

1 **Unwilling or willing but unable: can horses interpret human** 2 **actions as goal directed?**

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4 Social animals can gain important benefits by observing the behaviors of others and inferring
5 the intentions behind these behaviors. Indeed, this ability allows animals to understand and
6 predict the behavior of others and eventually to choose valuable social partners who share the
7 same goal (Call and Tomasello 2008; Woodward 2009; Hauser and Wood 2010). Intentions
8 have been defined as one's goal-directed action, including the goal, the means chosen to achieve
9 it and the rationale behind this means (Buttelmann et al. 2007). Despite its key importance, the
10 ability to infer others' intentions has only been investigated in a handful of nonhuman species
11 (primates: e.g., Call et al. 2004; Buttelmann et al. 2007, 2012; Wood et al. 2007, 2008; Phillips
12 et al. 2009; Canteloup and Meunier 2017; dogs: e.g., Range et al. 2007; parrots: Péron et al.
13 2010). One of the main paradigms used to study this ability is the unwilling *versus* unable
14 paradigm. An experimenter performs similar actions, all leading to the same outcome, the
15 subject does not receive the food that is presented, but differing in the intention of the
16 experimenter, i.e., either being unable to give the food or being able but unwilling to do so.
17 Chimpanzees, Capuchin monkeys, Tonkean macaques and grey parrots succeed in this task by
18 reacting differently according to the experimenters' intentions (Call et al. 2004; Phillips et al.
19 2009; Péron et al. 2010; Canteloup and Meunier 2017).

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21 In the present study, we investigated the ability to infer others' intentions in a species belonging
22 to a different taxon: domestic horses. Horses have a complex social system (Ringhofer et al.
23 2017) and have been shown to be very sensitive to the behavior of others, including humans
24 (e.g., Krueger et al. 2011; Bernauer et al. 2019; Trösch et al. 2019a; Trösch et al. 2020). For
25 instance, they can infer the current and past attentional state of humans (Proops and McComb
26 2010; Malavasi and Huber 2016; Trösch et al. 2019b), and some results even suggest that they
27 attribute a knowledge state to humans (Ringhofer and Yamamoto 2016; Trösch et al. 2019b).
28 Horses are thus an interesting species to study the inference of intentions.

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30 We used the unwilling *versus* unable paradigm: a human experimenter presented a piece of
31 food to a horse but failed to give it for three different reasons. In the unwilling condition, the
32 experimenter refused to give the food and took it back before the horse could reach it. In the
33 unable blocked condition, the experimenter was willing but unable to give the food to the horse
34 because of a physical barrier. In the unable clumsy condition, the experimenter was willing to

35 give the food but accidentally dropped it before the horse could reach it. Thus, the intentions of
36 the experimenter differed in the unwilling and willing (but unable) conditions. Our hypothesis
37 was that if horses can infer these intentions, they would react differently in the three conditions,
38 despite the outcome being the same in all conditions. Based on previous results in other species,
39 we expected the horses to show less interest (by turning away from the scene earlier and
40 attracting the attention of the experimenter less) in the unwilling condition than in the two
41 unable conditions.

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43 **Materials and methods**

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45 21 horses (8 mares, 12 geldings and 1 stallion) of various ages (Mean \pm SEM = 11.33 \pm 0.99)
46 and breeds were used. All were kept in a same stable and were privately owned: they lived in
47 stalls with regular access to individual outside paddocks, were fed three times a day with
48 concentrated pellets and hay and had access to water *ad libitum*.

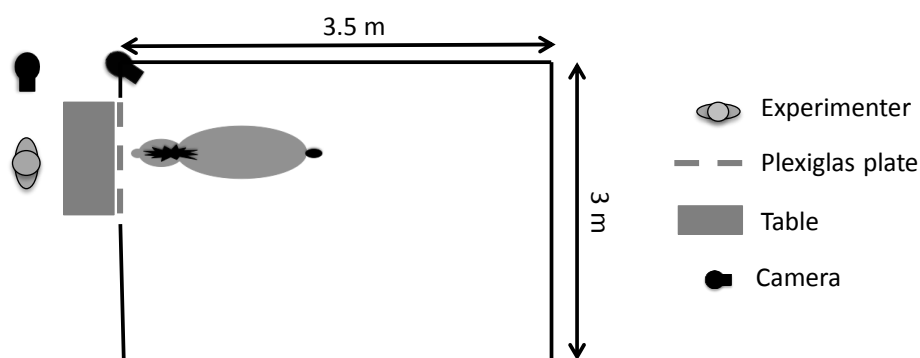
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50 All procedures were carried out in accordance with the guidelines of the Ethical Committee of
51 the French Ministry of Agriculture that gave us a positive recommendation (protocol number:
52 20190924-01-MT-CE19).

