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7 **Goats display audience-dependent human-directed gazing behaviour in a problem-**
8 **solving task**

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10 **Short title: Human-directed behaviour in livestock**

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28 **Abstract**

29

30 Domestication is an important factor driving changes in animal cognition and behaviour. In
31 particular, the capacity of dogs to communicate in a referential and intentional way with humans
32 is considered a key outcome of how domestication as a companion animal shaped the canid
33 brain. However, the lack of comparison with other domestic animals makes general conclusions
34 about how domestication has affected these important cognitive features difficult. We
35 investigated human-directed behaviour in an 'unsolvable problem' task in a domestic, but non-
36 companion species: goats. During the test, goats experienced a forward facing or an away
37 facing person. They gazed towards the forward facing person earlier and for longer and showed
38 more gaze alternations and a lower latency until the first gaze alternation when the person was
39 forward facing. Our results provide strong evidence for audience-dependent human-directed
40 visual orienting behaviour in a species that was domesticated primarily for production, and show
41 similarities with the referential and intentional communicative behaviour exhibited by domestic
42 companion animals such as dogs and horses. This indicates that domestication has a much
43 broader impact on heterospecific communication than previously believed.

44

45 Keywords: human-animal interaction; intentional communication; referential communication;
46 social cognition; ungulates

47 **1. Introduction**

48

49 Domestication is an important factor driving changes in animal cognition and behaviour. In
50 particular, the capacity of dogs (*Canis familiaris*), but not wolves (*Canis lupus*), to communicate
51 in a referential and intentional way with humans is considered a key outcome of how
52 domestication shaped the canid brain. Referential and intentional communication is defined as
53 the persistent use and elaboration of successive orienting between a communicative partner
54 and the target, and takes into account not only the presence but also the attentional stance of
55 an audience [1].

56

57 Dogs are capable of using gazing behaviour as a form of referential and intentional
58 communication [2,3]. This has often been tested with a so-called ‘unsolvable problem’ paradigm
59 in which subjects (after a training phase) are offered a task with an inaccessible food reward [2].
60 Although young dogs also show some human-directed gazing behaviour, this trait seems to be
61 influenced by developmental factors during their ontogeny [4]. In addition, both adult dogs and
62 human toddlers (*Homo sapiens*) take into account the attentional stance of a human and
63 increase their use of gaze alternations during an ‘unsolvable problem’ task, indicating the
64 communicative and referential nature of the behavioural outcome in this task [5].

65

66 Two other domestic species have been tested using the ‘unsolvable problem’ paradigm. Cats
67 (*Felis catus*) performed poorly and barely looked at humans, potentially due to their rather
68 solitary lifestyle [6]. Recently, horses (*Equus caballus*) were found to not only look at towards
69 humans, but they were also sensitive to the attentional state of the experimenter [7]. However,
70 both dogs and horses have been domesticated to work closely with humans, which may explain
71 their higher inclination to rely on human information. To date, no research on animals that have
72 been domesticated for food and related products, rather than companionship, has been
73 conducted to investigate whether these enhanced communication skills underlie a broader
74 effect of domestication. To answer this question, we investigated goat behaviour in an

75 'unsolvable problem' task, in which subjects that were highly habituated to human presence and
76 handling were either confronted with a forward facing or away facing human experimenter.

77

78 **2. Materials and methods**

79

80 *(a) Animals, keeping and management*

81 The study was carried out at Buttercups Sanctuary for Goats (<http://www.buttercups.org.uk>),
82 UK. We tested 34 adult goats (17 females and 17 castrated males; 2-15 years; various breeds),
83 which were fully habituated due to previous research [8]. In addition, the goats have
84 experienced many positive interactions with staff, volunteers and visitors at the sanctuary, as
85 well as circumstances in which food is inaccessible [8]. Routine care of the animals was
86 provided by sanctuary employees and volunteers. The goats had *ad libitum* access to hay and
87 were not food restricted before testing.

88

89 *(b) Test Procedure*

90 Goats were tested individually in a familiar test pen. A plastic box lid was attached to a wooden
91 board and placed in the middle of the pen. The main part of the transparent plastic box could be
92 fixed to the board by catches on the box lid. During all trials, one experimenter (E1) was
93 positioned on either the left or right side of the wooden board while a second experimenter (E2)
94 was positioned approximately 250 cm away. In training trials, Experimenter 1 placed a food
95 reward on the lid and covered it with the plastic box. Subjects could retrieve the reward by
96 moving or overturning the box in three training trials that lasted for 60 s. If a subject did not
97 complete two consecutive training trials within 60 s, then it was removed from the experiment (2
98 subjects). Thus, a total of 32 subjects (15 females and 17 males) were used in the tests. Test
99 trials ('unsolvable') were similar to the training trials, except that the box was fixed to the lid,
100 rendering the food reward visible but inaccessible. Each subject received only one test trial
101 which lasted 120 s and goats were assigned to one of two groups (16 goats per group). One
102 group received a test trial in which Experimenter 1 faced the box ('FORWARD', Figure 1a),
103 whereas the other group received a test trial in which Experimenter 1 faced away from the box

