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Goats Learn Socially from Humans in a Spatial Problem-Solving Task

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8 **Goats learn socially from humans in a spatial problem-solving task**

9
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25 **Highlights**

26 We assessed spatial and social problem-solving abilities in goats using a detour task.

27 Goats did not improve their performance over trials.

28 A single presentation by a human solving the detour resulted in goats solving the task faster.

29 Goats used the same route as the human demonstrator.

30 We provide evidence for social learning from humans in ungulate livestock.

31 **Abstract**

32 Domestication drives changes in animal cognition and behaviour. In particular, the capacity
33 of dogs to socially learn from humans is considered a key outcome of how domestication
34 shaped the canid brain. However, systematic evidence for social learning from humans in
35 other domestic species is lacking and makes general conclusions about how domestication
36 has affected cognitive abilities difficult. We assessed spatial and social problem-solving
37 abilities in goats (*Capra hircus*) using a detour task, in which food was placed behind an
38 inward or outward V-shaped hurdle. Goats performed better in the outward than in the inward
39 detour without human demonstration. Importantly, a single presentation by a human solving
40 the inward detour resulted in goats solving the task faster compared to the inward detour
41 without demonstration. Furthermore, 8/9 subjects that received a demonstration used the
42 same route as the demonstrator in the subsequent trial. Thus, goats learn socially from
43 humans. This provides strong evidence for social learning from humans in a domestic species
44 other than dogs.

45

46 **Keywords**

47 detour task; domestication; social cognition; social learning; spatial cognition

48 Animals may acquire new behaviours by either individual and/or social learning. Individual
49 learning occurs through an individual's own experience, but if the environment is
50 unpredictable, individual learning can lead to costly mistakes. By contrast, social learning
51 occurs when the acquisition of behaviour is influenced by observing or interacting with other
52 individuals (Galef & Laland, 2005; Heyes, 1994), and social animals should have plenty of
53 opportunities to learn from conspecifics. Social learning allows the acquisition of locally
54 adaptive information from conspecifics without having to pay some of the costs associated
55 with individual learning, such as a higher risk of predation (Galef & Laland, 2005). Animals
56 use a diversity of mechanisms to learn from others, including social facilitation, stimulus and
57 local enhancement, or observational conditioning (Heyes, 1994; Laland, 2004) and social
58 learning is evident in many taxa, including primates (Whiten, 2000), birds, reptiles (Kis,
59 Huber, & Wilkinson, 2014; Wilkinson, Kuenstner, Mueller, & Huber, 2010) and fish (Duffy,
60 Pike, & Laland, 2009).

61

62 Research on social learning often focusses on information transfer between conspecifics
63 (Laland, 2004; Andrew Whiten, Horner, Litchfield, & Marshall-Pescini, 2004), but social
64 learning between members of different species also occurs and may be particularly relevant
65 in human-animal interactions. For example, the ability of canids to solve a task in which they
66 had to go around an obstacle in order to reach a food reward (also known as "detour task")
67 has been widely investigated (Mersmann, Tomasello, Call, Kaminski, & Taborsky, 2011;
68 Pongrácz et al., 2001). Interestingly, dogs (*Canis lupus familiaris*), but not dingoes (*Canis*
69 *lupus dingo*), were quicker to find food in a detour task after watching a human demonstrator
70 (Pongrácz et al., 2001; Smith & Litchfield, 2010). This has led to the assumption that the
71 ability of dogs to learn socially from humans in a detour task is linked to their specific
72 domestication history as companion animals, which led to an increased inclination to interact

73 with humans and to pay attention to their communicative cues (Hare, Brown, Williamson, &
74 Tomasello, 2002). However, others have suggested that the ability of dogs to gain
75 information from humans is more closely associated with ontogeny, e.g. being raised by
76 humans (Udell, Dorey, & Wynne, 2008).

77

78 In general, detour tasks can be used to investigate social learning abilities between
79 conspecifics and heterospecifics (Pongrácz et al., 2001; Rørvang, Ahrendt, & Christensen,
80 2015; Wilkinson et al., 2010). However, to date, the effect of a human demonstrator during
81 detour tasks has only been assessed for canids (Mersmann et al., 2011; Pongrácz et al., 2001;
82 Pongrácz, Miklósi, Timár-Geng, & Csányi, 2003; Smith & Litchfield, 2010), and therefore
83 broad conclusions about the mechanism that resulted in this ability are not possible. Research
84 on other species, particularly domesticated ones, is crucial in order to evaluate which species
85 perceive and use information provided by humans.