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54 The horses were tested individually in the same stall (3.5 x 3 m; Fig.1). The window of the stall
55 was covered with a transparent Plexiglas plate (120 x 90 cm). The plate contained a small hole
56 (6.5 cm in diameter) at a height of 160 cm. This hole could be closed by a transparent Plexiglas
57 disk completely covering the hole except for an opening (1 cm in diameter) at the center to
58 allow for olfactory cues. A table (80 x 50 cm) was placed outside the door of the stall, below
59 the window.

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62 **Fig. 1** View of the stall.

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The horses were tested in the morning, in one session carried out in the following manner:

Familiarization. The horse was first left alone in the stall for 3 minutes to get familiarized with the situation after which, there was one motivational trial. A trial consisted of the experimenter placing a small piece of carrot on the table for 2 s and then giving it to the horse through the hole in the Plexiglas plate.

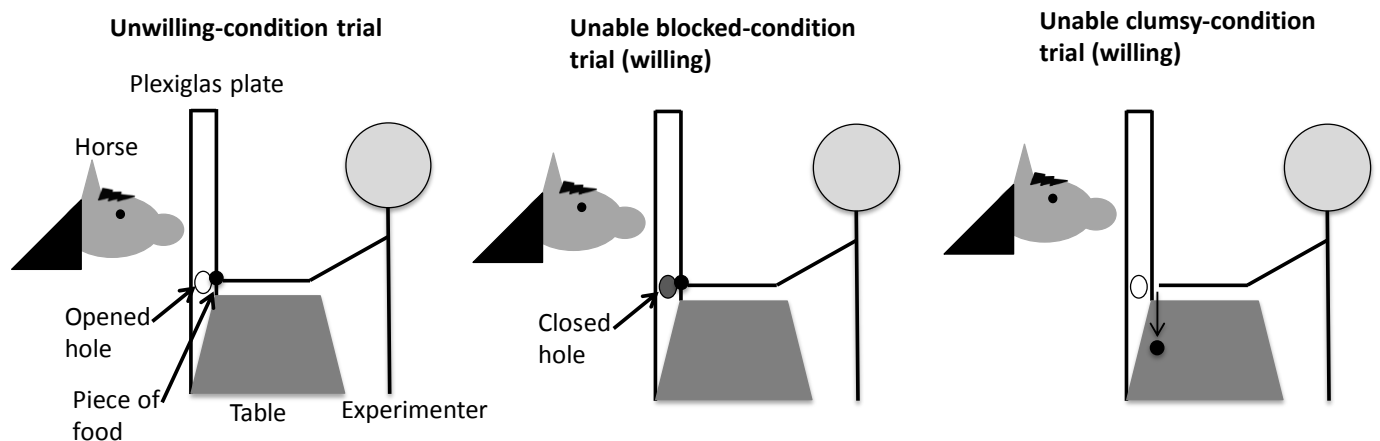
Test. At the end of the trial (when the horse finished eating the piece of carrot), the horse was tested in the three conditions in a counterbalanced order. The three conditions began with a motivational trial and were spaced by 10-s breaks, during which the experimenter went out of sight of the horse. Each condition consisted of 6 consecutive trials (with no gaps in between) starting and ending with the piece of food on the table (at the same point in the center of the table; Fig. 2 and Fig. S1).

Unwilling-condition. The experimenter put the piece of food on the table, moved it to the hole (stopping just before the piece of food entered the hole) and then put it back on the table, either immediately after the horse tried to take it or after 2 s, whichever occurred first.

Unable blocked-condition. The experimenter put the piece of food on the table, brought it to the hole, which was now closed by the transparent disk, and then put it back on the table, either when the horse tried to take it or after 2 s, whichever occurred first.

Unable clumsy-condition. The experimenter put the piece of food on the table, brought it to the hole and then accidentally dropped it, either when the horse tried to take it or after 2 s. The experimenter then took the piece of food back to the center of the table before starting a new trial.

