Anim Cogn (2008) 11:457–466
DOI 10.1007/s10071-008-0136-5

ORIGINAL PAPER

Comprehension of human pointing gestures in horses (*Equus caballus*)

Katalin Maros · Márta Gácsi · Ádám Miklósi

Received: 6 February 2007 / Revised: 4 January 2008 / Accepted: 17 January 2008 / Published online: 5 February 2008

Abstract Twenty domestic horses (*Equus caballus*) were tested for their ability to rely on different human gesticular cues in a two-way object choice task. An experimenter hid food under one of two bowls and after baiting, indicated the location of the food to the subjects by using one of four different cues. Horses could locate the hidden reward on the basis of the distal dynamic-sustained, proximal momentary and proximal dynamic-sustained pointing gestures but failed to perform above chance level when the experimenter performed a distal momentary pointing gesture. The results revealed that horses could rely spontaneously on those cues that could have a stimulus or local enhancement effect, but the possible comprehension of the distal momentary pointing remained unclear. The results are discussed with reference to the involvement of various factors such as predisposition to read human visual cues, the effect of domestication and extensive social experience and the nature of the gesture used by the experimenter in comparative investigations.

Keywords Human–animal communication · Pointing · Horse

K. Maros (✉)
Department of Organic Agriculture and Animal Welfare, Szent István University, Páter Károly u. 1, 2103 Gödöllő, Hungary
e-mail: maros.katalin@kti.szie.hu

M. Gácsi · Á. Miklósi
Department of Ethology, Eötvös Loránd University, 1117 Budapest, Hungary

Introduction

The comprehension of the human pointing gesture as a communicative cue indicating the location of hidden targets has received increased attention recently (for a review see Miklósi and Soproni 2006). The domestic cat (Miklósi et al. 2005), the domestic goat (Kaminski et al. 2005), the domestic horse (McKinley and Sambrook 2000), and different "wild" animals [e.g. chimpanzees (Itakura and Tanaka 1998), orangutans (Call and Tomasello 1994), monkeys (Vick and Anderson 2000; Neiworth et al. 2002), dolphins (Herman et al. 1999), seals (Pack and Herman 2004), wolves (Virányi et al. 2008), foxes (Hare et al. 2005)] have also been tested in some versions of the two-way object choice procedure (Anderson et al. 1995, and see below).

Extensive experimentation found that domestic dogs were very skillful with various forms of the pointing gesture (including distal momentary pointing, pointing with contra lateral hand, pointing to the contra lateral side etc, see also Soproni et al. 2002), which led some authors to suggest that this might reflect a special evolutionary history of this species (Hare et al. 2002; McKinley and Sambrook 2000; Miklósi et al. 1998, 2003, 2005; Soproni et al. 2001). Alternatively, the relatively good performance of other domesticated species like cats and goats led others to argue that domestication in general could have promoted the ability to rely on human visual gestures. Although the comparable level of performance in cats and dogs could be explained by similar amount of social experience with people (Miklósi et al. 2005), in goats, the performance could not be the result of the extensive experience of the individuals, because the experimental subjects were living in a zoo with relatively little human contact. The goats could rely on touching and distal dynamic-sustained pointing with gazing gestures during their choices. Moreover, young goats were as skillful in using the pointing cue as the adults (Kaminski et al. 2005). Putting aside the problem of comparative arguments that are based on methodologically divergent experimental studies (see discussion), here we aim to investigate the spontaneous ability for the utilization of human gestural signaling in horses which live in the human social environment.

The primary use of the domestic horse was/is carrying people and their belongings (Clutton-Brock 1999). Although there are claims for horse domestication as early as 4,500 BC, the earliest undisputed evidence is chariot burials dating to 2,000 BC (Jansen et al. 2002). According to Clutton-Brock (1999) "The horse was the last of the five most common livestock animals to be domesticated, and as a species it has been the least affected by human manipulation and artificial selection". The selection against fear and against aggression toward humans could be an important aspect of horse domestication (Jansen et al. 2002).

Horses most often communicate by using visual signals. As social prey animals, they organize themselves as a group but without attracting predators (McGreevy 2004). Subtle changes of the position of their ears, the orientation and widening of the eyes, the dilation of the nostrils, and the tension of the mouth are utilized as parts of communicative signals (see Waring 1983). Thus, both the history of being domesticated and the predisposition for utilizing visual cues of behavior can provide an advantage for horses in relying on human visual communicative gestures. They respond to the handler's body language and voice (McGreevy 2004), and can perceive and utilize subtle visual cues. The classic example, Clever Hans, showed that horses are able to rely on minute bodily signals emitted by humans (Pfungst 1911).

Visual stimuli are utilized widely in equine learning research and also in human interaction with horses (see Nicol 2002 for a review). Whether horses can rely on different human gestures was examined in one pilot study that tested four horses (McKinley and Sambrook 2000). In the experiment, two of the horses were able to find the hidden food when the experimenter touched the correct bucket, and only one of them was able to use the human pointing gesture as a cue to locate the food when the experimenter pointed towards the correct location. In general, horses performed less well in comparison to dogs that were studied for comparison. The discrepancy found was explained by differential social experiences of the horses in comparison to dogs and by the different selective pressures during domestication of these species.

