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Goats Display Audience-Dependent Human-Directed Gazing Behaviour in a Problem-7 Solving Task

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

Short title: Human-directed behaviour in livestock

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Abstract

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

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

1. Introduction

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

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

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

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

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

(c) Data scoring and analysis

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

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

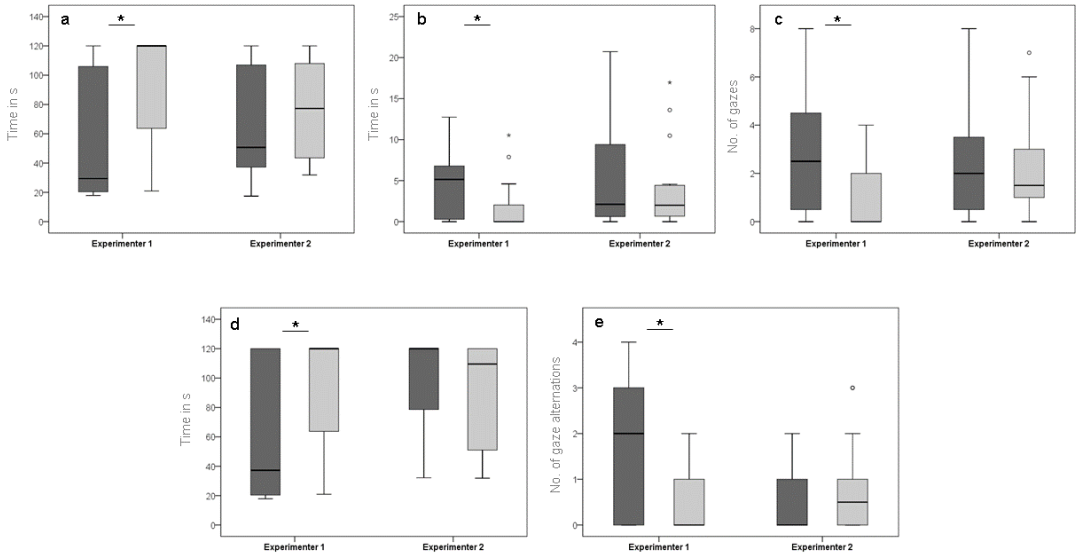
3. Results

(a) Training

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

(b) Test

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



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

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

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

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

5. Conclusions

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

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

Ethics

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

Data accessibility

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

Authors' contribution

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

Competing interests

The authors have no competing interests.

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