Horses prefer to solicit a person who previously observed a food-hiding process to access this food: A possible indication of attentional state attribution

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Abstract

Inferring what others witnessed provides important benefits in social contexts, but evidence remains scarce in nonhuman animals. We investigated this ability in domestic horses by testing whether they could discriminate between two experimenters who differed in what they previously witnessed and decide whom to solicit when confronted with an unreachable food source based on that information. First, horses saw food being hidden in a closed bucket (impossible for them to open) in the presence of two experimenters who behaved identically but differed in their attention to the baiting process (the "witness" experimenter faced the bucket, the "non-witness" faced away). Horses were then let free with both experimenters, and their interest towards each (gaze and touch) was measured. They gazed at and touched the witness significantly more than the non-witness ($n = 15$, gaze: $p = 0.004$; touch: $p = 0.003$). These results might suggest that horses inferred the attentional state of the experimenters during the baiting process and used this information to adapt their later behavior. Although further study would be necessary to conclude, our study provides new insight into attentional state attribution in horses and might hint to the existence of precursors of a Theory of Mind in horses.

Keywords: Horse, *Equus caballus*, Social cognition, Attentional state, Theory of Mind, Horse-human relationship

Disclosure of potential conflicts of interest

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1. Introduction

Several nonhuman species exhibit outstanding sensitivity to the behavior of others (conspecifics or not; e.g., Call and Tomasello 2008; Drayton and Santos 2016; Meunier 2017; Keefner 2016; Kaminski et al. 2009; Maginnity and Grace 2014; Malavasi and Huber 2016). This sensitivity can provide important benefits: for instance, by inferring what others have witnessed an individual can maximize its access to food resources (e.g., by following a knowledgeable conspecific: Hirata and Matsuzawa 2001; by avoiding competition: Hare et al. 2001; Marticorena et al. 2011; or by preventing pilfering: Bugnyar and Heinrich 2005).

It is particularly interesting to study this sensitivity to the behavior of others in domestic animals because through the domestication process and their daily interactions, this behavior might also extend interspecifically to humans. For instance, horses (domesticated 6000 years ago; Levine 2005) have been shown to respond to human attention towards them (their

34 "attentional state") to choose from whom to beg for food or by accordingly adapting their
35 communication behavior (Krueger et al. 2011; Malavasi and Huber 2016; Maros et al. 2008;
36 Proops and McComb 2010). In another study, a bucket, unreachable by horses, was filled with
37 food either in the presence (witness condition) or absence (non-witness condition) of the
38 animal's caretaker (Ringhofer and Yamamoto 2016). When confronted with the caretaker in a
39 second phase, the horses solicited the caretaker more in the non-witness condition. This
40 difference in behavior in the two conditions might suggest that horses have adapted their
41 behavior to what humans have previously witnessed. However, that might also be explained by
42 the fact that, in the witness condition, horses had already solicited the caretaker (without
43 success) during the first phase, which might have led to a reduced interest in the second phase.
44 The question of whether horses can infer whether humans have or have not witnessed a scene
45 thus remains unanswered. In our study, we addressed this question by investigating whether
46 horses can use information about the attentional state of two experimenters (a witness and a
47 non-witness) during an initial baiting process to adapt their subsequent begging behavior. We
48 solved the potential confounding issue in the previous study by Ringhofer and Yamamoto
49 (2016): in the present study, both experimenters were simultaneously present during the baiting
50 process and acted identically. They differed only in their visual access to the baiting process
51 during the first phase as the witness faced the bucket while the non-witness faced away.
52 Moreover, we used a new set of individuals and doubled the sample size. Our hypothesis was
53 that if horses were able to adapt their behavior to what the experimenters observed, they would
54 show more interest (by increased gaze and touches) towards the witness than the non-witness in
55 the second phase.

56 **2. Methods**

57

58 2.1. Animals and apparatus

59

60 We tested 19 adult saddle horses (age: mean ± SE = 10 ± 4 years old; 7 geldings, 11 mares and
61 1 stallion) in a private stable in France. These were privately owned horses with various
62 lifestyles, ridden several times a week. They were housed in individual stalls and fed three
63 times a day with concentrates and hay. They were not food restricted for the experiment.
64 The horses were individually tested in a familiar indoor paddock covered with sand (Fig. 1).
65 All experiments involved the same two female experimenters (a witness and a non-witness)
66 who were unfamiliar to the horses at the beginning of the experiment and were placed at two

predetermined points on each side of a fixed bucket (1 m away). Two assistants also participated in the experiment to handle the horse and place the food inside the bucket.