86

87 In ungulate livestock, vertical information transfer between individuals (e.g. social learning
88 by offspring from mothers) is important for the development of foraging skills (Glasser et al.,
89 2009; Oostindjer et al., 2011). Still, evidence for horizontal information transfer is scarce. For
90 example, there is no consensus as to whether horses (*Equus caballus*) are capable of social
91 learning from conspecifics or heterospecifics (Baer, Potter, Friend, & Beaver, 1983; Clarke,
92 Nicol, Jones, & McGreevy, 1996; Krueger, Farmer, & Heinze, 2014). Horses that observed a
93 demonstrator horse manipulating an apparatus to receive a reward also spent more time near
94 the test apparatus. However, observer horses did not learn to manipulate the apparatus more
95 quickly compared to control horses (Ahrendt, Christensen, & Ladewig, 2012), indicating that
96 they relied on stimulus and/or local enhancement cues from the demonstrators. In another
97 task, observer horses copied specific following behaviours towards humans if the

98 demonstrator was a dominant conspecific, whereas this was not the case if the demonstrator
99 horse was subordinate or unknown to the observer (Krueger & Heinze, 2008).

100

101 Less attention has been paid to investigating heterospecific learning in domestic ungulates,
102 e.g. from humans. Held et al. (2001) reported that pigs directly trained by a human
103 experimenter to find food (in one of several corridors) learned to locate the reward. Although
104 pigs learned to visit the correct location, this can only be considered as non-systematic
105 evidence, because data for the training trials were not analysed in detail. More importantly,
106 no control group without a human demonstrator was tested. In addition, there is no evidence
107 for horizontal information transfer or heterospecific social learning in other ungulate
108 livestock species, e.g. goats and sheep. (Baciadonna, McElligott, & Briefer, 2013; Briefer,
109 Haque, Baciadonna, & McElligott, 2014). Some of the negative findings might be explained
110 by test subjects not approaching higher-ranking conspecifics or by potential food depletion
111 when a conspecific moves to a rewarded position first (Baciadonna et al., 2013; Rørvang et
112 al., 2015). Methodological constraints are an alternative explanation for the lack of positive
113 results. The test setups may have been too difficult to master for the subjects after only a
114 limited amount of exposure to a demonstrator, e.g. by using a 2-step puzzle box (Briefer et
115 al., 2014). Furthermore, the ability of subjects to pay attention to demonstrators may have
116 been reduced due to presentation times being too long, or the actions performed by the
117 demonstrator may not have been ecologically meaningful to the observer, e.g. pulling a string
118 (Briefer et al., 2014). To solve some of these issues, one solution would be to use attention-
119 getting behaviours during the task as this has already been shown to improve dogs' detour
120 performance (Pongrácz, Miklósi, Timár-Geng, & Csányi, 2004).

121

122 In previous research, detour tasks with ungulate livestock have focused mostly on the effects
123 of laterality (Versace, Morgante, Pulina, & Vallortigara, 2007) and/or spatial learning
124 (Osthaus, Proops, Hocking, & Burden, 2013; see Rørvang et al., 2015 for lack of social
125 learning in horses using a detour task). In our study, we investigated the effect of a human
126 demonstrator on the performance of goats in a detour task and addressed potential
127 shortcomings in previous research. We implemented attention-getting behaviours (i.e. rattling
128 sound of food rewards) to attract the attention of subjects towards the human demonstration
129 of the task (Pongrácz et al., 2004). Furthermore, we examined their flexibility in generalising
130 learned solutions in the spatial problem-solving task. To accomplish this, we presented goats
131 with a series of trials of either inward or outward detour tasks before reversing the detour in a
132 final trial (see Figure 1). Canids solved the outward configuration faster compared to the
133 inward configuration, likely due to an avoidance of corners (Pongrácz et al., 2001; Smith &
134 Litchfield, 2010). In a similar manner, we expected goats to perform better in the outward
135 compared to the inward task. For this reason, we only gave them a human demonstration in
136 the inward, but not outward detour configuration. This is because we expected a floor effect
137 for their latencies in the outward detour that would have hampered our ability to detect
138 performance improvements after prior human demonstration. Importantly, we expected them
139 to improve in their detour performance once they have observed a human solving the inward
140 task (Pongrácz et al., 2001; Pongrácz, Miklósi, Vida, & Csányi, 2005).