The goal of the present study is to extend the number of domesticated species tested by investigating the ability of horses to rely on different human pointing gestures. Because in the frame of a single experiment it was not possible to subject the horses to the various pointing gestures that have been used in the literature for this first study, we decided to select the a few gestures on the basis of some critical features, and the experiment was divided into three subsequent phases. In the first phase, we wanted to see whether socialized horses are able to utilize the distal momentary pointing gesture (the signal is not present during the choice) for which there was positive evidence in the case of socialized cats (Miklósi et al. 2005) and dogs (Soproni et al. 2001). In the second phase, we tested the ability of the horses to utilize the dynamic-sustained distal pointing signals in case of which the cue is visible during the choice. This pointing signal has been applied in a range of comparative studies (see Miklósi and Soproni 2006). To control for the effect of the distance between the pointing hand and the target, we utilized a proximate momentary pointing gesture sharing all other features of the momentary distal pointing applied in the first phase. The third pointing cue that was utilized in this phase was accompanied by gaze turning to the appropriate direction. So far, most species tested were able to utilize this later gesture which was included here for reasons of comparability of performance. Finally, in the third phase we wanted to know whether the exposure to a series of various pointing gestures improved the capacity of the horses to rely on the distal momentary pointing cue, and finally a control series was run without any cuing. In general, we have predicted that the performance of the horses would be similar to that of goats or maybe better due to their more individual experiences with humans.

Methods

Participants

The subjects were horses ($N = 14$, seven geldings, six mares, and one stallion; age 10 ± 4.38 years) and ponies—horses that are 147 cm or less as measured at the withers—($N = 13$, three mares and ten stallions; age 10 ± 4.48 years) of different breeds. The horses were kept at two different riding schools and were ridden on a regular basis. The ponies lived in the Budapest Zoo and were ridden regularly by children. Both horses and ponies had daily contact (being fed, groomed, and led between their stall and the outdoor area) with their human caretakers. The subjects were neither ridden, fed by concentrated feed for at least 3 h prior to the tests, nor given apples on the test day prior to the test trials. The horses were handled exclusively by their owners, riders or trainers (a person who regularly handles the horse: "handler") during the whole procedure. The pretraining sessions were run by a familiar experimenter in the case of six horses and by an unfamiliar experimenter in the case of the others. The experimenters were women.

Later in the tests, the pointing person was an unfamiliar experimenter.

Procedure

The location of the pretraining and test sessions was always a closed and relatively small paddock (approx. 15 × 15 m) with minimal distractions, near to the actual subject's stable. It was familiar to the horse, and we ensured that the subjects had not experienced any harm or stress at this location previously. The horse was allowed to run around and explore the experimental location for a few (2–3) minutes before the sessions. If there were other horses in nearby paddocks or in the stable, the subjects were positioned for the testing in a way that any other uncontrolled events could only occur behind them.

Pretraining (see Fig. 1)

The role of the pretraining was to assess motivation and the possible stress of the test situation, and to familiarize subjects with the test situation without influencing their later performance. There were at least 2 days but not more than a week between the two pretraining sessions. The order of the two pretraining sessions was randomized.

Session A: invisible bait

In this pretraining session, the horse was shown that the bait is/can be in the bucket and became used to the presence of the experimenter near the bucket. One white plastic bucket (30–40 cm in diameter, 40 cm height) was placed 3–4 m from the horse that was held by the handler on a lead rope. The experimenter first offered and delivered a quarter of an apple to the horse from her hand at the starting point (SP). Then she showed the next piece of apple to the horse and—while trying to maintain its attention (talking to it, waving the apple)—walked to the bucket, visibly dropped the apple into it, and stood motionless behind the bucket. Then the handler released the lead rope and the horse was allowed to visit the bucket and eat the apple. The handler could reassure the horse by verbal praising or patting its neck to walk by itself to the bucket.

There were at least four trials, but if the horse failed to eat the apple pieces from the bucket, another six trials were executed.

Session B: visible bait

This pretraining was designed to give the horse a chance to learn that the bait (apple piece) can be at either of two places. The subject had to learn to make a choice independent of the order of manipulation. Two uniform white plastic buckets (see above) were placed upside down, approximately 2 m from each other and at 3–4 m from the SP. The horse was held by the handler on a lead rope (he or she was always standing on the same side of the horse during the session.).

Before the session, the experimenter petted the test subject shortly and then offered and delivered a piece of apple to it from her hand at the SP. She showed the next piece to the horse and whilst trying to maintain its attention, walked to the buckets (first always to the one at the right and then to the other at the left side) put her hand for 1 s on each bucket, and placed the apple on the top of either of them that was visible to the horse (left and right sides are defined relative to the position of the experimenter during the test trials.). Finally, she went back to the SP and stood motionless on the opposite side of the horse from the handler.

Then the horse was allowed to go by itself and make a choice. It was allowed to eat the apple only if it went to the correct bucket first. The handler could reassure the horse by verbal praising or patting its neck. At least six such training trials were run alternating the left and right sides of apple presentation. If the horse did not make at least four correct choices and eat the apple at least two times on both sides, it received another six trials. If it could not fulfill the criteria in these second six trials (due to lack of motivation, fear of the buckets or the experimenter), it was excluded from further testing. Four horses and three ponies were excluded, so we performed the test trials on 20 subjects, ten horses (six geldings, four mares) and ten ponies (nine stallions, one mare).