In every condition, the experimenter looked at the piece of food while picking it up, looked at the horse while bringing the food to the hole and then looked at the food again when bringing it back to the table. The experimenter was instructed to keep a neutral facial expression during the whole procedure.



94 **Fig. 2** Schematic representation of the experimental set up.

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96 **Video and statistical analysis**

97 The behavior of the horse was filmed during the entire session by a camera fixed on the above
 98 corner of the stall front door (at a height of 150 cm), to the right of the horse (Fig. 1). The videos
 99 were analyzed using BORIS v. 6.2.3 (Friard and Gamba 2016) for the following behaviors. (1)
 100 The percentage of time spent looking at the scene before the horse turned away for the first time
 101 during the total duration of each condition. The horse was considered to turn the head away
 102 when its muzzle was not directed within 45° from the center of the Plexiglas plate. Latency is
 103 a common measure in the studies using the unwilling *versus* unable paradigm (Call et al. 2004;
 104 Phillips et al. 2009). Here, we chose to use a percentage instead of a simple latency to account
 105 for the variation in the duration of the trials. (2) The percentage of time the horse spent touching
 106 the Plexiglas plate during the total duration of each condition. This behavior was defined as
 107 pressing its nose against the plate without touching the hole (to exclude the times the horse was
 108 only trying to take the food through the hole). Touching the Plexiglas plate can be interpreted
 109 as a mark of interest for the scene or as an attempt to solicit the experimenter.

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111 Furthermore, the actions of the experimenter during the three conditions were recorded by a
 112 camera positioned to the experimenter's left side and at a height of 1 m (Fig. 1) to ensure that
 113 those were consistent between the three conditions. We analyzed the total duration of the trials,
 114 the duration of the experimenter's first movement (bringing the piece of food from the table to
 115 the horse) and second movement (bringing the piece of food back to the table) and the time the
 116 experimenter spent looking at the horse during each trial.

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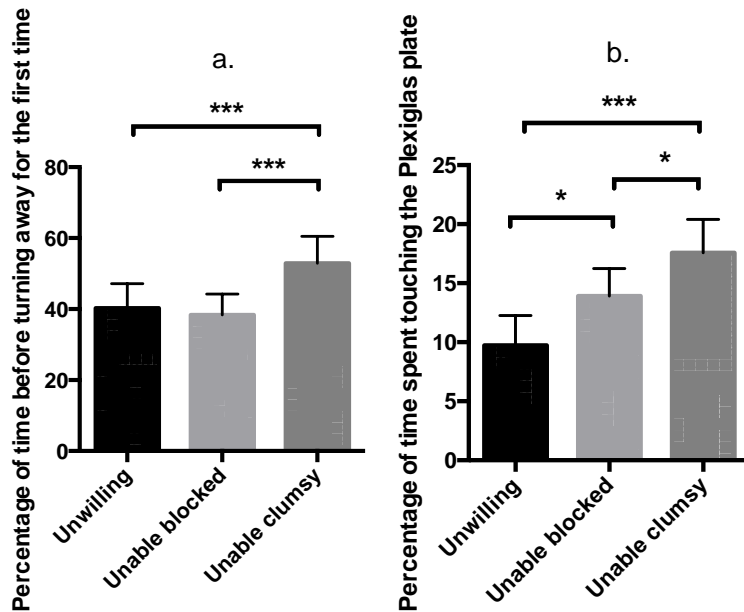
118 All statistical analyses were performed using R 3.0.2 (R Core Team, 2013). The significance
119 threshold was fixed at 0.05. Concerning the behavior of the horses, both variables were
120 analyzed with a generalized linear mixed model with a Binomial distribution and a logit link
121 function, using a Likelihood ratio test in the ‘lmer’ function in the lmerTest package
122 (Kuznetsova et al. 2015). For every model, the condition was added as a fixed effect, and the
123 identity of the horse was added as a random effect. We checked for overdispersion and the
124 independence of the observations graphically and assessed the accuracy of our models by
125 calculating the Pearson’s correlation between the observed and the predicted values (the
126 accuracy was high for both models: percentage of time spent looking at the scene before looking
127 away for the first time: $r = 0.82$, $P < 0.001$; percentage of time the horse spent touching the
128 Plexiglas plate: $r = 0.75$, $P < 0.001$). Tukey’s post hoc analysis was performed using the function
129 “summary.glht” in the multcomp package (Hothorn et al. 2019). Concerning the experimenter’s
130 actions, the different variables were analyzed with linear mixed models (using the ‘lmer’
131 function): the condition was added as a fixed effect and the identity of the horse as random
132 effect. The normal distribution and homoscedasticity of the residuals were checked graphically
133 and respected the assumptions of parametric analyses for all models.

