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1 **Juvenile domestic pigs (*Sus scrofa domestica*) use human-given**
2 **cues in an object choice task**

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19 **Abstract**

20 Research on the comprehension of human-given cues by domesticated as well as non-
21 domesticated species has received considerable attention over the last decade. While several
22 species seem to be capable of utilizing these cues, former work with domestic pigs (*Sus scrofa*
23 *domestica*) has shown inconclusive results. In this study, we investigated the use of human-
24 given cues in an object choice task by young domestic pigs (N = 17; seven weeks of age) who
25 had very limited human contact prior to the experiments. Subjects had to choose between two
26 bowls of which only one was baited with a reward. Over the course of five experiments, pigs
27 were able to use proximal and, with some constraints, also distal pointing cues presented in
28 both a dynamic-sustained and in a momentary manner. When the experimenter was pointing
29 from the incorrect bowl towards the correct one, most of the subjects had problems solving
30 the task – indicating that some form of stimulus/local enhancement affected pigs’ decision
31 making. Interestingly, pigs were able to utilize the body and head orientation of a human
32 experimenter to locate the hidden reward but failed to co-orient when head or body
33 orientation of the experimenter was directed into distant space with no bowls present. Control
34 trials ruled out the possibility that other factors (e.g., odour cues) affected subjects’ choice
35 behaviour. Learning during experiments played a minor role and only occurred in three out of
36 twelve test conditions. We conclude that domestic pigs, even at a very young age, are skillful
37 in utilizing various human-given cues in an object choice task - raising the question whether
38 pigs only used stimulus/local enhancement and associative learning processes or if they were
39 able to comprehend the communicative nature of at least some of these cues.

40

41 Key words: Domestic pig; Social cognition; Object choice; Human-given cues; Human-
42 animal interaction

43 **Introduction**

44

45 Obtaining information from other individuals is crucial for survival, either in a
46 communicative or competitive context. However, the mechanisms by which receivers
47 recognize the underlying mental states of signalers are still under debate. The comprehension
48 of the human pointing gesture as a communicative cue indicating the location of a hidden
49 reward in an object choice task has recently received increased attention (for a review see
50 Miklósi and Soproni 2006, Kaminski and Nitzschner 2013). Some researchers hypothesize
51 that artificial selection pressures by humans (i.e., domestication processes) has led to reduced
52 emotional reactivity (i.e., a reduction of fear and aggression towards humans) in dogs (*Canis*
53 *familiaris*) and, due to additional selection for companionship, altered the socio-cognitive
54 capacities adaptive for living with humans. Dogs seem to be especially skillful in
55 comprehending human-given cues such as different forms of pointing gestures or gaze
56 direction in object choice tasks (Agnetta et al. 2000; McKinley and Sambrook 2000; Soproni
57 et al. 2001; Hare et al. 2002; Hare and Tomasello 2005; Miklosi et al. 2005) – letting them
58 outperform their wild counterparts, wolves, in the same task (Hare et al. 2002; Virányi et al.
59 2008). In addition, dogs already utilize these cues at a very young age of six weeks, leaving
60 little space for ontogenetic factors (Riedel et al. 2008). Other domestic species like cats
61 (Miklosi et al. 2005), goats (Kaminski et al. 2005), and horses (Maros et al. 2008; Proops et
62 al. 2010) appeared to be able to utilize some of the pointing gestures applied to dogs – letting
63 other researchers argue that domestication in general could have promoted the ability to rely
64 on human-given cues (Hernádi et al. 2012). However, the species mentioned above failed to
65 use the body or head orientation of a human experimenter. The results obtained in these
66 studies with horses, goats, and cats can alternatively be explained by the use of stimulus/local
67 enhancement effects, as subjects only had to move towards the part of the human body that
68 was closest to one of two possible targets. For horses (Maros et al. 2008; Proops et al. 2010),

69 a learned food-hand-association may additionally account for the good performance in solving
70 the pointing gesture – as observed by a high number of approaches to the experimenter’s hand
71 and/or index finger before making a choice. As there is no comparative work where the same
72 methodology was applied to the wild counterparts of cats, goats, or horses, no conclusions can
73 be drawn to potential effects of domestication processes in these species. So in general, due to
74 longstanding human animal interactions and pre-existing training histories, individual
75 ontogenetic factors cannot be ruled out completely from accounting for the performances of
76 those other domestic species, especially since no studies with very young and human-
77 inexperienced subjects have been conducted with cats or horses (but see for goats: Kaminski
78 et al. 2005). In addition, even some non-domesticated species seem to be able to follow
79 human-given cues including gaze direction (e.g., grey parrots: Giret et al. 2009; rooks:
80 Schmidt et al. 2011; seals: Scheumann and Call 2004). However, individuals in these studies
81 all had considerable human contact before testing, were professionally trained or had previous
82 test experience.

83 The domestication of the pig (*Sus scrofa domestica*) started more than 9000 years ago
84 (Umberto 2007) from several locations in Eurasia. The pig, as an omnivorous species, may
85 have experienced a similar early domestication history as the dog (Clutton-Brock 1995), that
86 is, scavenging around early human settlements searching for waste and leftovers. Compared
87 to dogs and horses, which were probably selected mainly for companionship, sport or working
88 purposes, pigs were presumably selected largely for meat quality and quantity. Pigs are also
89 highly gregarious animals, forming a social hierarchy and are able to distinguish not only
90 unfamiliar from familiar conspecifics (Mendl et al. 2002), but also different familiar
91 individuals from each other using visual, auditory or olfactory cues alone (McLeman et al.
92 2005). Several studies on domestic pigs have also shown some more sophisticated cognitive
93 abilities of these animals, including the use of a mirror to obtain information (Broom et al.
94 2009), social exploitation in a spatial foraging task (Held et al. 2000, 2002), and potentially

95 taking the visual perspective of conspecifics (Held et al. 2001). However, studies
96 investigating more complex interactions between pigs and heterospecifics (e.g., humans)
97 rather than conspecifics are rare.