141

142 **METHODS**

143

144 *Subjects and housing*

145 The study was carried out at a goat sanctuary (Buttercups Sanctuary for Goats,
146 <http://www.buttercups.org.uk>), UK. Initially, we tested 42 adult goats (14 females and 28
147 castrated males, Table 1), which were fully habituated to human presence because of
148 previous research (Baciadonna et al., 2013; Briefer & McElligott, 2013). They were aged 3-
149 16 years and of various breeds. Routine care of the animals was provided by sanctuary
150 employees and volunteers. The goats had ad libitum access to hay and were not food
151 restricted before testing.

152

153 *Procedure*

154 The experiment was carried out in a temporary enclosure (700 x 500 cm), which we set up
155 within the normal daytime range of the goats. Subjects were tested from 12:00-16:00 during
156 September 2015. The test subjects were visually isolated from other goats, but remained in
157 auditory and olfactory contact with them. Two transparent metal hurdles (height: 120 cm,
158 length: 200 cm) were positioned in the middle of the test arena according to the different test
159 conditions (Fig. 1a). Before the start of each training and test trial, the test subjects were kept
160 on a leash by one experimenter to standardize its starting position during the trials.

161

162 **Table 1.** Characteristics and group assignment of the goats

Subject	Age	Sex	Breed	Test group
a1	5	Male	Toggenburg Mix	Inward detour (no demonstrator)
a3	4	Male	Anglo-Nubian	Inward detour (no demonstrator)
a4	8	Female	Saanen Mix	Inward detour (no demonstrator)
a6	10	Male	Golden Guernsey	Inward detour (no demonstrator)
a7	4	Female	Toggenburg	Inward detour (no demonstrator)
a8	11	Female	Alpine	Inward detour (no demonstrator)
a10	3	Male	Pygmy	Inward detour (no demonstrator)
a11	8	Male	Pygmy	Inward detour (no demonstrator)
a12	13	Male	Pygmy	Inward detour (no demonstrator)
a13	13	Male	Saanen	Inward detour (no demonstrator)
b1	5	Male	Saanen x Toggenburg	Outward detour (no demonstrator)
b2	16	Male	Pygmy	Outward detour (no demonstrator)
b3	10	Male	Anglo-Nubian	Outward detour (no demonstrator)
b4	4	Female	Toggenburg Mix	Outward detour (no demonstrator)
b5	9	Female	Pygmy	Outward detour (no demonstrator)
b6	15	Female	Pygmy	Outward detour (no demonstrator)
b7	8	Female	Saanen	Outward detour (no demonstrator)
b8	13	Female	Angora	Outward detour (no demonstrator)
b9	3	Male	Toggenburg x Pygmy	Outward detour (no demonstrator)
b10	4	Female	Anglo-Nubian	Outward detour (no demonstrator)
c1	7	Male	Saanen	Inward detour (demonstrator)
c2	12	Female	Pygmy	Inward detour (demonstrator)
c3	8	Female	Saanen	Inward detour (demonstrator)
c4	11	Female	Toggenburg Mix	Inward detour (demonstrator)
c5	9	Male	Saanen	Inward detour (demonstrator)
c8	13	Male	Pygmy	Inward detour (demonstrator)
c9	6	Male	Toggenburg Mix	Inward detour (demonstrator)
c13	7	Male	Pygmy	Inward detour (demonstrator)
c14	3	Male	Pygmy	Inward detour (demonstrator)

163

164

165

166 *Training*

167 The initial training period consisted of three trials for every subject before testing. An
168 experimenter baited a transparent plastic box (10 x 20 cm) with a piece of dry pasta visible to
169 the subject, positioned the box in front of the hurdles and shook the box once. The subject
170 was then released and was free to explore the arena and the box. After the subject obtained
171 the reward from the box, the subject was brought back to the starting point and a new training
172 trial started. Subjects that went reliably towards the box after three trials were included in the
173 test. Subjects were assigned to one of the following three experimental groups:

174

175 *Inward detour group (no demonstrator)*

176 This inward detour group with no demonstrator consisted of 13 goats. Three goats were
177 excluded because they did not approach the box reliably in the training trials. A second
178 experimenter remained with the goat at the starting pen and prevented it from seeing inside
179 the test arena by using opaque livestock fencing. The first experimenter placed the baited box
180 through the V-shaped hurdles on the inner side of the intersecting angle, not visible to the test
181 animal (Fig. 1b), and shook the box once to draw the subject's auditory attention towards it.
182 When the first experimenter returned to the starting pen, the second experimenter released the
183 goat and started the trial. Both experimenters remained in the starting pen. If the goat was not
184 able to obtain the reward within 60 s, the trial was terminated, and the next trial was started.
185 After three trials the shape of the hurdles was reversed (outward detour; Fig. 1c). The
186 procedure for the fourth trial was the same as reported for the first three trials.

187

188 *Outward detour group (no demonstrator)*

189 The outward detour group with no demonstrator consisted of 10 goats. Two goats were
190 excluded because they did not approach the box reliably in training trials. Goats in this group

191 were exposed to the same test procedure as described for the inward detour group, but in
192 reverse order. There were three consecutive outward detour trials followed by a single inward
193 detour test (trial 4).

194

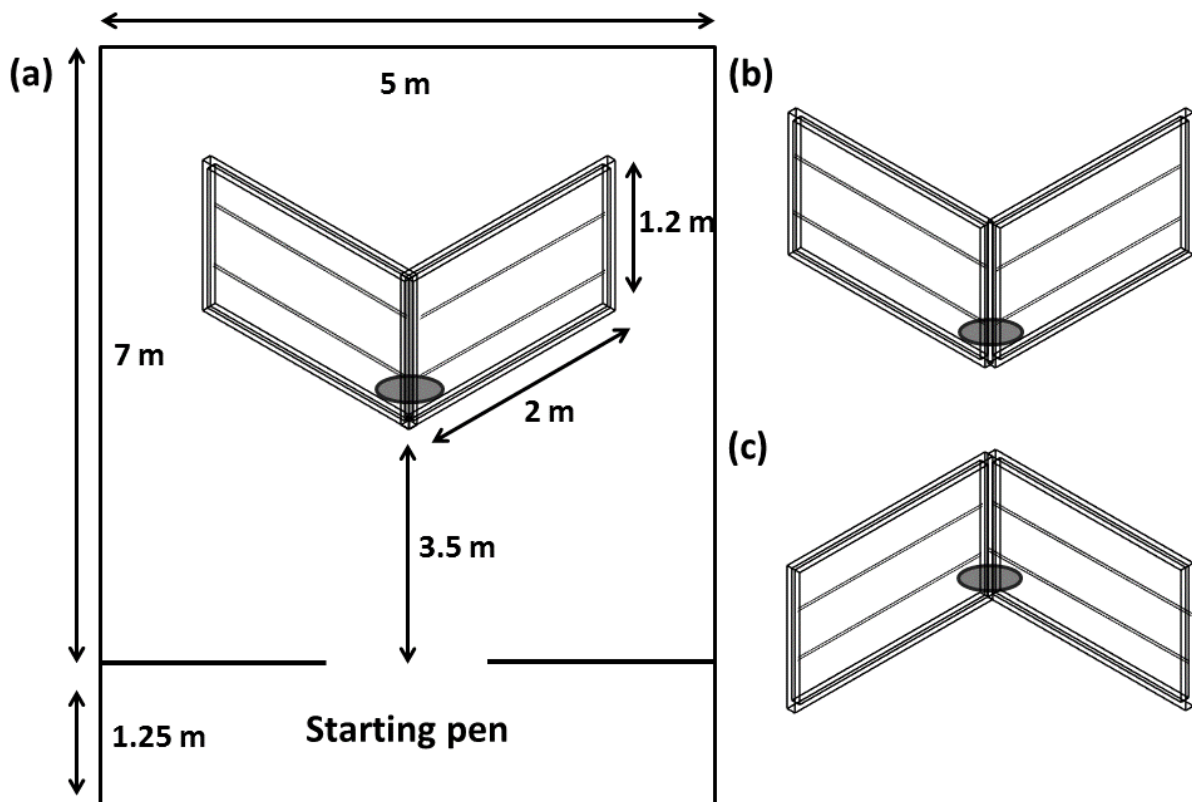
195 *Inward detour group (human demonstrator)*