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135 **Results**

136 There was a significant effect of condition on the percentage of time before turning the head
137 away ($X^2 = 65.78$, $P < 0.001$) and the percentage of time spent touching the Plexiglas plate ($X^2 =$
138 24.69 , $P < 0.001$). The horse spent more time looking at the scene before turning away in the
139 unable clumsy condition (mean \pm SEM = $52.87\% \pm 7.61\%$) than in both the unwilling condition
140 (mean \pm SEM = $40.29\% \pm 6.87\%$; $Z = 6.20$, $P < 0.001$) and the unable blocked condition (mean
141 \pm SEM = $38.37\% \pm 5.88\%$; $Z = 7.47$, $P < 0.001$; Fig. 3a). There was no significant difference
142 between the unwilling and unable blocked conditions ($Z = 1.17$, $P = 0.473$). The horses spent
143 significantly more time touching the Plexiglas plate in the unable clumsy condition (mean \pm
144 SEM = $17.57\% \pm 2.85\%$) than in the unwilling condition (mean \pm SEM = $9.73\% \pm 2.53\%$; $Z =$
145 4.89 , $P < 0.001$) and the unable blocked condition (mean \pm SEM = $13.91\% \pm 2.33\%$; $Z = 2.34$,
146 $P = 0.050$; Fig. 3b). Moreover, the horses spent significantly more time touching this plate in
147 the unable blocked condition than in the unwilling condition ($Z = 2.70$, $P = 0.019$).

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150 **Fig. 3** Behavioral responses during the three conditions: a. Percentage of time spent looking at the scene before turning
 151 away for the first time. b. Percentage of time spent touching the Plexiglas plate.

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153 The experimenter's actions did not significantly differ between the three conditions, for any of
 154 the measured variables (trials duration: $F= 1.36$, $P= 0.258$; duration of experimenter's first
 155 movement: $F= 0.83$, $P= 0.435$; duration of experimenter's second movement: $F= 2.25$, $P=$
 156 0.107 ; gaze duration towards the horse: $F= 1.33$, $P= 0.266$). The means \pm SEM are given in
 157 Table S1.

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159 **Discussion**

160 Horses spontaneously discriminated between the three conditions. In the unwilling condition,
 161 they spent a lower percentage of time facing the scene before turning away for the first time
 162 than in the unable clumsy condition and touched the Plexiglas plate less than in the two other
 163 conditions. The percentage of time facing the scene before turning away for the first time is a
 164 similar measure to the latency used in previous studies using the same paradigm and was
 165 interpreted as an indication of interest (Call et al. 2004; Phillips et al. 2009). Touching the
 166 Plexiglas plate could be interpreted as an attempt to solicit the experimenter. In previous
 167 studies, horses were found to similarly touch the experimenters as an attention-seeking behavior
 168 (Malavasi and Huber 2016; Ringhofer and Yamamoto 2016; Trösch et al. 2019b). Here, horses
 169 could not reach the experimenter and might have touched the plate instead. Thus, taken
 170 together, our results show that horses expressed less interest in the unwilling than in the two
 171 unable conditions. This might be explained by low-level processes or by an understanding of
 172 the experimenter's actions as goal directed.

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174 Horses might have used arbitrary cues or have perceived the behavior of the experimenter using
175 low-level behavior reading. The experimenter used gestures that were as similar as possible in
176 the three conditions. For all three conditions, the experimenter interacted with the food,
177 bringing the food to the hole in the Plexiglas plate and bringing it back to the center of the table
178 at the end of the trial. However, there was a slight difference in gesture in the unable clumsy
179 condition as the piece of food was dropped on the table and then brought back to the center,
180 which might have attracted the attention of the horse more compared to the other conditions.
181 Nevertheless, this slight difference in gesture alone cannot explain all our results since we also
182 found a significant difference in behavior between the unable blocked and the unwilling
183 conditions, in which the gestures used by the experimenter were totally identical. A further low-
184 level explanation can also be proposed for the difference between the unable blocked and the
185 unwilling condition. Indeed, horses might have behaved differently in the unable blocked
186 condition because they used the blocked hole as a cue that getting the food was impossible (as
187 also suggested in Call et al. 2004; Canteloup and Meunier 2017). In this case, we would have
188 expected them to show more interest when the hole was open (i.e., unwilling condition; Call et
189 al. 2004). However, our results show the opposite, and we thus believe this hypothesis to be
190 unlikely. Moreover, as there was an opening in the disc, the differences observed between the
191 unable blocked condition and the two other conditions are also unlikely to be caused by a
192 difference in olfactory cues.