98 Besides a recent study of Nawroth et al. (2013) there is another one of Albiach-
99 Serrano and colleagues (2012), who applied a test battery of object choice tasks with various
100 test conditions, both in the physical and socio-cognitive domain. Albiach-Serrano and
101 colleagues found that wild boars, but not domestic pigs, were able to follow human pointing
102 gestures. However, they tested individuals behind a mesh that separated them from the
103 experimenter. Although this methodology is necessary under some circumstances (e.g., for
104 safety reasons), it has been found to influence the performance, as a partial visual barrier
105 might distract subjects and therefore decrease performance, at least for dogs (Udell et al.
106 2008).

107 Here, we present the first study that explicitly addresses the use of various human-
108 given cues in juvenile domestic pigs, tested without a barrier. Subjects were tested in five
109 different experiments and were seven weeks old at the beginning of the first one. Because
110 there was no possibility of constraining the subjects as in other studies with dogs or horses
111 (e.g., Agnetta et al. 2000; Proops et al. 2010), we used a slightly different procedure where
112 subjects were free to enter the test area by passing through a long corridor (see Kaminski et al.
113 2005). Subjects had to choose between two bowls of which only one was baited with a
114 reward. While pigs were passing through the corridor, they inevitably saw the experimenter in
115 front of them, administering different gestures indicating the baited bowl. In the first
116 experiment, we used the most common human-given cues (see Miklósi and Soproni 2006) for
117 comparative reasons. These cues are proximal pointing (i.e., the experimenter pointed from a
118 kneeling position) and distal pointing gestures (i.e., experimenter pointed from a standing
119 position), both presented in a momentary and dynamic-sustained manner. In the second
120 experiment, the experimenter administered distal pointing cues in a kneeling position to

121 present those gestures in a more salient way. In the third experiment, we examined whether
122 subjects used only stimulus/local enhancement by the human body itself for finding the
123 correct bowl or if they had some understanding of the informative value of the experimenter's
124 pointing gesture. In the fourth experiment, we investigated whether pigs could also use other
125 social cues like the body or the head orientation of the experimenter. In the last experiment,
126 we examined whether pigs would follow head and body orientation into distant space when
127 no bowls and no food were present. We expected, in accordance with studies in goats and
128 horses (Kaminski et al. 2005; Proops et al. 2010), that pigs would be able to use proximal and,
129 to some degree, distal pointing cues.

130 **General Methods**

131

132 *Subjects*

133

134 Initially, a total of 23 pigs (male: 11; female: 12) participated and were transferred into their
135 home pens at the age of five weeks. All individuals were reared at the research facilities. Pigs
136 had access to a commercial diet ad libitum. Water was provided from nipple drinkers in the
137 home pens at all times. During habituation and training we had to exclude five subjects, one
138 for being injured at the start of the habituation phase and four for not solving the training
139 phase where they had to learn that only one bowl out of two was baited. Thus, 18 pigs
140 participated but some of them had to be excluded during the different experiments due to a
141 lack of motivation (for a detailed list see Table 1).

142

143 ---

144 Table 1

145 ---

146

147 *Housing*

148

149 Pigs were socially housed in a barn of the Institute of Agricultural and Nutritional Sciences in
150 Merbitz, Germany. Temperature was maintained at about 23°C and artificial light was
151 provided from 7 am to 5 pm. Pigs were housed in groups of 7-9 individuals in pens (250 x
152 400 cm) on solid floor with straw bedding. Branches were used as additional enrichment
153 material.

154

155 *Habituation*

156

157 After subjects were transferred to the pig pens they got one week of habituation to reduce
158 aggressiveness and to get familiar with the new environment. Every day, the experimenter
159 entered the pig pens for about 20 min. During the last two days of this phase, he additionally
160 placed a bowl with grapes into the middle of the pen to make subjects familiar with the bowls
161 and the new food source. Subsequently, pigs received four days of habituation to the test area
162 (see Figure 1) and the adjacent resting area before experiments began. On the first two days,
163 they were introduced as a group for about 15 min to both areas. On the third day, they were
164 introduced alone, again for about 15 minutes and could explore the areas on their own while
165 some grapes were spread over the floor of the test area. On the fourth day of habituation, pigs
166 were exposed alone to the test area for 15 min. This time the experimenter placed a grape into
167 a metal food bowl (20 cm in diameter and 5 cm in height), positioned out of the subjects’
168 view about 1 m away from the entrance of the test area when the subject was exploring the
169 resting area. The food reward was always put into the bowl on the side facing the entrance to
170 avoid visual cues. Additionally, the back of the bowl was covered with black tape to prevent
171 reflections of the food items. Subjects had to learn to approach the bowl and get the grape and
172 were forced afterwards to leave the test area into the resting area. This was repeated ten times
173 at minimum and for some individuals as long as they needed to approach the bowl
174 immediately, but with no more than 20 trials within a session.