196 The inward detour group with a human demonstrator consisted of 14 goats. Two goats were
197 excluded because they did not approach the box reliably in training trials. Goats in this group
198 were exposed to the same test procedure as the inward detour group without demonstration,
199 with one exception. Before the first trial started, subjects had the opportunity to watch the
200 first experimenter baiting the box at the training position (i.e. in front of the hurdles) and
201 moving it behind the V-shaped hurdles. During this time, the first experimenter shook the box
202 repeatedly to draw the subject's visual and auditory attention towards the movement (see
203 SEM video). After the experimenter positioned the box, he took the same route back (either
204 left or right of the hurdle). He then moved behind the goat in the starting pen, the subject was
205 released. Half of the subjects received a demonstration using the left side of the hurdle, while
206 the other half received a demonstration using the right side. Subjects did not receive a
207 demonstration prior to subsequent trials. Again, after three trials the shape of the hurdles was
208 reversed (trial 4, outward detour; Fig. 1c).

209

210 In all trials, the distance between the entrance of the arena and the intersecting angle of the
211 hurdles was kept the same (3.5 m). The box was always positioned behind this angle and
212 close to the hurdles. Groups were counterbalanced for breed, age and sex. Some subjects had
213 to be excluded from the final analysis because they were not able to solve the detour in one or
214 more out of the first three trials (inward detour - no demonstrator, 2 subjects; inward detour -
215 human demonstrator, 5 subjects). An additional subject had to be removed from the inward

216 detour (no demonstrator) group because it jumped over the hurdles. Thus, a total of 29
217 subjects (inward detour - no demonstrator, 10 subjects; outward detour - no demonstrator: 10
218 subjects, inward detour - human demonstrator: 9 subjects) were included in the analysis.
219



220
221 **Figure 1** (a) Experimental apparatus (b) Inward detour used with and without human
222 demonstrator (c) Outward detour; the grey circle represents the final position of the box
223 containing the reward

224

225 *Ethical Note*

226 Animal care and all experimental procedures were in accordance with the ASAB/ABS
227 Guidelines for the Use of Animals in Research (Association for the Study of Animal
228 Behaviour, 2016). The study was approved by the Animal Welfare and Ethical Review Board
229 committee of Queen Mary University of London. All measurements were non-invasive, and

230 the experiment lasted no more than 10 min for each individual goat. If the goats had become
231 stressed, the test would have been stopped.