Test trials: human gestural pointing (see Fig. 2)

The first test was run within 2 weeks of the second pretraining session. We cut the apples into quarters and the same two buckets were used for hiding the pieces. The buckets were placed 2–2.5 m apart (depending on the gesture type) and the experimenter stood 50 cm back from the middle line between the buckets. The experimenter wore a yellow raincoat [microscopic studies of the equine retina showed that there are two peaks in the spectral sensitivity of equine

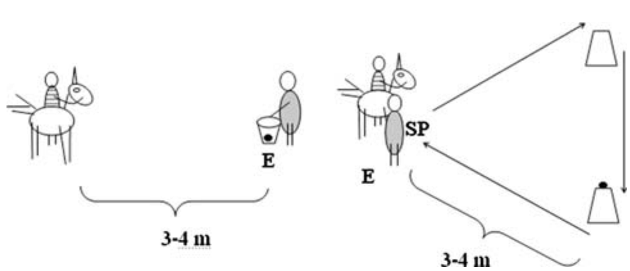

Fig. 1 Schematic drawing of the pretraining—session A (*left*) and B (*SP* starting point, *E* experimenter)

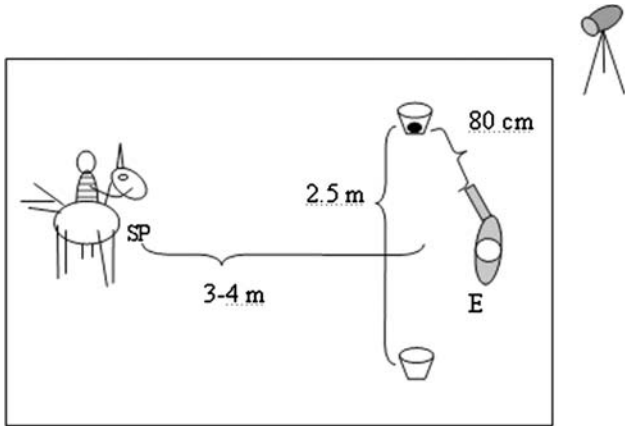

Fig. 2 Schematic drawing of the test situation (*SP* starting point, *E* experimenter)

cones at 428 nm and 539 nm. This means that horses probably are able to distinguish pastel blue and yellow from grey (Carroll et al. 2001)]. The subject with the handler faced the experimenter at a distance of 3–4 m.

There were two "warm up" trials both involving hiding locations when the experimenter showed a piece of apple to the subject and then dropped it into one of the buckets with slow movements, so that the animal could see the baiting. Then the subject was allowed to go to the bucket and encouraged to eat the food. This procedure was repeated prior to the mixed pointing test as well.

Two test sessions, including 20 and 18 trials, were done with each subject. There were at least 2 weeks (but not more than four) between the two sessions. A third session was carried out with half of the subjects partly as a control without using pointing gestures as cues (ten trials) and partly to test their comprehension to DM pointing repeatedly (ten trials). During the tests, the handler held the horse on a leading-rein and stood on the left side of the subject during the whole test. When the signaling experimenter obtained the final body position at the end of the signaling, the handler dropped the rein and verbally encouraged the horse ("You can go."). When the horse left the handler, she/he remained in her/his initial position and only went to catch the horse after it made a choice.

In all test trials a third person, who was standing outside the paddock and was handling the camera, verbally instructed the experimenter about the actual gesture types and actual side of the baiting. The baiting took place in full view of the facing horse. The experimenter held the two buckets in one hand, put her other hand into both buckets one after the other placing a piece of apple into either of them and she then exchanged the buckets in her hands two times. Next, she put them to the ground, placing always the right one first, and then stepped back to the middle position between the two buckets. Whether the horse was orienting at her or not she attracted the attention of the horse prior to signaling and took up the predetermined posture. Subjects were restrained gently by the handler until the end of the cueing (see below). The handlers were instructed in advance when to let the horse go, so the experimenter did not say anything during or after the cuing. If the horse did not orient to the experimenter, she called it by its name or gave some noise to get its attention. The experimenter enacted the cueing gesture (see below) only when the horse oriented at her. If the horse changed his line of view during the presentation, approached the experimenter or wandered off to anywhere but not in the direction of the buckets or did not leave the starting point within 3 s, the cueing was repeated. By choosing the baited bucket the horse could eat the food and was also praised verbally and stroked manually. If it visited the empty bucket first, it was not allowed to go to the other bucket and failed to get the food. The handler led the horse back to the starting point and the next trial started.

Test 1: Distal momentary pointing (DM) (20 trials) In these test trials, the experimenter enacted a short (1 s long), definite pointing with an extended index finger toward the baited bucket. During the cuing she was looking at the horse. The distance between the pointing finger and the bucket was more than 80 cm. After cuing she placed her hands back in front of her chest and then the subject was released and allowed to make a choice. As some horses seemed to get tired during the test a short break (not more than 2 min) was inserted after the tenth trial if the subject was shaking its head or tried to leave the handler during the last baiting of the first ten trials.

In half of the trials the baited bucket was placed on the right side, and in the other half it was on the left. The order of baiting was defined randomly with the restriction that both sides could be the correct choice not more than twice in a row (and only twice) but this must not happen at the very beginning of the testing.

Test 2: Mixed pointing (6 + 6 + 6 trials) The order of baiting and gesture types was defined randomly with the restrictions that neither the same side nor the same gesture could occur more than twice in succession, and this must not take place at the very beginning of the trial. The order balance of the sides was also applied for the gesture types (3–3 to the left and right).