175

176 *Training*

177

178 In a pilot study on social cues with pigs, subjects received no training trials and eight out of
179 11 subjects showed a strong side bias from the very first trial. To prevent this in the present
180 study, we introduced training trials to make subjects familiar with only one of the two bowls
181 being baited. On the first training day, two bowls were positioned 150 cm away from the

182 entrance and 60 cm apart from each other with the experimenter kneeling about 30 cm behind
183 the midline (see Fig. 1). When the subject entered the test area, the experimenter, holding a
184 grape in his hand, slowly moved his hand to one (sham baited) bowl and then to the second
185 (baited) bowl where he slowly released the reward. The subject was not constrained and free
186 to explore the whole procedure until it picked up the grape from the baited bowl. After it
187 found the food, the subject was slightly forced to go back into the resting area and was then
188 allowed to re-enter the test area. This was repeated ten times. On the second training day, the
189 distance between the two bowls was increased to 140 cm. The remaining procedure was the
190 same. Some individuals received a third training day, similar to the second. At the end of the
191 training, most individuals (four had to be excluded because they did not walk straight to a
192 bowl when they entered the test area) reliably followed the food item to the correct bowl and
193 no longer explored the one that was sham baited. Individuals received a maximum of 20 to 30
194 training trials, which is comparable to those used in similar studies with non-canid species
195 (Giret et al. 2009; Schmidt et al. 2010). Of the participating 18 subjects, 11 received two
196 training sessions and seven received three sessions. At the beginning of Experiment 1, all
197 subjects were seven weeks old.

198

199 ---

200 Figure 1

201 ---

202

203 **Experiment 1**

204

205 In the first experiment, we administered a standard testing procedure with four of the most
206 prominent human pointing gestures (i.e., dynamic-sustained and momentary, proximal and

207 distal pointing cues) previously applied to other species (Miklosi et al. 2005; Maros et al.
208 2008; Giret et al. 2009).

209

210 *Procedure*

211

212 Two bowls were placed 150 cm away from the entrance and 140 cm apart from each other
213 while the experimenter was in a kneeling position about 30 cm behind the midline (see Fig.
214 1). Before every test session, individuals received two training trials, one using the left and
215 one the right bowl to assure that they recognized that only one food bowl was baited. We
216 administered the following four conditions to the subjects (see Fig. 2):

217 Proximal dynamic-sustained pointing and gaze (PDS-G): The experimenter kneeled
218 between the two bowls and as soon as the subject entered the corridor, he pointed and turned
219 his head towards the baited bowl until the subject made a choice. The distance between the tip
220 of the index finger and the baited bowl was about 30 cm.

221 Proximal momentary pointing (PM): The experimenter kneeled between the two bowls
222 and as soon as the subject entered the corridor, he pointed towards the baited bowl for about
223 one second or as long as the subject was still in the corridor. Pigs never entered the test area
224 while the gesture was still being administered. The distance between the tip of the index
225 finger and the baited bowl was about 30 cm.

226 Distal dynamic-sustained pointing (DDS): The experimenter stood between the two
227 bowls and as soon as the subject entered the corridor, he pointed towards the baited bowl until
228 the subject made a choice. The distance between the tip of the index finger and the baited
229 bowl was about 80 cm.

230 Distal momentary pointing (DM): The experimenter stood between the two bowls and
231 as soon as the subject entered the corridor, he pointed towards the baited bowl for about one
232 second or as long as the subject was still in the corridor. Pigs never entered the test area while

233 the gesture was still being administered. The distance between the tip of the index finger and
234 the baited bowl was about 80 cm.

235 Each subject received five sessions on five consecutive days of 16 trials each and
236 every session consisted of four trials for each of the four conditions, resulting in 20 trials for
237 each condition in total. A single grape was used as reward. After a trial, subjects were slightly
238 pushed to leave the test area and the experimenter surreptitiously baited one of the bowls.
239 Reward side and cue type were counterbalanced across a session with the exception that no
240 side or cue type was used more than twice in a row. When pigs were distracted or not
241 motivated anymore, a session was terminated and completed the following day. If sessions
242 had to be terminated for two consecutive days, the subject was excluded from further testing.
243 If a subject had chosen one specific side six times in a row, two training trials to the opposite
244 side were introduced to prevent side biases.

245

246 ---

247 Figure 2

248 ---

249

250 *Data Scoring and Analysis*

251

252 All trials were coded live and were additionally videotaped. For individual data, binomial
253 tests were conducted. If a subject chose at least in 15 out of 20 trials the correct bowl, it was
254 counted as significant deviation from chance level ($P = 0.041$, one-tailed). Parametric
255 analyses (paired t-tests, repeated measures ANOVAs) were used when comparing the number
256 of correct trials between conditions. To test against chance level (50%) we used one sample t-
257 tests. We also analyzed whether pigs' choice behaviour was influenced by the amount of
258 finger touches of the experimenter, using correlations (see Riedel et al. 2008). All choices

259 could be classified unambiguously as correct or incorrect, so we did not calculate inter-
260 observer reliability.

261

262 *Results*

263

264 One individual refused to participate from the very first test session and was therefore
265 excluded, resulting in a sample size of 17 subjects. Two subjects ('R' and 'V') showed a
266 strong side bias by choosing the right bowl in 72 and 78 out of 80 trials. All other pigs
267 showed no particular preference for either the left or the right side. We found a significant
268 difference between test conditions ($F_{3,45} = 30.47$; $P < 0.001$) but no effect of sex ($F_{1,15} =$
269 0.003 ; $P = 0.96$) and no interaction between them ($F_{3,45} = 0.57$; $P = 0.64$). We therefore did
270 not analyze 'sex' as a variable any further. Bonferroni-corrected pair-wise comparisons
271 revealed that subjects as a group performed better in PDS-G trials compared to DM, DDS and
272 PM trials (all comparisons: $P < 0.001$). In addition, subjects' performance was better in PM
273 trials compared to DM and DDS trials (both comparisons: $P < 0.05$). No other differences
274 were found. Pigs as a group did not perform significantly better than chance (50%) in the
275 distal pointing trials (DM: $t_{16} = 1.71$; $P = 0.11$, DDS: $t_{16} = 1.66$; $P = 0.12$), but performed
276 above chance in the proximal pointing trials (PM: $t_{16} = 3.75$; $P = 0.002$ and PDS-G: $t_{16} = 9.53$;
277 $P < 0.001$; see Fig. 3). Analysis on an individual level confirmed this pattern. In the distal
278 trials no subject performed above chance level, whereas some did in PM (5 out of 17) and
279 PDS-G (14 out of 17) trials (see Electronic Supplementary Material). In the PDS-G trials, pigs
280 sometimes touched the index finger of the experimenter before making a choice (Mean \pm
281 SEM = 0.71 ± 0.29 ; $N = 17$) but no correlation with performance was found ($r_s = -0.06$; $N =$
282 17 ; $P = 0.81$). To control for learning effects, we compared the first ten against the last ten
283 trials of each condition but found no effect on performance in any of the four conditions
284 (paired t-tests; all $P > 0.05$).