232

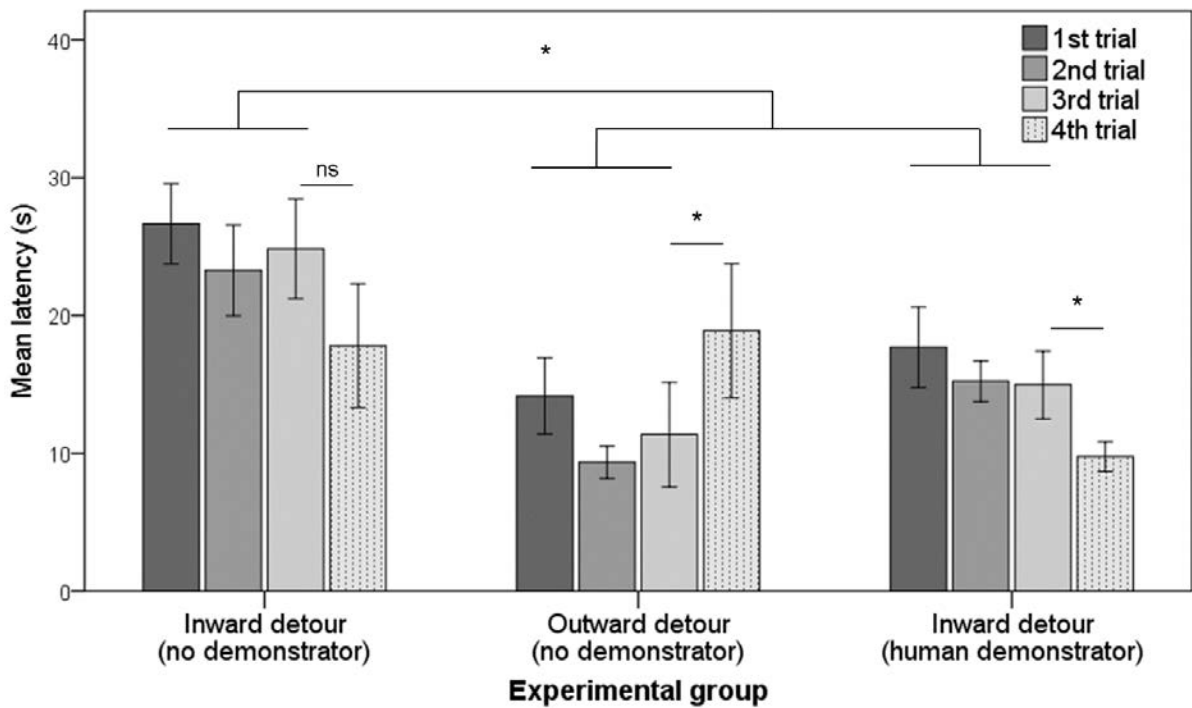
233 *Data scoring and analysis*

234 Latency times the starting point to reach the baited box and the route taken (left or right) were
235 scored live during the test and were also videotaped (Sony HCR-CX190E Camcorder). A test
236 trial started after a goat entered the test arena and finished when the goat either fed from the
237 box within 60 s or after 60 s had passed. If a goat did not reach the box containing the food
238 reward, it was led out of the test arena and the latency for the trial was scored with 60 s. A
239 second coder, unfamiliar with the hypothesis, scored the latency and route taken by the
240 subjects of 20 % of the total trials. Inter-observer agreement for latencies (Spearman rank
241 correlation; $r_s = 0.979$; $P < 0.001$) and for the route taken (Cohen's $k = 1.0$) was excellent.
242 We used parametric tests (ANOVA, t -tests) for the latency data. The effect of trial number
243 (1-3; within-subject factor) and the experimental group (between-subject factor) was analysed
244 with mixed ANOVA for repeated measures to the within-subject factor. Paired t -test were
245 used for each group separately for the comparison of the third and fourth trial (Pongrácz et
246 al., 2001). To analyse whether goats used the same route as the human demonstrator, we used
247 a two-sided binomial test. Concordance in the direction to detour the obstacle over trials 1-3
248 (left/right) was analysed using Wilcoxon signed rank tests, by comparing the route taken in
249 the second and third trials with the route taken in the first trial. To achieve this, we used the
250 number of subsequent trials in which concordance occurred compared to the direction of the
251 first trial. This mean that concordance could vary between 0 (choosing the opposite route
252 compared to trial 1 in trial 2 and 3) and 2 (choosing the same route compared to trial 1 in trial
253 2 and 3). The alpha level for all tests was set at 0.05.