Distal dynamic-sustained pointing (DDS)

The experimenter enacted a definite pointing toward the baited bucket and her arm was held in the pointing position during the trial. The distance between the pointing finger and the bucket was more than 80 cm (the same gesture as the DM pointing with the only exception that in this case the experimenter held her arm in the pointing position until the subject made his choice.). During the cuing she was looking at the horse. The subject was released and allowed to make a choice as soon as the experimenter "froze" in the pointing position.

Proximal momentary pointing (PM)

The same short cue and procedure was applied as in the case of the distal momentary pointing trials, but the experimenter was sitting on her heels and the buckets were placed about 2 m apart so that the baited bucket was about 10 cm from the tip of the pointing finger. During the cueing she was looking at the horse. After cueing she placed her hands back in front of her chest and then the subject was released and allowed to make a choice.

Proximal dynamic-sustained pointing with gazing (PDS-G)

The buckets were placed about 2 m apart, the experimenter was sitting on her heels and the baited bucket was about 10 cm from the pointing finger. She held her arm in the pointing position and she also gazed towards the baited bucket until the subject made its choice. The subject was released and allowed to make a choice as soon as the experimenter froze in the above position.

Test 3: DM2 and control (10 + 10 trials) This test was run a few weeks after the mixed pointing test on five ponies and five horses chosen from the two samples. First, we performed ten additional DM trials, and then after a few minutes break, ten control trials. The function of these DM trials was to control for possible learning effects during the mixed pointing session (Test 2). The control trials were necessary to show whether unintended visual or olfactory cues affected the performance. In half of the control trials, the baited bucket was placed on the right side, in the other half it was on the left. Using the same procedure otherwise, the experimenter attracted the attention of the horse and then stood still for 2 s looking at the horse. Then the subject was released and allowed to make a choice.

Data analysis

We calculated the percentage of correct choices from the similar trials for each individual. As all data did not differ significantly from a normal distribution (Kolgomorov–Smirnov test), we used one sample *t* test (two tailed) to compare the groups' performance against chance performance (50%). The success in the different gesture types was compared by repeated measures ANOVA. The individual performances were also analyzed with binomial test. A subject was presumed to use the pointing gesture over chance if it had 15 or more correct choices in case of the DM signal (binomial distribution: five errors out of twenty; $P = 0.041$). As all other gesture types were run 6×, so only subjects with six correct choices were reported as using the given signal correctly ($P = 0.031$).

Results

The performances of the horses and the ponies were statistically indistinguishable in all test types (DM: $t_{18} = 0.636$, $P = 0.533$; DDS: $t_{18} = 0$, $P = 1$; PM: $t_{18} = -0.824$, $P = 0.421$; PDS-G: $t_{18} = -1.819$; $P = 0.086$). Considering, however, that the two groups were not balanced for gender (almost all of the ponies but none of the horses were stallions), the possible significance of these variables could not be determined. In this sample, only one subject showed a typical side bias by making 19 left side choices out of 20 in Test 1 and 16 out of 18 in Test 2.

The performance of the subjects did not differ from the random choice level (50%) in Test 1 for the DM pointing signal (20 trials: $t_{19} = 1.16$, $P = 0.26$). However, they were more successful in the comprehension of the other three pointing gestures in Test 2 and chose the correct bucket above chance level in DDS ($t_{19} = 2.33$, $P = 0.03$), PM ($t_{19} = 4.16$, $P = 0.001$), and PDS-G ($t_{19} = 4.53$, $P < 0.001$) trials as well (Fig. 3). The difference in the results of the three pointing types in the mixed trials was not significant ($F_{2,19} = 1.97$, $P = 0.15$). The binomial analysis of the subjects' individual performance confirmed the group results, as none of the horses had 15 or more correct choices in the 20 DM trials; however, there were individuals with maximum number of correct choice (6/6) in case of DDS trials ($N = 2$), PM trials ($N = 3$), and PDS-G trials ($N = 6$). For individual performance data see Table 1.

We compared the percent of correct choices in the first and second halves (10–10 trials) of the DM test to look for changes over time in the performance of the horses. We did

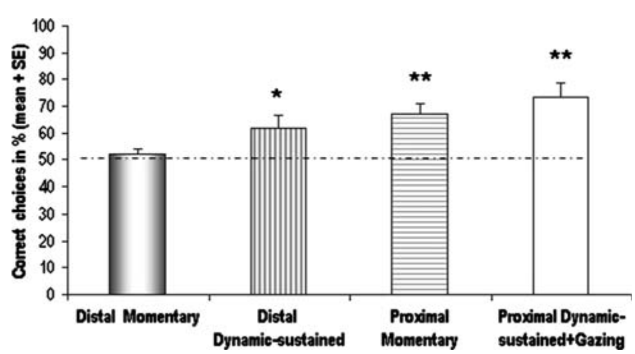

Fig. 3 The 20 horses' performance in Test 1 (DM) and in Test 2 (mixed pointing: DDS, PM, PDS-G) compared to chance level (50%) in the two-way choice test. * $P < 0.05$, ** $P < 0.01$