2.2. Procedure

Experiments were performed once (one control and one test trial per horse) and consisted of the following three consecutive steps.

1. Familiarization with the apparatus: The horse had a free habituation period of five minutes in the paddock containing an open, empty bucket.

2. Control trial: Experiments always began with the control trial to check for the absence of a pre-existing arbitrary preference for a side of the bucket or an experimenter. The control trial consisted of two phases.

Phase 1: An assistant entered and held the horse at the center of the paddock, facing towards the empty bucket. The two experimenters then placed themselves on each side of the bucket with the witness facing the bucket and the non-witness facing away (Fig. 1). A second assistant entered the paddock, approached the horse with her hands behind her back and then stood behind the bucket until the end of phase 1. The witness and the non-witness displayed exactly the same gestures, looking straight ahead and slightly bowing so that the witness could pretend to pay attention to the actions of the second assistant. Which experimenter acted as witness and whether she was standing to the left or to the right of the bucket was counterbalanced among the horses.

Phase 2: The two experimenters turned to face the horse, and both stood still, looking at the ground and displaying a neutral posture and facial expression. The first assistant released the horse, and both assistants exited the paddock and stayed out of sight of the horse. The horse's behavior was then filmed for 120 s.

3. Test trial: The test trial was identical to the control trial except that, in phase 1, the second assistant approached the horse to show the food rewards and then put the food inside the bucket before closing the lid.

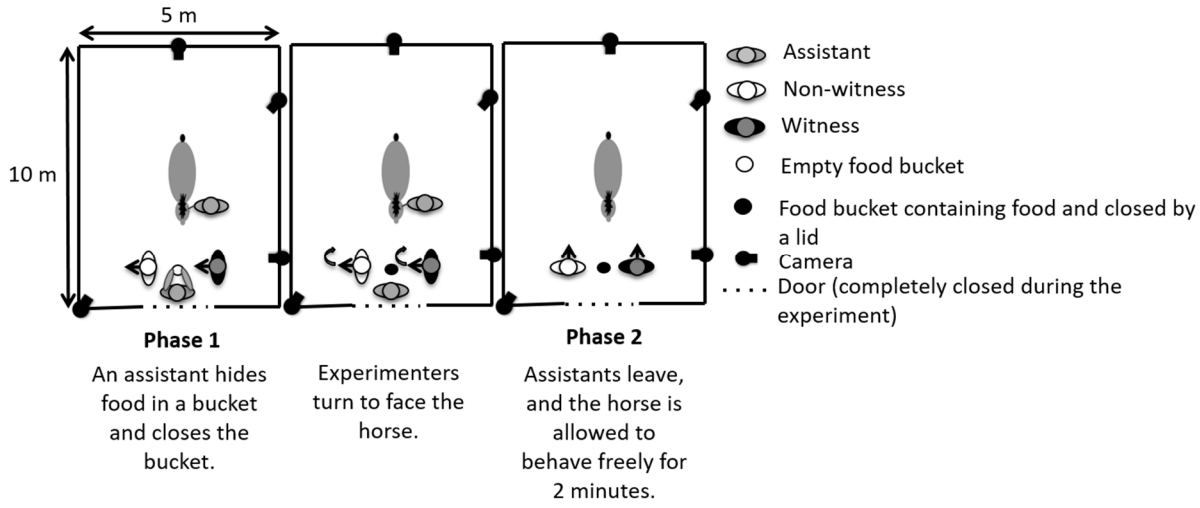

Figure 1. Schematic representation of a trial. During phase 1, an assistant was standing to the left of the horse, facing the bucket but with his eyes on the ground so that he didn't know who/where the witness was.

2.3. Coding and statistical analyses

Video recordings were analyzed using BORIS software (v. 6.0.6; Friard and Gamba 2016). We analyzed gaze duration (as defined in Ringhofer and Yamamoto 2016) during phase 2 for both the control and test trials. This target behavior has been widely used in horses in person-discrimination tasks (e.g., Lampe and Andre 2012; Malavasi and Huber 2016; Ringhofer and Yamamoto 2016; Proops and McComb 2012) and was the most sensible among the different variables used in the previous study (Ringhofer and Yamamoto 2016). All of the videos were analyzed by two coders who were blind to the role of the experimenters (interobserver reliability: ICC = 0.79; lower bound = 0.69, which is considered a good reliability: Koo and Li 2016). We used the arithmetic means of the gaze durations coded by the two coders for the analyses. Additionally, the number of touches (physical contacts between the horse muzzle and an experimenter) was recorded because this tactile signal has been proposed to be an attention-seeking behavior in horses (Malavasi and Huber 2016; Ringhofer and Yamamoto 2016). Touches were usually a brief pushing of the experimenter to attract attention; however, when those were longer, we took this into account by counting a new occurrence every three seconds if a horse continuously touched an experimenter for more than three seconds (the same procedure was used, for instance, in Lansade et al., 2018).