254 **RESULTS**

255 We found that the time taken for goats to detour around the obstacle was affected by their
256 experimental group (repeated measures ANOVA: $F_{2,26} = 12.17, P < 0.001$; Figure 2). We did
257 not find an effect by the trial numbers (trial 1 – 3; $F_{2,52} = 1.52, P = 0.23$), or an interaction
258 between both factors on the time to do the detour ($F_{4,52} = 0.08, P = 0.99$). Goats were faster to
259 reach the reward in the first three trials in the outward detour group and inward detour group
260 with a human demonstrator, compared to the inward detour group with no demonstrator
261 (Student-Newman-Keuls post hoc test: all $P < 0.05$). However, no difference between groups
262 could be found for trial 4 (reverse trial; one-way ANOVA: $F_{2,26} = 1.50, P = 0.24$). In
263 addition, we compared latencies for the third and the fourth (reverse) trial in the three groups
264 to analyse potential performance differences when a new spatial configuration of the detour
265 was presented. Goats did not improve their performance in the inward detour group without a
266 demonstrator when switching towards an outward detour (paired t test: $t_9 = 1.63, P = 0.14$),
267 whereas goats in the inward group with a human demonstrator significantly improved their
268 performance from the third towards the fourth trial ($t_8 = 2.51, P = 0.037$). Furthermore, goats
269 in the outward detour group decreased in their detour performance when confronted with an
270 inward detour ($t_9 = -4.20, P = 0.002$). In addition, we compared the number of subjects that
271 had to be excluded because they were not able to solve the detour in one or more out of the
272 first three trials. The number of subjects did not differ between the three test groups (chi-
273 square test: $\chi^2 = 4.416, P = 0.11$). Finally, we analysed the route (left or right) goats used in
274 the first three trials. Concordance for detour routes over trials in all three experimental groups
275 was not different from chance level (Wilcoxon signed-rank test; inward detour (no
276 demonstrator): $Z = -0.45, N = 10, P = 0.66$; outward detour (no demonstrator): $Z = .66, N =$
277 $10, P = 0.32$; inward detour (human demonstrator): $Z = -1.0, N = 9, P = 0.32$), indicating that
278 individual goats were not consistent in the route they used to detour the hurdles. For the

279 inward detour task with a human demonstrator, 8/9 subjects took the same route as the human
 280 demonstrator in the first trial (binomial test: $K = 8, N = 9, P = 0.04$; two-sided). However,
 281 this was not the case for the following trials (all $P > 0.5$). Thus, human demonstration
 282 improved detour performance of goats using an inward spatial configuration, whereas
 283 repeated exposure to the same task did not result in improved individual learning (Figure 2).
 284



285
 286 **Figure 2** Latencies (mean \pm SE) to solve the task in the three experimental groups. * indicate
 287 significant differences with $P < 0.05$

288

289 **DISCUSSION**

290 We investigated the ability of goats to socially learn from humans in a spatial problem-
291 solving task. We found that goats that had seen a single demonstration of a human solving an
292 inward detour task had significantly shorter latencies to detour around an obstacle compared
293 to those that did not receive a demonstration. Although no difference between groups in the
294 reverse trial could be found, goats that experienced an inward detour with a human
295 demonstrator significantly decreased their latencies to detour an outward V-shaped obstacle.
296 This was not the case for the group that received the inward detour without a demonstration.
297 Contrary to some results for dogs (Pongrácz et al., 2001), 8/9 goats that received a human
298 demonstration used the same route as the demonstrator in the subsequent trial. However, this
299 was only the case for the first trial immediately after the human demonstration, but not for
300 any subsequent trials. Surprisingly, and in contrast to other results on motor laterality in
301 ungulates, individuals choice of side to detour (left or right) showed no concordance over
302 repeated trials (Leliveld, Langbein, & Puppe, 2013). We show that animals that have been
303 primarily domesticated for food production are capable of perceiving information from
304 humans, in a similar manner to companion animals such as dogs. Thus domestication might
305 have a much broader impact on cognitive capacities than previously believed (Hare &
306 Tomasello, 2005; Hare et al., 2005; Nawroth, Brett, & McElligott, 2016).

307

308 There are several possible explanations regarding the mechanisms involved in goats socially
309 learning from humans (Laland, 2004). The most likely explanation is that stimulus or local
310 enhancement have occurred if the action of the demonstrator drew the attention of the goats
311 to particular objects or locations in the environment. The movements of the human
312 demonstrator could have directed the attention of the goat to the path the demonstrator was
313 walking, to the corner of the hurdle where the demonstrator turned back, or to the object that

314 was carried behind the hurdle. However, goats may have solved the task simply by following
315 the baited container and not the human demonstrator (Mersmann et al., 2011), or due to a
316 general tendency to follow the path of the demonstrator. This would have resulted in reaching
317 the food reward faster compared to the corresponding non-social condition. Future research
318 should control for this non-social stimulus enhancement by using devices that move a baited
319 container without the help of a human (Mersmann et al., 2011). In addition, social facilitation
320 might have affected goats' performance. The mere presence of the demonstrator could have
321 contributed to the enhanced performance of the goats in the inward group with human
322 demonstration (Zajonc, 1965). Alternatively, because learning took place after only one trial
323 and goats choose the same route as the demonstrator, we cannot exclude the possibility that
324 the goats imitated the detouring behaviour of the human (Huber et al., 2009).