Table 1 Number of correct choices for each individual across the tests

TRIAL	Test 1				Test 2								Test 3			
Name	DM		DM first ten trials	DM second ten trials	DDS		PM		PDS-G		Mixed first nine trials	Mixed second nine trials	DM2		Control	
	Trial N	Hit	Hit	Hit	Trial N	Hit	Trial N	Hit	Trial N	Hit	Hit	Hit	Trial N	Hit	Trial N	Hit
Dogán	20	12	5	7	6	3	6	4	6	3	4	6	10	5	10	4
Tomaj	20	11	6	5	6	2	6	4	6	2	5	3				
Lord	20	12	6	6	6	3	6	3	6	4	7	3				
Iza	20	9	5	4	6	5	6	3	6	*6	6	8	10	5	10	3
Komám	20	11	5	6	6	3	6	*6	6	5	8	6	10	4	10	6
Cinóber	20	9	6	3	6	4	6	4	6	4	7	5	10	5	10	3
Matador	20	11	6	5	6	*6	6	5	6	3	7	7	10	6	10	5
Picur	20	9	4	5	6	4	6	3	6	1	4	4				
Dior	20	13	6	7	6	3	6	3	6	5	6	5				
Rozi	20	10	6	4	6	4	5	3	6	*6	6	7				
Charlie (P)	20	8	5	3	6	1	6	4	6	5	4	6	10	7	10	5
Bonifác (P)	20	10	6	4	6	4	6	4	6	*6	8	6	10	6	10	5
Murphy (P)	20	11	5	6	6	*6	6	4	6	*6	8	8	10	8	10	6
Tomi (P)	20	6	4	2	6	2	6	3	6	5	6	4				
Rocco (P)	20	9	4	5	6	5	6	*6	6	4	6	9				
Fifty (P)	20	11	6	5	6	3	6	5	6	*6	7	7	10	6	10	4
Rotschild (P)	20	11	6	5	6	5	6	4	6	*6	8	7				
Tündi (P)	20	13	8	5	6	5	6	*6	6	4	7	9				
Kevin (P)	20	11	6	5	6	3	6	3	6	4	4	6				
Kópé (P)	20	12	8	4	6	3	6	3	6	4	4	6	10	6	10	5
Mean (%)		52.3	56.5	48		61.7		67.2		74.2	67.8	67.8		58		46

* Data points that are significantly above chance (two-tailed binomial test)

P pony, *DM*, *DM2* distal momentary pointing, *DDS* distal dynamic-sustained pointing, *PM* proximal momentary pointing, *PDS-G* proximal dynamic-sustained pointing with gazing

not find any sign of learning during the session; on the contrary, the performance of the horses was significantly worse in the second part of the test ($t_{19} = 2.33$, $P = 0.031$) (Fig. 4). Interestingly, there was no similar difference in Test 2 between the results of the first and the second halves (9–9 trials) of the mixed pointing session ($t_{19} = 0.00$, $P = 1.00$).

Interestingly enough, however, if we analyze only the results of the first ten trials of Test 1, on the group level the horses show a relatively good performance with the DM pointing signal. They chose the baited bucket significantly above chance level, both in the case of the 20 subjects ($t_{19} = 2.45$, $P = 0.024$) included in Test 1 and those ten horses that were retested ($t_9 = 2.33$, $P = 0.045$). However, at the individual level, none of the subjects performed above chance level.

Further, we used the data of the ten subjects that participated in Test 3 to control for the stability of the performance and for possible learning effects that could have manifested in better performance in the mixed pointing session. We compared the retested subjects' performance in their first ten DM trials in Test 1 to their results in Test 3 (DM2; involving only ten trials) and found no difference ($t_9 = 0.22$, $P = 0.83$) (Fig. 5). The retested ten horses showed a better performance with the DM pointing cue in Test 3 in comparison to the control trials ($t_9 = 3.09$, $P = 0.013$), and their performance was almost significant if compared to chance level ($t_9 = 2.23$, $P = 0.053$). None of the horses had nine or ten correct choices, which corresponds to significantly better performance than chance at the individual level.

The rate of successful choices in the control trials did not differ from chance level ($t_9 = -1.18$, $P = 0.27$), so without voluntary human cuing the horses chose randomly.

Discussion

In the present experiment we tested whether socialized horses have the ability to rely on different human pointing gesture types. The results show that our subjects were able

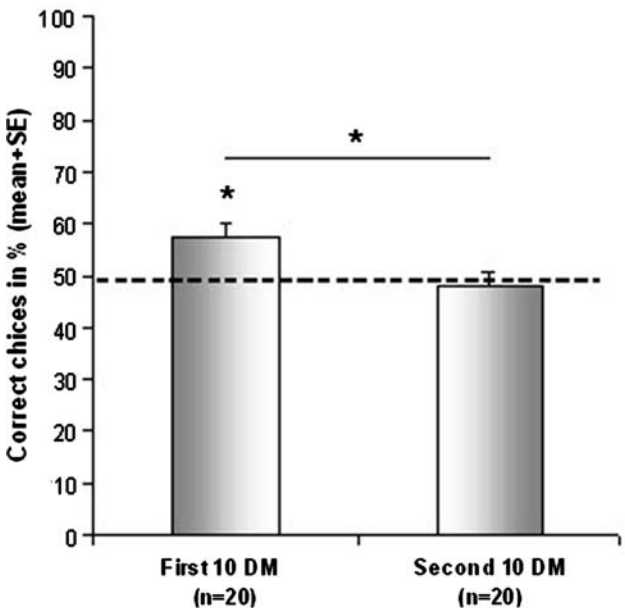

Fig. 4 The 20 horses' performance in the first and second halves of the DM trials in Test 1. The mean performance in the first ten trials was significantly better than chance level (50%: signed by the *dotted line*). There is significant difference between the results in the first and second halves. * $P < 0.05$