285

286 ---

287 Figure 3

288 ---

289

290 **Experiment 2**

291

292 In the first experiment, pigs performed above chance with the two proximal cues but failed to
293 use the two distal cues. This is a surprising result, as dogs, cats (both Miklosi et al. 2005), and
294 horses (Maros et al. 2008; Proops et al. 2010) have been reported to be able to utilize distal
295 pointing cues. Given pigs' size and especially due to their rooting foraging ecology, we
296 assumed that they failed to use distal cues because the presentation was out of their range of
297 visual attention. Therefore we repeated the presentation of the two distal pointing cues (i.e.,
298 dynamic-sustained and momentary) in a kneeling position and increased the distance of the
299 bowls to maintain the distance between index finger and target bowl equal to that in the distal
300 conditions in Experiment 1.

301

302 *Procedure*

303

304 The same subjects as in Experiment 1 participated. Two bowls were placed 150 cm away
305 from the entrance and 280 cm apart from each other with the experimenter's position about 30
306 cm behind the midline (see Fig. 1). The distance between the tip of the index finger and the
307 baited bowl was always about 80 cm. All other circumstances were the same as in Experiment
308 1. We administered the following two gestures (see Fig. 2):

309 Distal dynamic-sustained pointing kneeling (DDS-K): The experimenter kneeled
310 between the two bowls and as soon as the subject entered the corridor, he pointed and turned
311 his head towards the baited bowl until the subject made a choice.

312 Distal momentary pointing kneeling (DM-K): The experimenter kneeled between the
313 two bowls and as soon as the subject entered the corridor, he pointed and turned his head
314 towards the baited bowl for about one second or as long as the subject was still in the corridor.
315 Pigs never entered the test area while the gesture was still being administered.

316 Each subject received two sessions of 20 trials, each session consisting of ten trials for
317 each of the two conditions, resulting in 20 trials for each condition in total. Reward side and
318 cue type were counterbalanced across a session except that no side or cue type was used more
319 than three times consecutively.

320

321 *Data Scoring and Analysis*

322

323 Data scoring and analysis were the same as in Experiment 1.

324

325 *Results*

326

327 Two subjects showed a lack of motivation during testing and were excluded resulting in a
328 sample size of 15 pigs. One subject ('V') showed a strong side bias, choosing the right bowl
329 in 39 out of 40 trials. All other pigs showed no particular preference for either the left or the
330 right side. Subjects as a group performed better in DDS-K compared to DM-K trials (paired t-
331 test; $t_{14} = -5.57$; $P < 0.001$). In addition, subjects as a group performed above chance (50%) in
332 both conditions (DM-K: $t_{14} = 4.17$; $P = 0.001$; DDS-K: $t_{14} = 11.63$; $P < 0.001$; see Fig. 3).

333 Individual analyses showed that in DM-K trials four out of 15 subjects and DDS-K trials 13
334 out of 15 subjects performed above chance level (see Electronic Supplementary Material). In

335 the DDS-K trials, pigs relatively often touched the index finger of the experimenter before
336 making a choice ($M \pm SEM = 2.33 \pm 0.61$; $N = 15$) but, as in Experiment 1, no correlation
337 with performance was found ($r_s = 0.21$; $N = 15$; $P = 0.45$). Comparing the first ten with the
338 last ten trials of every condition, we found that subjects' performance increased significantly
339 in DM-K ($t_{14} = -3.90$; $P = 0.002$) but not in DDS-K trials ($t_{14} = -0.52$; $P = 0.61$). Nonetheless,
340 subjects as a group were already performing above chance in the first ten DM-K trials ($t_{14} =$
341 2.674 ; $P = 0.018$).

342

343 **Experiment 3**

344

345 The two previous experiments showed that pigs performed above chance with different
346 pointing gestures. However, they might have used stimulus or local enhancement to solve the
347 tasks. To test this, we introduced two new conditions where the experimenter was always
348 close to one particular bowl.

349

350 *Procedure*

351

352 The experimenter positioned himself behind one of the bowls at a distance of about 30 cm.
353 The remaining setup was the same as in Experiment 1. We administered the following two
354 conditions (see Fig. 2):

355 Kneeling behind correct location (behind): The experimenter kneeled behind the
356 baited bowl and remained there without moving, looking straight at the entrance.

357 Pointing from incorrect location (incorrect): The experimenter kneeled behind the non-
358 baited bowl and as soon as the subject entered the corridor, he pointed and turned his head
359 towards the baited bowl until the subject made a choice. The distance between the tip of the

360 index finger and the baited bowl was about 80 cm. The tip of the index finger was always
361 closer to the incorrect bowl than to the correct one.

362 Each subject received two sessions of 20 trials. Each session consisted of ten trials for
363 each of the two conditions, resulting in 20 trials for each condition in total. Reward side and
364 cue type were counterbalanced across a session with the exception that no side or cue type
365 was provided more than three times consecutively. If pigs became distracted or ceased to be
366 motivated anymore, a session was terminated and completed the following day.