325

326 For the spatial component, the initial presentation of the detour ('inward' vs 'outward') had a
327 significant effect on detour latencies. Goats that received the outward V-shaped detour were
328 faster at solving the task compared to subjects that received an inward V-shaped detour.
329 We observed that most subjects in the outward group did not approach the edge of the hurdle,
330 but were instead detouring immediately. This most likely led to the increase in performance
331 found in the outward group because this shortcut was not available for subjects of the inward
332 group. Interestingly, the same pattern was found for dogs (Pongrácz et al., 2001) and it seems
333 likely that goats (like dogs) avoid particular shaped spatial configurations that might resemble
334 corners, like those presented in the outward V-shaped hurdles. These results are confirmed by
335 the goats' performance in the reverse trial. Subjects that experienced an inward detour, either
336 with or without a human demonstrator, in general increased their performance to detour the
337 outward V-shaped obstacle, while goats that received the inward detour after prior exposure
338 to the outward detour decreased in their performance. The lower dropout rate in the outward

339 group additionally indicates that the outward formation was perceived as less demanding than
340 the inward formation. Overall, latencies over trials within each experimental group did not
341 differ, indicating no rapid individual learning in the task. This poor individual learning ability
342 in the detour task is in line with findings from canids (Marshall-Pescini, Virányi, & Range,
343 2015; Pongrácz et al., 2001; Smith & Litchfield, 2010).

344

345 Our findings on the use of a human demonstrator are in contrast with other research on
346 domestic ungulates that used conspecific demonstrators, either in similar detour tasks
347 (Rørvang et al., 2015), maze learning tasks (Baciadonna et al., 2013), or in operant learning
348 tasks (Baer et al., 1983; Clarke et al., 1996). Several approaches may be relevant to explain
349 the contrast between our results and previous negative findings on social learning in
350 ungulates. Most previous studies used conspecific demonstrators (but see Held et al., 2001 for
351 non-systematic support for heterospecific social learning in pigs), and observers may simply
352 assume that the demonstrator consumed the reward and thus expected depletion of the reward
353 after arrival (Smolla, Gilman, Galla, Shultz, & Smolla, 2015). Another difference between
354 our findings and previous research in goats is that the delay between the demonstration and
355 test (i.e. the time needed for the experimenter to go from the test arena to the starting pen;
356 approximately 10-15 seconds) was rather short compared to previous studies (Baciadonna et
357 al., 2013; Briefer et al., 2014). This may have improved goats' ability to socially learn from
358 humans and may also explain why in subsequent trials, in which there were no more
359 demonstrations, they would choose another route. In addition, subjects in previous
360 experiments may have avoided approaching the same location as the conspecific depending
361 on the social rank differences between observers and demonstrators (Baciadonna et al., 2013;
362 Clarke et al., 1996). We assume that our subjects' improved performance after observing a
363 demonstrator might be also accounted for by our specific procedure used in the test trials. In

364 our experiment, the subjects' attention was directed towards the experimenter, who shook the
365 box with the food reward during the demonstration. In most other studies, observer attention
366 may have been lacking until the delivery of the reward at the very end of the test (Briefer et
367 al., 2014; Rørvang et al., 2015). This lack of attention may also account for some negative
368 findings on social learning in ungulates (Briefer et al., 2014; Truskanov & Lotem, 2015).
369 Moreover, previous work with wolves in the detour task did not involve a social component,
370 reflecting the need for future research that takes into account the impact of domestication on
371 detour demonstration by a human in dogs (Frank & Frank, 1982; Marshall-Pescini et al.,
372 2015).

373

374 *Conclusions*

375 Our results demonstrate that ungulates use information from humans in a spatial problem-
376 solving task. This provides systematic evidence for social learning from humans in a
377 domestic species other than dogs.

378

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382

383 **COMPETING INTERESTS**

384 The authors declare that they do not have competing interest.

385

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392

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