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194 Horses might also have interpreted the experimenter's actions as goal directed. Their reduced
195 interest in the unwilling condition compared to the two unable conditions could suggest that
196 they have inferred that they would not receive any food because the experimenter did not intend
197 to give it to them. In contrast, in the unable conditions, they could have understood that the
198 experimenter had the intention to give them the food, even though the attempt was unsuccessful.
199 The increased interest of horses in the unable clumsy condition compared to that in the unable
200 blocked condition could be explained by the absence of a physical barrier in the first. Indeed,
201 they might have inferred that the experimenter was more likely to succeed in giving them the
202 food when it was physically possible. Interestingly, our subjects did not show any difference in
203 the percentage of time facing the scene before turning away for the first time between the unable
204 blocked and the unwilling conditions. A potential explanation could be that the horses perceived
205 that they were as unlikely to obtain the food when the experimenter was unwilling to give it
206 and when a physical barrier made the food impossible to reach. Still the horses touched the

207 plate significantly more in the unable blocked than in the unwilling condition. This difference
208 between our two variables could be explain by the fact that touching the plate is a more sensitive
209 variable, or because the horses specifically increased this behavior in the blocked condition as
210 an attempt to solicit the help of the experimenter reaching an unreachable food, as it was shown
211 in previous studies (Ringhofer and Yamamoto 2016; Trösch et al. 2019b). Taken together, our
212 results suggest that horses not only perceived the behavior of the experimenter using low-level
213 behavior reading but might also have interpreted the experimenter’s actions as goal directed.
214 Hence, they might be capable of inferring at least the lowest level of intentionality, the
215 intentions in action, i.e., the intentions that an individual has while performing an action, as
216 opposed to the more complex prior intentions (Searle 1983). Our results are also consistent with
217 the results found in other species using the same paradigm. For example, Chimpanzees and
218 capuchin monkeys left the test area earlier in the unwilling condition than in the unable
219 conditions (especially in the unable clumsy condition; Call et al. 2004; Phillips et al. 2009).
220 Moreover, Tonkean macaques exhibited less begging behavior toward the experimenter in the
221 unwilling condition than in the unable blocked condition (Canteloup and Meunier 2017).

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223 Interestingly, even though our study was designed to test the social skills of horses, it offers
224 promising preliminary results in terms of physical cognition as well. Indeed, the behavioral
225 differences between the unable blocked and the two other conditions suggest that horses could
226 use the presence of a physical barrier (the disc closing the hole in the unable-blocked condition)
227 between them and the food as an indication that the passage of food was impossible. Hence,
228 that could suggest that they have exhibited causal reasoning about surface continuity, i.e., that
229 objects cannot go through a physical barrier (similar to the “trap-tube” task: Visalberghi and
230 Limongelli 1994; Taylor et al. 2009; Teschke and Tebbich 2011). To our knowledge, this
231 capacity has not been demonstrated in horses as of yet, and further research will be required to
232 confirm this possibility.

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234 Horses are thought to have a low visual acuity at short distances (Murphy et al., 2009). Our
235 results suggest that this visual acuity was still sufficient to perceive and respond to visual
236 differences in the three conditions, even though they usually stood at less than 1 m from the
237 scene. Consistently, previous studies showed that horses can discriminate symbols and even
238 pictures of human faces on a screen while standing very close to the screen (Tomonaga et al.,
239 2015 ; Gabor & Gerken 2012, 2014 ; Lansade et al., 2020).

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241 To conclude, our study strengthens previous results showing that this species is very sensitive
242 to human behavior. Indeed, horses have been shown to be able to infer the current and past
243 attentional state of humans (Proops and McComb 2010; Malavasi and Huber 2016; Trösch et
244 al. 2019b) and might even infer the knowledge state of humans (Ringhofer and Yamamoto
245 2016; Trösch et al. 2019b). Our results suggest that horses might also infer human goals or even
246 intentions in action.

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