367

368 *Data Scoring and Analysis*

369

370 Data scoring and analysis were the same as in Experiment 1.

371

372 *Results*

373

374 The same subjects participated as in Experiment 2 but one refused to participate and was
375 therefore excluded. Therefore we analyzed the choice behaviour of 14 pigs. Two subjects ('Q'
376 and 'V') showed a strong side bias by choosing the right bowl in 37 and 39 out of 40 trials.

377 All other pigs showed no particular preference for either the left or the right side. Comparing
378 the test conditions, subjects performed better in the behind condition compared to the
379 incorrect condition (paired t-test: $t_{13} = 4.69$; $P < 0.001$). In addition, subjects as a group
380 performed significantly above chance level in the behind ($t_{13} = 7.65$; $P < 0.001$) but not the
381 incorrect condition ($t_{13} = -0.55$; $P = 0.59$). Individual data confirmed these finding, since nine
382 out of 14 subjects performed above chance in the behind condition whereas only one subject
383 did so in the incorrect condition (see Electronic Supplementary Material). Although subjects
384 improved their performance in the second half of the incorrect condition ($t_{13} = -2.24$; $P =$

385 0.043), they still did not perform above chance level in the second half of trials in this
386 condition ($P > 0.05$). There was no change of performance in the behind condition ($P > 0.05$).

387

388 **Experiment 4**

389

390 In the first experiment, subjects were able to utilize a proximal dynamic-sustained pointing
391 that was coupled with a head cue. To investigate if pigs would use the pointing cue or the
392 head orientation alone, they were tested with three new conditions, involving proximal
393 pointing, body and head orientation.

394

395 *Procedure*

396

397 The procedure was the same as in Experiment 1. We administered the following three
398 gestures (see Fig. 2):

399 Proximal dynamic-sustained pointing (PSD): The experimenter kneeled between the
400 two bowls and as soon as the subject entered the corridor, he pointed towards the baited bowl
401 until the subject made a choice, but remained looking straight forward. The distance between
402 the tip of the index finger and the baited bowl was about 30 cm.

403 Body orientation (Body): The experimenter was kneeled between the two bowls and as
404 soon as the subject entered the corridor, he oriented his body and head towards the baited
405 bowl until the subject made a choice. The distance between the experimenter's face and the
406 baited bowl was about 100 cm. As the experimenter turned his whole body in a kneeling
407 position towards the bowl, this gesture had similarities to a pointing gesture with the knee.
408 The distance between the experimenter's knee and the baited bowl was about 70 cm, whereas
409 the distance to the incorrect bowl was about 75 cm.

410 Head orientation (Head): The experimenter was kneeled between the two bowls and as
411 soon as the subject entered the corridor, he turned his head towards the baited bowl until the
412 subject made a choice. The distance between the experimenter’s face and the baited bowl was
413 about 100 cm.

414 Each subject received three consecutive sessions with 20 trials each and each session
415 consisted of six trials for each of the three conditions, resulting in 18 trials for each condition.
416 In a fourth session, six test trials (two for each condition) were administered, resulting in a
417 total of 20 trials for each condition. In addition, 12 control trials were presented after the test
418 conditions in the fourth session. In those no cue at all was provided. We presented the control
419 condition *en bloc* because previous pilot tests showed that subjects are likely to develop side
420 biases when no cue at all was provided during test sessions. We administered the control trials
421 to all subjects that participated in Experiment 1. If their motivation faded, this was done
422 across two sessions. Side and cue type were counterbalanced across a session with the
423 exception that no side or cue type was provided more than twice in a row. If pigs became
424 distracted or ceased to be motivated anymore, a session was terminated and completed the
425 following day.

426

427 *Data Scoring and Analysis*

428

429 Data scoring and analysis were the same as in Experiment 1.

430

431 *Results*

432

433 The same subjects as in Experiment 3 participated but one showed a lack of motivation during
434 testing and was excluded. We therefore analyzed the choice behaviour of 13 pigs. One subject
435 (‘V’) showed a strong side bias, choosing the right bowl in 58 out of 60 trials.

436 We found a significant effect of condition ($F_{2,24} = 27.37$; $P < 0.001$). Bonferroni-corrected
437 pair-wise comparison revealed that subjects as a group performed better in PDS trials
438 compared to Body and Head trials (both comparisons: $P < 0.001$). There was no difference
439 between the Body and the Head condition ($P = 0.69$). Subjects as a group performed above
440 chance in all three conditions (PDS: $t_{12} = 15.03$; $P < 0.001$; Body: $t_{12} = 4.15$; $P = 0.001$; Head:
441 $t_{12} = 2.84$; $P = 0.015$; see Fig. 3). Twelve out of 13 subjects performed above chance in the
442 PDS trials, whereas five and three respectively did so in the Body and Head condition (see
443 Electronic Supplementary Material). In PDS trials, none of the subjects touched the index
444 finger first. Comparing the first half with the last half of trials, performance did not change in
445 Body and Head trials (Body: $t_{12} = 0.86$; $P = 0.408$, Head: $t_{12} = 0.19$; $P = 0.85$). However,
446 subjects' performance improved in PDS trials ($t_{12} = -2.31$; $P = 0.04$), but they were already
447 choosing above chance level in the first ten trials ($t_{12} = 14.1$; $P < 0.001$).

448

449 *Control*

450

451 We administered twelve control trials to 16 subjects (see Table 1) to rule out that other factors
452 (e.g. odour cues) that might have affected subjects' choice behaviour. In these trials, the
453 experimenter was kneeling motionless between the two bowls looking straight forward. One
454 subject ('Q') refused to participate due to a lack of motivation. In control trials, none of the
455 pigs performed above chance at an individual level. As a group ($N = 16$), pigs' performance
456 did not differ from chance ($t_{15} = -0.79$; $P = 0.44$).