Statistical analyses were performed with R 3.0.2 (R Core Team, 2013) with a significance threshold of 0.05. To check for the absence of a pre-existing preference for a side or an

experimenter, a two-tailed binomial test was run that compared the gaze duration towards the witness during phase 2 of the control trial to that expected by chance (defined as: $\frac{proportion\ of\ time\ spent\ looking\ at\ witness + proportion\ of\ time\ spent\ looking\ at\ non-witness}{2}$). Four of our 19 horses showed a significant bias and were excluded from the experiment.

The gaze duration was analyzed with a mixed linear model using the 'lmer' function in the lmerTest package (Kuznetsova et al., 2015). The mean number of touches was analyzed with a generalized linear mixed model with a Poisson distribution (as it was count data) using the same function. In both models, type of trial (test or control), role of the experimenter the horse was looking at (witness or non-witness), and their interaction effect were included as fixed effects. Trial number nested in the identity of the horse was added as a random effect. As the interaction between the trial and role was significant for both models, post hoc interaction analyses with a Bonferroni adjustment for the P-values were performed using the "test Interaction" function of the Phia package (De Rosario-Martinez et al., 2015). We checked the residuals graphically for normal distribution and homoscedasticity.

3. Results

There was a significant interaction effect of trial by role (X^2 = 5.34, p = 0.021). The horses looked significantly longer at the witness than at the non-witness during the test trial (witness: 19.94 ± 4.51 s (mean ± s.e.m), non-witness: 8.12 ± 1.78 s; X^2 = 9.57, p = 0.004), but not during the control trial (witness: 7.25 ± 1.65 s, non-witness: 7.77 ± 1.71 s; X^2 = 0.02, p = 1.000). Similarly, horses looked significantly longer at the witness in the test compared to the control trial (X^2 = 11.03, p = 0.002) but there was no difference with the non-witness (X^2 < 0.01, p = 1.000; Fig. 2).

There was a significant interaction effect of trial by role on the mean number of touches (X^2 = 10.28, p = 0.001). The horses touched the witness significantly more times than the non-witness during the test trial (witness: 4.00 ± 1.43, non-witness: 1.93 ± 0.87, X^2 = 9.90, p = 0.003) but not during the control trial (witness: 0.36 ± 0.22, non-witness: 1.00 ± 0.50, X^2 = 3.75, p = 0.105). They touched the witness significantly more during the test trial than during the control trial (X^2 = 28.70, p < 0.001), while this difference was not present with the non-witness (X^2 = 3.97, p = 0.093; Fig. 2).