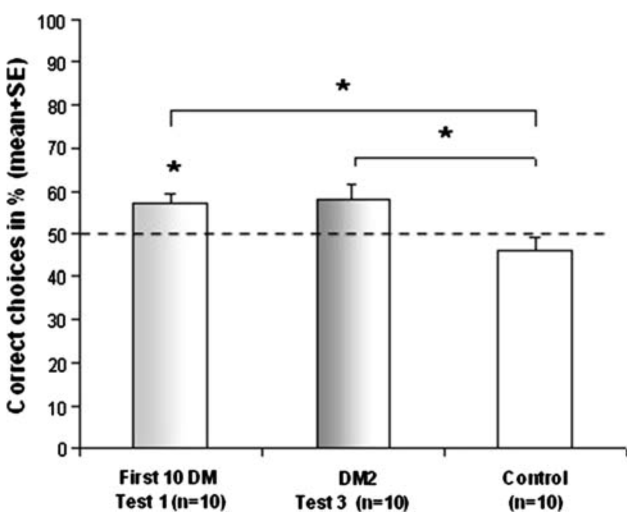

Fig. 5 The result of the retested ten horses in Test 1 (only first ten trials) and Test 3. Their performance in DM2 was statistically indistinguishable from DM, which was different from chance level. Their results, both in DM and DM2, are better compared to the control trials. * $P < 0.05$

to utilize three types of pointing (distal dynamic-sustained, proximal momentary, and proximal dynamic-sustained with gazing) gestures to locate the hidden food in a two-choice situation test. The only cue that they failed to use when calculated for the group for the whole test session was the distal momentary pointing, and none of the horses could solve this task at the individual level. Interestingly, however, the group mean was significantly above the chance performance when we calculated it only from the first half (ten trials) of the session and very similar results were obtained at the repetition of this test some weeks later (ten trials) with ten individuals.

Unfortunately, recent comparative work on animal utilization of human gestural signals is not exempt from methodological contradictions because researchers vary the applied cues without realizing or emphasizing that this could affect the performance of the subjects and there is very little rationale behind using one or other type of gestural cues. Thus, in this study we tried to apply those types of pointing gestures that have been used previously in the literature (for reasons of comparison). In this sense the present study presents a step forward in characterizing this ability in horses (in relation to McKinley and Sambrook 2000) but cannot be regarded as a systematic investigation.

The utilization of gestural signals presupposes some cognitive skills on the part of the receiver beyond the ability to generalize from everyday communicative interaction with humans to a more controlled experimental situation. In this regard, our subjects proved to be generally skillful but nevertheless certain features of the pointing signal might have either promoted or worsened their success. Comparative research has identified that local stimulus enhancement, gaze following response and memory could play a role in the cognitive processing of the gestural cue (Miklósi and Soproni 2006). All these factors could have affected the performance of the horses because in this study there was also a tendency that the performance declined in the case of cognitively more demanding gesture types.

There is comparative evidence in apes (Itakura and Tanaka 1998), goats (Kaminski et al. 2005), dogs and cats (Miklósi et al. 2005) that pointing signals increase their effectiveness if the pointing finger is closer to the target (proximal pointing). This effect can be increased further if the signal is present until the subject makes a choice. To some extent the better performance of the horses with distal dynamic-sustained pointing and proximal dynamic-sustained pointing signals support these observations. This effect of proximity can be viewed as a form of local or stimulus enhancement (Kaminski et al. 2005), which enhances the salience of the signal. Unfortunately, the present combination of the signals in Test 2 excludes the unambiguous separation of effects of continuity and distance.

Interestingly, the continuous presentation of the signal could also lead to alternative solutions of the task which lack a communicative component. McKinley and Sambrook (2000) mentioned that, during the pointing trial the successful horse "…tended to move his nose down the length of the experimenter's arm, past her hand and then onto the correct bucket". We had the very similar experience with some horses during their correct choices. Other horses went directly to the experimenter's pointing finger, sometimes smelled and licked it and only after this they turned their head toward the bucket.

In many experiments the pointing gesture was accompanied with gazing turning toward the target. Without exception, this behavioral feature improved the performance in apes (Povinelli et al. 1997), but very often such gazing alone was also very effective in seals (Pack and Herman 2004), dolphins (Scheuman and Call 2004), dogs (Hare et al. 2002), and to a lesser degree in goats (Kaminski et al. 2005). The problem of this type of gesturing is that it confounds the effects of gaze following response and the utilization of the pointing gesture because both gestures have the potential to evoke gaze following (see also Povinelli et al. 1997). In this case, we are not able to determine whether the subject was attracted to the correct location because of the head turn (which is often applied repeatedly by the experimenters) or the extended pointing hand. This synergic effect of the two parallel gestures has also been found in horses, as there was a tendency, similarly to goats, chimpanzees and dogs, that subjects achieve the highest performance in these trials.