104 ('BACK', Figure 1b). Experimenter 2 always looked straight to the box and thus served as a
105 control for the general inclination of subjects in both test groups to gaze at humans. Throughout
106 the duration of the training and test trials, both experimenters did not interact with the goat (see
107 ESM for a detailed description).
108



109
110 **Figure 1.** Experimenter 1 in the test arena demonstrating the group conditions: **left** FORWARD
111 condition; **right** BACK condition; Experimenter 2 (not in the image) was positioned on the right
112 side of the camera in both test conditions.

113

114 (c) *Data scoring and analysis*

115 All trials were videotaped (Sony HCR-CX190E Camcorder) and analysed using Kinovea 0.8.15.
116 For training trials, a Friedman test was carried out in order to evaluate whether there was a
117 reduction in the latencies to retrieve the food reward across the three training trials. Bonferroni-
118 corrected Wilcoxon signed rank tests were used for later pairwise comparisons. In test trials,
119 subjects' interactions with the box were recorded as an indicator of motivation to retrieve the
120 food reward. Human-directed behaviours, such as general gazes towards the two
121 experimenters and gaze alternations between experimenter and box (and vice versa) within 2
122 seconds were analysed (see ESM for a detailed description). One quarter of the training and
123 test trials were double-coded by C.N. and J.M.B. for the time to solve the task (training),
124 frequency, latency and total duration of gaze and gaze alternating behaviours towards each of
125 the experimenters (test). These were highly reliable (all at or above $r_s = 0.89$, $p < 0.01$).
126 Because data from test trials were not normally distributed, we used Mann-Whitney U tests to
127 compare groups in each behavioural variable. Age, sex and breed were counterbalanced

128 between groups, and therefore these parameters were not included in the analysis. Alpha was
129 set at 0.05. All statistical analyses were conducted in R 3.1.0 [9].

130

131 **3. Results**

132

133 (a) Training

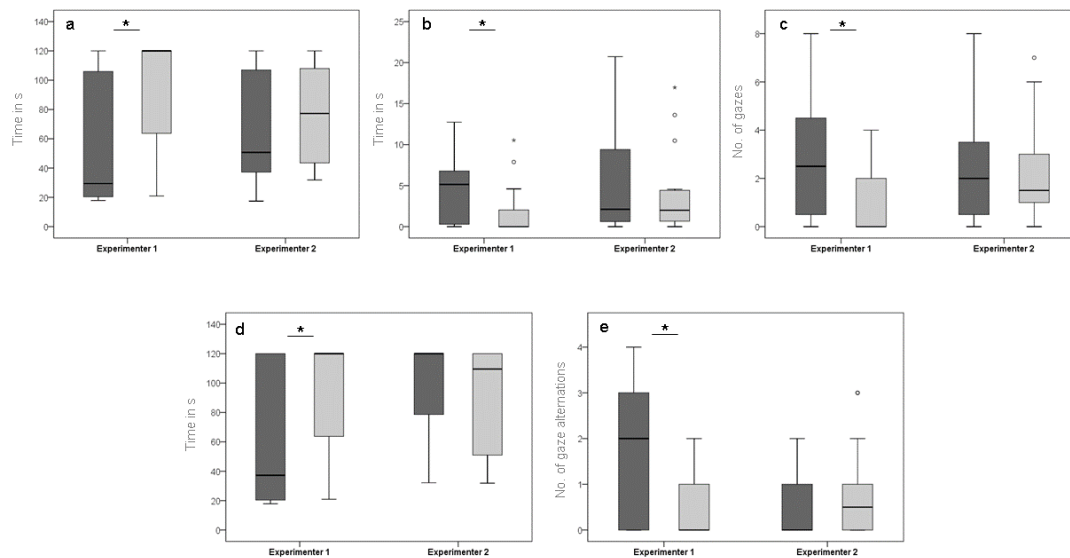
134 The time taken to retrieve the food reward was significantly reduced over the training trials
135 (median times for first trial: 9.18 s, second trial: 6.16 s, third trial: 5.36 s; Friedman $\chi^2 = 28.65$, df
136 $= 2$, $p < 0.001$). There were significant reductions in the time taken for the goats to retrieve the
137 reward from Trial 1 to Trial 2, and from Trial 2 to Trial 3 (both p 's < 0.025). The latencies to
138 retrieve the food reward in training trials did not differ between groups (all p 's > 0.4). Goats
139 never looked back during training trials.