457

458 **Experiment 5**

459

460 Since Experiment 4 showed that subjects were able to utilize body and head orientation to
461 find a reward when given the choice between two bowls, it was now investigated whether

462 subjects would follow the experimenter's body and head orientation into distant space.
463 Several species, from primates to reptiles (e.g. apes: Tomasello et al. 1998; goats: Kaminski et
464 al. 2005; tortoises: Wilkinson et al. 2010), have been shown to be capable of following the
465 gaze of a con- or heterospecific into distant space. Surprisingly, despite their skillful
466 comprehension of human-given cues, dogs failed in such tasks (Agnetta et al. 2000) and,
467 indeed, studies on other species showed that the mechanism for gaze following and the
468 spontaneous use of gaze in a food related object choice task may be of different origin or at be
469 least context dependent (Kaminski et al. 2005; Schloegl et al. 2007; Schloegl et al. 2008;
470 Rosati and Hare 2009).

471

472 *Procedure*

473

474 No bowls or food were present. All subjects received only a single trial in each of the
475 following three conditions:

476 Body orientation: The experimenter was kneeling at the same place as in Experiment 4
477 and as soon as the subject entered the corridor, he turned his body and head to the left.

478 Head orientation: The experimenter was kneeling at the same place as in Experiment 4
479 and as soon as the subject entered the corridor, he turned his head to the left.

480 Control: The experimenter was kneeling at the same place as in Experiment 4 and
481 remained without moving, looking straight towards the entrance.

482 The order of the conditions was counterbalanced between subjects.

483

484 *Data Scoring and Analysis*

485

486 All trials were videotaped for further analysis. We scored whether subjects initially moved to
487 the left or the right half of the test area. In addition, we scored whether subjects started to

488 show foraging behaviour (snout on ground), either on the left or the right side of the area. A
489 trial ended once the subject was begging for food from the experimenter and was physically
490 interacting with him. We used this as an indicator that the subject was still paying attention to
491 the experimenter and was not distracted. The time between the subject entering the area and
492 the finishing of the trial was recorded and analyzed with Interact[®]. As these approach time
493 data were positively skewed they were \log_{10} transformed. Chi-square tests were used to
494 analyze whether subjects behaved differently in their initial movement or foraging side during
495 the three different conditions. An ANOVA was run to analyze potential effects of condition
496 and trial number on the approach times.

497

498 *Results*

499

500 We tested all 18 individuals but five of them had to be excluded because they lacked
501 motivation to enter the area or were not eager to interact with the experimenter after entering
502 the test area. We found no differences in subjects' initial movement or foraging side between
503 the three conditions (movement left side: Body: $n = 5$; Head: $n = 4$; Control: $n = 5$; $\chi^2 = .223$;
504 $P = 0.895$; movement right side: Body: $n = 4$; Head: $n = 8$; Control: $n = 6$; $\chi^2 = 2.476$; $P =$
505 0.290 ; forage left side: Body: $n = 2$; Head: $n = 3$; Control: $n = 3$; $\chi^2 = .315$; $P = 0.854$; forage
506 right side: Body: $n = 2$; Head: $n = 6$; Control: $n = 4$; $\chi^2 = 2.889$; $P = 0.236$). The discrepancies
507 to the sum of 13 are explained by trials in which subjects approached the experimenter
508 immediately after entering the test area.

509 Approach times differed significantly between conditions ($F_{2,10} = 4.330$; $P = 0.022$;
510 Mean Log response times \pm SEM: Body: $0.52 \text{ s} \pm 0.04$; Head: $0.61 \text{ s} \pm 0.04$, Control: $0.44 \text{ s} \pm$
511 0.05 ; $N = 13$), but neither an effect of trial number or an interaction of trial number and
512 condition was found (both $P > 0.05$). A Bonferroni-corrected post-hoc comparison showed

513 that approach times only differed significantly between the Head and the Control condition (P
514 = 0.028), suggesting longer search times in the Head condition.

515 **General Discussion**

516

517 Experiments 1 and 2 showed that pigs are able to use proximal momentary and dynamic-
518 sustained pointing cues from the start and also utilized distal momentary and dynamic-
519 sustained pointing cues when the experimenter was in a kneeling position. If he was in a
520 standing position, pigs' performance was at chance level. In Experiment 3, pigs were
521 successful when the experimenter was kneeling behind the correct bowl. Nonetheless, when
522 the experimenter pointed from the incorrect bowl towards the correct one, pigs as a group
523 performed at chance level. However, one individual performed significantly above chance in
524 this condition, suggesting that local enhancement alone may not explain this subject's
525 performance. Experiment 4 revealed that pigs were also able to use body and head orientation
526 to locate the baited bowl. Subsequent control trials ruled out other factors (i.e. odour cues)
527 might have affected subjects' choice behaviour. The individual data confirmed findings at
528 group level in all test conditions. Finally, subjects in Experiment 5 failed to utilize head and
529 body directions when gaze was directed into distant space and no reward was involved.
530 Interestingly, we found a significant difference in response times suggesting longer search
531 times in the head condition than in the control condition. However, we cannot conclude that
532 this time difference was due to subjects following the gaze direction. Pigs may have simply
533 experienced the position of the experimenter in the control trials as more familiar and
534 therefore approached the experimenter faster than in the test conditions. Alternatively, they
535 could also have recognized that the experimenter's attention was directed towards them
536 (Nawroth et al. 2013).