A further complicating factor is the duration of the gesturing. Actually, some researchers argue (Hauser 1996) that behavior cues and behavioral signals should be differentiated on the basis of whether they are present at the time when subject (the receiver) modifies its behavior. In any case, signals of short duration demand a better memory on the part of the receiver. This idea receives support in the case of the pointing gestures where there is evidence that performance is higher with sustained pointing gestures in comparison to momentary gestures (Miklósi et al. 2005). Horses seem to be no exceptions because their performance was generally lower with the momentary pointing gestures both in Test 1 and Test 3 in comparison to the dynamic-sustained pointing gestures in Test 2. Actually, there is some evidence that horses experience problems in remembering a visual cue associated with feeding location if the delay is 10 s (McLean 2004). However, in our test the time lag between the cue and the release of the animal was much shorter (<1 s) in both DM and PM pointing trials. As PM pointing was a solvable task for horses, we can probably rule out the possibility of memory decay as an explanation of the failure with DM cueing.

Former studies with a comparative aim have often assumed that animal species share similar perceptual abilities, which is clearly not the case. Thus, differences in performance can also be attributed to species-specific differences in perception. Stimulus position has been found to affect the ability of the horse to perform tasks involving visual discrimination. In a study by Hall et al. (2003), horses were trained to perform a two-choice, black/white discrimination with stimuli presented at one of two heights about 6.5 m away from the subjects. Performance was better when stimuli were presented at ground level instead of at a height of 70 cm from the ground. The authors concluded that equine visual learning could be enhanced by ground level presentations and the associated lowering of the head. In our case, the horses' performance seemed to be more convincing when the gestural cues were presented closer to the ground (in PM and PDS-G). This might be attributed mainly to the local enhancement of these cues (see above) but perceptional factors (more accurate vision of objects/stimuli presented on the ground level) cannot be excluded. Note that we also cannot exclude that the better performance in Test 2 can be attributed to the somewhat smaller distance between the buckets in the proximal trials.

Importantly, the change of performance with time points to the importance of further experimental variables. In the present study, the horses showed a decreasing performance for the second half of the DM trials in Test 1. In addition, the higher performance during the first part of the DM trials in Test 1 was also found in Test 3 and similar phenomenon was also reported in goats in case of distal dynamic-sustained pointing with gazing (Kaminski et al. 2005). For our case, there seem to be at least three types of explanations. First, decreased performance indicates mental exhaustion in the subjects. As argued above, DM gestures are cognitively the most demanding that might cause a declining performance. In support of this explanation, we did not find such a change over time with those gestures that resulted in a higher overall performance. Second, decreased motivation could have also contributed to the observed effect. Generally, subjects were less successful with the DM gestures that resulted in smaller amount of the preferred reward (apple). Again, this was a less significant factor in the mixed trials when horses could obtain reward regularly, which sustained their interest and attention necessary for the task. On some occasions, horses attempted to attack the experimenter when failing, which is also an indication for frustration. Third, we cannot exclude the possibility that the greater variability of the stimuli (types of gestures) presented in Test 2 had a stimulating effect on attention of the horses.

Studies investigating the utilization of interspecific signals have usually implicitly assumed that socialization influences the observed performance. Unfortunately, this factor has rarely been controlled for systematically. Although researchers have tested zoo animals [with restricted socialization to humans, e.g. goats (Kaminski et al. 2005)], laboratory raised (chimpanzees: Povinelli et al. 1997) or highly enculturated subjects (chimpanzees: Itakura and Tanaka 1998), and pets living in human families (dog and cats: Miklósi et al. 2005); unfortunately, there is little direct comparative evidence (using the same methodology) that would show the effect of socialization to humans. There are two exceptions. Hare et al. (2002)

argued that dog puppies with little human exposure show comparable performance than puppies living in families; however, they used the proximal dynamic-sustained pointing gesture accompanied by gaze turning in which case simple local/social enhancement cannot be excluded. Socialization had possibly an enhancing effect on wolves' performance in this task because hand reared wolves that socialized extensively with humans were more skillful even in the case of distal and momentary type of gestures (Miklósi et al. 2003) than wolves with restricted social exposure to humans (Hare et al. 2002).

Though it is hardly questionable that socialization to humans contributes to the performance in such tasks but this is very difficult to control for and to investigate experimentally. In contrast, most studies (independently from species) found little evidence of learning when using such a relatively short set of trials (20–30) like in the present case. However, there is evidence that at least in the case of extensively socialized wolves, the exposure to 100 or more trials could lead to significant improvement in performance (Virányi et al. 2008). On this basis, we could assume that the performance of the horses could have been influenced by their former experience with gesturing humans, but throughout the study their performance was not affected by learning.

This study does not provide direct evidence whether in these tasks horses rely on their ability to recognize intraspecific visual signals and/or domestication has enhanced their ability to read human behavior. The sensitivity to minute intraspecific visual bodily movements in horses plays very likely an important role in attending and responding to human visual signals (Waring 1983; McGreevy 2004). Similarly, in the course of horse domestication, one cannot exclude that humans have selected for animals that were more attentive and responsive to both visual and acoustic human signaling.