140

141 (b) Test

142 There were no significant differences between both groups regarding their interactions with the
143 box (duration: $U = 91$, $p = 0.17$; latency: $U = 123$, $p = 0.87$; frequency: $U = 119$, $p = 0.75$). Thus,
144 subjects from both groups were equally motivated to retrieve the reward. In general, goats
145 gazed towards the forward-facing Experimenter 1 earlier ($U = 61$, $p < 0.001$, Figure 2a), for
146 longer ($U = 187$, $p = 0.02$, Figure 2b) and more frequently ($U = 191$, $p = 0.013$, Figure 2c) than
147 towards the experimenter facing away. Goats also performed their first gaze alternation earlier
148 ($U = 76$, $p = 0.038$, Figure 2d) and performed gaze alternations more frequently ($U = 181$, $p =$
149 0.033 , Figure 2e) when Experimenter 1 was forward-facing compared to the away-facing
150 experimenter. Importantly, no behavioural differences between groups were found regarding
151 Experimenter 2 (all p 's > 0.4 , Figure 2).

152



153

154 **Figure 2.** Boxplots presenting the median times for (a) gaze latencies, (b) gaze durations, (c)
 155 gaze frequencies, (d) latencies until first gaze alternation and (e) frequencies of gaze
 156 alternations towards either Experimenter 1 or Experimenter 2. dark grey bars: FORWARD
 157 group; light grey bars: BACK group. ‘*’ indicates significant differences between groups.

158

159 **4. Discussion**

160

161 We investigated human-directed behaviour of goats in the ‘unsolvable problem’ paradigm [2].
 162 Goats often exhibited gazing and gaze alternations at both experimenters during the test and
 163 clearly adjusted their behaviour depending on the attentional stance of Experimenter 1. Our
 164 results show that animals domesticated primarily for production show audience-dependent
 165 human-directed behaviour in a similar manner to companion animals such as dogs and horses
 166 [2,7]. Thus, domestication has probably had a much broader impact on heterospecific
 167 communication than previously believed.

168

169 Goats gazed earlier and for longer towards a forward facing experimenter compared to an
 170 experimenter who had his back turned towards them. Goats also showed a higher frequency of
 171 gaze alternations and a lower latency until the first gaze alternation when the experimenter was

172 facing forward. This has previously been shown for human toddlers, dogs, and horses [5,7] and
173 is in line with previous findings showing that goats alter their behaviour depending on human
174 body and head orientation [10]. Importantly, no such difference between groups occurred for the
175 second experimenter, who always faced the subjects, indicating no difference in the general
176 predisposition of both groups to gaze at humans.

177

178 All subjects physically interacted with one or both experimenters, most likely to beg for food.
179 Interestingly, we observed an additional, very specific type of approach behaviour. Here, goats
180 stopped for approximately 2-3 seconds, 20-40 cm in front of the experimenter (see ESM video)
181 with little or no physical contact, before returning to the box. This specific approach behaviour
182 might be considered as an elaboration of the previously used gaze alternations. However, only
183 14/32 of goats (6 in the FORWARD and 8 in the BACK condition) exhibited this behaviour,
184 making more detailed analysis impossible.

185

186 Goats in our study have experienced a history of positive long-term interactions with humans
187 (e.g. receiving food) as well as circumstances in which food is inaccessible. Thus, this specific
188 ontogeny, leading to an additional reduction of fear responses and/or the establishment of a
189 referential problem space [11], may have affected the expression of human-directed behaviours
190 that we report. It would be intriguing to test both hypotheses by comparing the behaviour of
191 tame non-domesticated goats with domestic ones that are kept under similar husbandry
192 conditions. Research that compared canids in the unsolvable task points towards a strong effect
193 of domestication [2], although results in related tasks, like following human pointing gestures,
194 indicated that previous experiences with humans can be a strong factor affecting the
195 performance of canids [12].

196

197 **5. Conclusions**

198

199 Goats show human-directed visual orienting behaviour similar to the referential and intentional
200 communication shown in hominoids, which is also evident in companion animals such as dogs

201 and horses. This challenges the view that a specific kind of domestication, i.e. the selection for
202 companionship, has led to the development of complex communication with humans in
203 domestic animals.

204

205 **Ethics**

206 Animal care and all experimental procedures were in accordance with the ASAB/ABS
207 Guidelines for the Use of Animals in Research. The study was approved by the Animal Welfare
208 and Ethical Review Board committee of Queen Mary University of London (Ref.
209 QMULAWERB032015).

210

211 **Data accessibility**

212 The data underlying this study are available from Dryad: <http://dx.doi.org/10.5061/dryad.kt2kd>
213 [13].

214

215 **Authors' contribution**

216 C.N., J.M.B. and A.G.M. conceived/designed the study; J.M.B. and C.N. conducted experiments
217 and analysed the data; C.N., J.M.B. and A.G.M. wrote the manuscript. All authors gave final
218 approval for publication and agree to be held accountable for the work performed.

219

220 **Competing interests**

221 The authors have no competing interests.

222

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226

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