537 Our results are in contrast to the results of Albiach-Serrano and colleagues (2012) who
538 found no evidence that domestic pigs are able to use a particular human-given cue to find a
539 hidden reward. As mentioned in the introduction, one factor may be the different setup of the
540 task. Subjects in Albiach-Serrano et al.'s study were separated from the experimenter by a

541 mesh, whereas in our study subjects were free to choose one of the options without a physical
542 barrier. The use of a mesh has been criticized in a study with dogs (Udell et al. 2008) as a
543 partial visual barrier might distract subjects and therefore decrease performance. Another
544 difference between our study and that of Albiach-Serrano et al. (2012) concerns the way the
545 various cues were presented. Albiach-Serrano and colleagues used alternating pointing and
546 gaze (plus head) cues, whereas in our study we used momentary and dynamic-sustained
547 pointing cues and dynamic-sustained sustained gaze (plus head) cues. Obviously, comparing
548 the results of different object choice studies, a slightly different way of cue presentation can
549 lead to different results – as also shown in several studies on primates (see Mulcahy and Call
550 2009; Mulcahy and Hedge 2011) and in the differences of our results from Experiment 1 and
551 Experiment 2. So a lack of evidence for some species to follow distal pointing gestures, either
552 momentary or dynamic-sustained, may be due to an unsuccessful adoption of common test
553 paradigms to the physiologically needs and constraints of different species.

554 Surprisingly, Albiach-Serrano et al. (2012) found that wild boar were able to use a
555 pointing gesture to find hidden food. The authors speculated that the wild boar were
556 successful in using this gesture because people often threw food into their enclosure -
557 performing a gesture that potentially resembles pointing. An alternative explanation for the
558 different performances between the domestic pig and the wild boar in this study refers to
559 differences in the amount of training trials between the wild boars and the domestic pigs –
560 with wild boars receiving a larger amount of training trials than domestic pigs (mean of 12.57
561 vs. 4.66 trials). Their wild boars thus could have simply used a learned food-hand-association
562 from training trials to succeed in later test trials. Because each subject only received four test
563 trials in each condition, a meaningful analysis for learning effects during training and testing
564 was not available, but could possibly explain the different performances between wild boar
565 and domestic pig.

566 In our study, general learning effects during testing occurred in only three out of the
567 eleven conditions (Exp. 2: distal momentary pointing in kneeling position; Exp.3: pointing
568 from incorrect position; Exp. 4: proximal dynamic-sustained pointing). In two of these
569 conditions (Exp. 2: distal momentary pointing in kneeling position; Exp. 4: proximal
570 dynamic-sustained pointing) subjects were already performing above chance during the first
571 ten trials whereas in the third condition (incorrect) they did not perform above chance overall.
572 Due to the sequential presentation of test conditions we cannot rule out the possibility of
573 learning over the course of the experiments. One might, for instance, interpret the better
574 performance of subjects in the proximal dynamic-sustained pointing in Experiment 4
575 compared to Experiment 1 as learning over experiments. Another explanation for the apparent
576 increase in performance would be that, as some less motivated subjects had to be excluded
577 over the course of the study, only the motivated remained, and they were probably more
578 focused on the tasks. Alternatively, subjects might have become calmer over the course of the
579 experiments, got less excited and playful and were therefore more focused on the task, as
580 personal observations suggest.

581 Although the tested subjects were at a very young age (seven weeks at the beginning
582 of Experiment 1) and had very restricted contact and handling experience with humans before
583 training began, they had some opportunity to associate the experimenter's hand and head with
584 the baited bowl during, or even prior to the training sessions. If subjects simply learned a
585 food-hand-association during the 20-30 training trials they received, one would expect that
586 performance would increase in the first test sessions, and also that subjects would frequently
587 inspect the hand/index finger before making a choice. Interestingly, we found no increase in
588 performance in any condition in Experiment 1. Additionally, as in Riedel et al. (2008), we
589 found no correlation between subjects touching the index finger first and their success rate in
590 Experiment 1 and 2. Prior contact to humans was not avoidable since, without proper
591 habituation and training, young pigs would be too fearful to participate in a task with a human

592 experimenter and would probably lack an understanding that only one of the two bowls was
593 baited.

594 Pigs in our study still approached the index finger relatively often before making a
595 choice in the distal dynamic-sustained kneeling as well as in the proximal dynamic-sustained
596 pointing, suggesting that a form of stimulus/local enhancement or learned food-hand-
597 associations have been additional influencing factors even though there was no correlation
598 between finger contact and performance across the group. The results of Experiment 3 point
599 into the same direction by indicating that pigs had problems in choosing correctly when the
600 experimenter was behind the incorrect target while pointing at the correct one. The same
601 mechanisms have been suggested for the performances of goats (Kaminski et al. 2005) and
602 horses (Proops et al. 2010). Interestingly, our pigs were able to utilize the head direction of
603 the experimenter – a finding that cannot be explained by stimulus/local enhancement effects
604 or a learned association between the experimenter’s hand and a food item.

605 Finally, we will consider several potential explanations for the fact that our results
606 show the use of body and especially head orientation in an object choice task by juvenile pigs.
607 In the case of body orientation, the experimenter’s knee was slightly closer to the baited than
608 to the unbaited bowl, resembling a pointing gesture and making it therefore more prone to
609 stimulus/local enhancement effects. However, these effects cannot explain the use of the head
610 direction to infer the baited target.