Finally, although in this study we show that horses as a group are able to utilize some types of human pointing cues, one might ask whether we are entitled to talk about "comprehension" or "understanding" human communicative gestural signals. Until now this issue has not received much attention and statistics was often misused in this regard. Importantly, such notions take the perspective of the sender when he/she observes that the receiver responds to the signals at a relatively high rate. Thus, in studies aiming at investigating spontaneous signal use it does not seem to be enough to show that the signals are responded to at a statistically significant level by the group as a whole but also that this is reflected at the individual level. One should perhaps discriminate between utilization of a signal (group level effect) and reliability of signal utilization (individual level). It follows that "comprehension" or "understanding", which refers to spontaneous utilization, should be reserved for cases when group level of utilization is associated with a high proportion of individuals being reliable responders. In this regard, horses fulfill only the first condition for most gestures used here, with the possible exception of the PDS-G (proximal pointing with gazing) in case of which 30% of the subjects performed over the chance level but to make comparable statements, other species should be tested and evaluated in a similarly rigorous manner.

Acknowledgments We thank Rita Lénárd and Krisztina Kurucz, the caretakers (and partly the owners) of the ponies of the Budapest Zoo. We also thank Péter Tóth, Rita Nánási and Gyula Mészáros for their help and support in working with the other horses and the horse owners for their cooperation. In addition, we thank Celeste Pongracz for reviewing the English and the four anonym reviewers for their revision of the manuscript. We confirm that our research was done in adherence to the *Guidelines for the use of animals in research* and the *national laws of Hungary about the animal welfare and abusement.*

References

Anderson JR, Sallaberry P, Barbier H (1995) Use of experimenter-given cues during object-choice tasks by capuchin monkeys. Anim Behav 49:201–208

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

Carroll J, Murphy CJ, Neitz M, Ver Hoeve JN, Neitz J (2001). Photopigment basis for dichromatic color vision in the horse. J Vis 1:80–87

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

Hall CA, Cassaday HJ, Derrington AM (2003) The effect of stimulus height on visual discrimination in horses. J Anim Sci 81:1715–1720

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

Hare B, Plyusnina I, Ignacio N, Schepina O, Stepika A, Wrangham R, Trut L (2005) Social cognitive evolution in captive foxes is a correlated by-product of experimental domestication. Curr Biol 15:226–230

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

Herman LM, Abichandani SL, Elhajj AN, Herman EYK, Sanchez JL Pack AA (1999) Dolphins (*Tursiops truncatus*) comprehend the referential character of the human pointing gesture. J Comp Psychol 113:347–364

Itakura S, Tanaka M (1998) Use of experimenter given cues during object-choice task by chimpanzees (*Pan troglodytes*), an orangutan (*Pongo pygmaeus*), and human infants (*Homo sapiens*). J Comp Psychol 112:119–126

Jansen T, Forster P, Levine Marsha A, Oelke H, Hurles M, Renfrew C, Weber J, Olek K (2002) Mitochondrial DNA and the origins of the domestic horse. Proc Natl Acad Sci USA 99:10905–10910

Kaminski J, Riedel J, Call J, Tomasello M (2005) Domestic goats, *Capra hircus*, follow gaze direction and use social cues in an object choice task. Anim Behav 69:11–18

McGreevy P (2004) Equine behavior. A guide for veterinarians and equine scientists. Saunders, Philadelphia

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

McLean AN (2004) Short-term spatial memory in the domestic horse. Appl Anim Behav Sci 85:93–105

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

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

Miklósi Á, Kubinyi E, Topál J, Gácsi M, Virányi Z, Csányi V (2003) A simple reason for a big difference: wolves do not look back at humans but dogs do. Curr Biol 13:763–766

Miklósi Á, Pongrácz P, Lakatos G, Topál J, Csányi V (2005) A comparative study of the use of visual communicative signals in interactions between dogs (*Canis familiaris*) and humans and cats (*Felis catus*) and humans. J Comp Psychol 119(2):179–186

Neiworth JJ, Burman MA, Basile BM, Lickteig MT (2002) Use of experimenter-given cues in visual co-orienting and in an object-choice task by a new world monkey species, cotton top tamarins (*Sanguinus oedipus*). J Comp Psychol 116:3–11

Nicol CJ (2002) Equine learning: progress and suggestions for future research. Appl Anim Behav Sci 78:193–208

Pack AA, Herman LM (2004) Bottlenosed dolphins (*Tursiops truncatus*) comprehend the referent of both static and dynamic human gazing and pointing in an object-choice task. J Comp Psychol 118:160–171

Pfungst O (1911) Clever Hans, the horse of Mr. von Osten. Henry Holt, New York

Povinelli DJ, Reaux JE, Bierschwale DT, Allain AD Simon BB (1997) Exploitation of pointing as a referential gesture in young children, but not adolescent chimpanzees. Cogn Dev 12:423–461

Scheuman M, Call J (2004) The use of experimenter-given cues by South African fur seals (*Arctocephalus pusillus*). Anim Cogn 7:224–230

Soproni K, Miklósi Á, Topál J, Csányi V (2001) Comprehension of human communicative signs in pet dogs (*Canis familiaris*). J Comp Psychol 115:122–126

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

Vick S, Anderson JR (2000) Learning and limits of use of eye gaze by capuchin monkeys (*Cebus paella*) in an object-choice task. J Comp Psychol 114:200–207

Virányi Z, Gácsi M, Kubinyi E, Topál J, Belényi B, Ujfalussy D, Miklósi Á (2008) Comprehension of human pointing gestures in young human-reared wolves (*Canis lupus*) and dogs (*Canis familiaris*). Anim Cogn. doi:10.1007/s10071-007-0127-y

Waring GH (1983) Horse behavior. The behavioral traits and adaptations of domestic and wild horses, including ponies. Noyes Publications