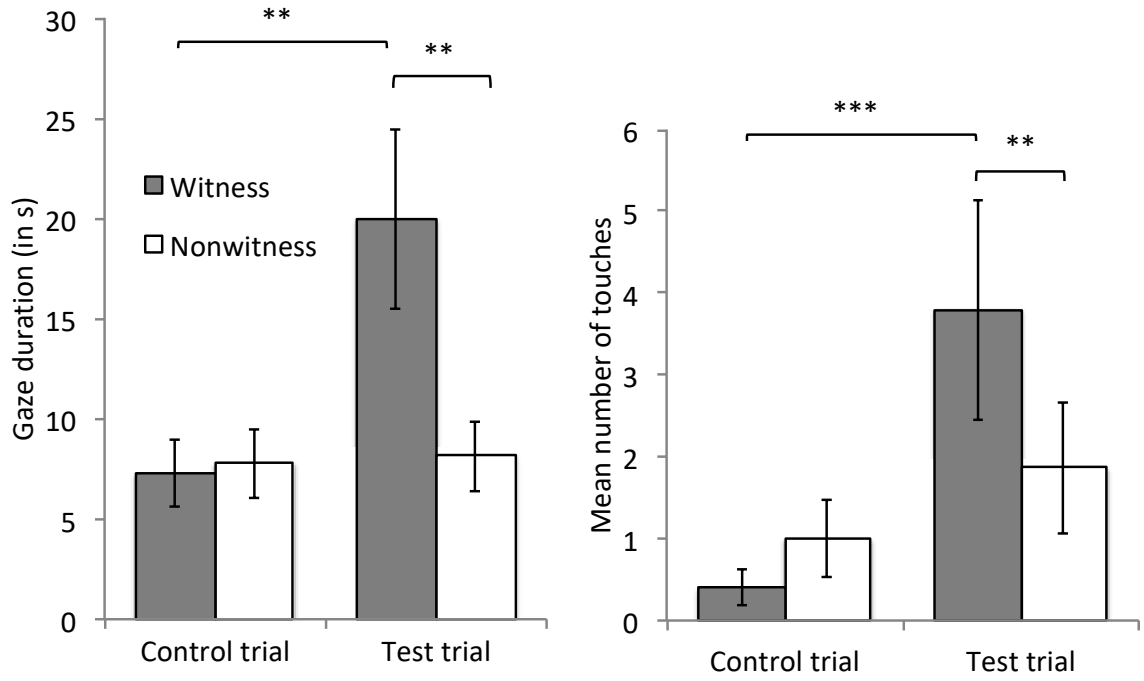

Figure 2. Gaze duration and absolute number of touches (mean ± s.e.m.) towards the witness and the non-witness. Significance was tested by a linear mixed model followed by post hoc interaction analysis with a Bonferroni adjustment: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. n = 14 individuals.

4. Discussion

Our results showed that horses can discriminate between an experimenter who faced a food-hiding process and an experimenter who did not. Consistent with our hypothesis, the horses looked at and touched the witness significantly more than the non-witness. Moreover, horses interacted more with the witness when food was hidden in the bucket (in the test trials compared to the control trials), suggesting that horses understood the food was unreachable and solicited assistance.

The preference for the witness is unlikely to be explained by the behavior of the experimenters since they both behaved identically. The use of learned associative rules specific to testing design (such as the use of the eyes-to-object line proposed by Heyes 1994) can also be ruled out as these horses had not been previously confronted with a similar test situation and the experiment consisted of only one test trial. However, we cannot completely exclude that horses used the target-directed behavior that the witness showed towards the bucket as a cue instead of inferring the witness' attention towards the baiting (i.e., the witness slightly bowed towards the

bucket while the non-witness bowed facing away), although the horses did not show this bias in the control trials.

Previous studies (Proops and McComb 2010; Proops et al. 2013) had suggested that horses were able to infer the human attentional state, and this might have been the case in our study as well: horses might have inferred the attentional state of the experimenters towards the baiting process (and not only towards themselves, as it was the case in these other studies) and hence show more interest towards the witness later on. That horses might adapt their behavior to what a human had witnessed was already suggested by the results from Ringhofer and Yamamoto (2016). However, their results were counterintuitive as the horses actually solicited the non-witness more than the witness. In their experiment, the horses' caretaker was present during the baiting process in the witness (but not in the non-witness) condition. Thus, the horses might have begged the caretaker for the food with no success during baiting and could have interpreted that the caretaker had no intention to help them get the food, which might explain their results. Here, the two experimenters were present during the entire trial and behaved similarly, and the horses reacted as predicted, showing more interest in the witness who was more likely to help them access the food.

That the horses would have inferred what the experimenters witnessed in our experiment seems plausible considering the long evolutionary history horses share with humans and that many horses (including our test subjects) interact daily with them. In that sense, a high sensitivity to human behavior—either by innate or by acquired mechanisms—is likely to be a crucial issue for domestic horses and was, for instance, observed in the case of Clever Hans (Pfungst and Rahn 1911). It would be interesting in future studies to investigate the effect of the relationship between the horses and humans (e.g., the level of training of the horse) and of their age on their sensitivity to human behavior.

In conclusion, and consistent with our hypothesis, we found that horses preferred an experimenter who witnessed a food-hiding process over a non-witness when they needed assistance accessing a food source. Hence, although further study would be necessary to draw this conclusion, horses might have inferred the attentional state of human experimenters towards a baiting event and used this information to accordingly act at a later time. These results might hint at the existence of precursors of a Theory of Mind (i.e., mental state attribution, Call and Tomasello 2008) in horses and call for further study with horses in this research area.

Compliance with ethical standards

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

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