoric and modern horse genome recently revealed that domestication affected some genes related to cognitive functions, such as social cognition (Schubert et al. 2014). In dogs, for example, it seems that domestication played an important role in the shaping of socio-cognitive abilities and the establishment of a special sensitivity towards human's communicative behaviour such as 'pointing' or 'showing' (for a recent review, see Kaminski and Marshall-Pescini 2014).

Conclusion

Several studies provide evidence for the existence of advanced cognitive abilities in horses, such as categorization (Hanggi 1999), cross-modal individual recognition (Proops et al. 2009), social learning (Krueger 2007; Krueger et al. 2014) and numerical discrimination (Petrazzini 2014). Our results add to this body of evidence by suggesting that horses act like active informers and are able to recognize recipients as communicative agents. In our experiment, they tended to influence the behaviour of a human experimenter using their eyes, providing evidence they understand that intentions can be communicated between individuals using gaze. They also activated mechanisms promoting shared attention depending on that individual's attentional state. We therefore suggest adding horses to the species capable of flexible and intentional use of communicative signals, along with several primate species, dogs, corvids, dolphins and reef fish. It remains an open question whether intentional communication and referential signalling require advanced cognitive processes like perspective taking and strategic thinking (Pika and Mitani 2006; Vail et al. 2013). After dogs, horses would be the second domesticated species for which this ability to communicate with humans has been shown.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. All applicable international, national and/or institutional guidelines for the care and use of animals were followed.

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