611 In the case of head orientation, a change in the head direction of a con- or
612 heterospecific is a very subtle cue and recognizing it can be difficult – especially for pigs,
613 which are known to have a poorer visual acuity than human and dogs (Zonderland et al.
614 2008). In previous studies, goats (Kaminski et al. 2005), horses (Proops et al. 2010) and
615 domestic pigs (Albiach-Serrano et al. 2012) failed to use the head orientation of an
616 experimenter to infer the location of a reward. But unlike the pigs in the present study, the
617 subjects in these experiments completed only one experiment with various cues in a

618 randomized order and received fewer test trials in each condition (goats: 16 trials; horses: a
619 single trial; domestic pigs: four trials). Thus, pigs in our study may have gained sufficient
620 experience with pointing and head cues due to the sequential presentation of experiments (in
621 contrast to the of procedures of Kaminski et al. 2005, Proops et al. 2010, Albiach-Serrano et
622 al. 2012) and one may argue that pigs in Experiment 4 had learned the head direction of the
623 experimenter as a cue indicating the baited bowl as it was presented with a dynamic-sustained
624 pointing gesture in the prior Experiments 1 and 3. However, the fact that no learning effect
625 was found in the head or in the body condition of Experiment 4 when comparing the first
626 against the last half of trials in both conditions contradicts this assumption.

627 Another explanation for the use of a human's head direction would be that domestic
628 pigs and dogs (and their wild relatives), as well as other species that seem to be able to use the
629 head direction in this test paradigm, share specific similarities in their social structure that
630 made it to an adaptive advantage to follow the head or body direction of conspecifics in
631 certain contexts. This, in turn, may have increased their adaption to utilizing head cues given
632 by heterospecifics such as humans. Wolves and wild boar live in stable groups and rely on
633 more or less patchily distributed food sources. This can, in the case of wolves/dogs, lead to an
634 increase in cooperative behaviour that is, for instance, needed to hunt down big prey (Mech
635 2007; but see Muro et al. 2011). And indeed, a recent study suggests that wolves are capable
636 of following the gaze direction of conspecifics (Range and Virányi 2011). However, the
637 results for dogs are ambiguous (Agnetta et al. 2000).

638 Unfortunately, there are no experimental studies examining cooperative or competitive
639 behaviour in wild boar but domestic pigs seem to have retained the foraging behaviour of
640 their wild ancestors (Wood-Gush et al. 1990). Studies on domestic pigs investigating the
641 exploitation of subdominant conspecifics by dominant subjects indicate that the subdominant
642 pig takes into account the body orientation of the dominant individual while foraging (Held et

643 al. 2002). In another study by Held and colleagues (2001), one tested pig appeared to be able
644 to take the visual perspective of its conspecifics.

645 For the pointing gestures, stimulus/local enhancement seems relevant for explaining
646 our results but we cannot exclude the possibility that domestication processes have influenced
647 pigs' decision making and, for example, a decreased emotional reactivity, expressed in
648 reduced aggressiveness and fear against humans, may have improved their ability to utilize
649 the presented pointing gestures (Hare et al. 2002; Hare and Tomasello 2005; Hernádi et al.
650 2012). Hence a comparison with the domestic pig's closest relative, the wild boar, in a similar
651 test setup would be of advantage for investigating the potential influence of general
652 domestication processes (Hernádi et al. 2012). Furthermore, there is still restricted knowledge
653 about the utilization of human-given cues in other domesticated species and their wild
654 counterparts, including cattle and poultry. Keeping in mind handling problems in future object
655 choice studies, our test setup (a test area with a corridor at the entrance) proved to be useful
656 for animals that cannot be restricted by hand (see also Kaminski et al. 2005). The question
657 remains whether pigs only used stimulus enhancement and associative learning processes or if
658 they were able to comprehend the communicative nature of some of the human-given cues
659 presented (i.e., body and head direction), as is partially suggested by our results.

660 We conclude that domestic pigs, even at a very young age, are skillful in utilizing
661 human-given cues in an object choice task, including the body and head orientation of
662 humans, making them therefore a suitable species for further research in socio-cognitive
663 studies, especially with regard to human-animal interactions and effects of domestication.

664 **Ethical note**

665

666 The experiments were carried out at facilities of the Institute of Agricultural and Nutritional
667 Sciences of the University of Halle-Wittenberg under license of the regional veterinary
668 control board. Housing facilities met the German welfare requirements for farm animals.

669 **Acknowledgment**

670

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777 **Tables**

778

779 **Table 1** List of subjects. Numbers represent the experiments a subject participated in. C = control
780 trials (administered *en bloc* at the end of Experiment 4)

781 **Figures**

782

783 **Fig. 1** Measurements of the test area. E represents the position of the experimenter in training trials
784 and in Experiment 1, 2, 4 and 5. T1: Distance of bowls at first day of training; E1: Distance of bowls
785 at second/third day of training and in Experiment 1, 3, 4 and in control trials; E2: Distance of bowls in
786 Experiment 2

787

788 **Fig. 2** Images of the different human-given cues: A) PDS-G (proximal dynamic-sustained pointing
789 and gaze) B) PM (proximal momentary pointing) C) DM (distal momentary pointing) and DDS (distal
790 dynamic-sustained pointing) D) DM-K (distal momentary pointing kneeling) and DDS-K (distal
791 dynamic-sustained pointing kneeling) E) behind (E behind correct bowl) F) incorrect (E behind
792 incorrect bowl, dynamic-sustained pointing and gazing at correct bowl) G) PDS (proximal dynamic-
793 sustained pointing) H) Body (dynamic-sustained body and head orientation) I) Head (dynamic-
794 sustained head orientation)

795

796 **Fig. 3** Mean correct choices. Numbers indicate the amount of subjects that performed above chance on
797 an individual level compared to the total number of subjects participating; DM = distal momentary
798 pointing; DDS = distal dynamic-sustained pointing; PM = proximal momentary pointing; PDS-G =
799 proximal dynamic-sustained pointing and gaze; DM-K = distal momentary pointing kneeling; DDS-K
800 = distal dynamic-sustained pointing kneeling; behind = E behind correct bowl; incorrect = E behind
801 incorrect bowl, dynamic-sustained pointing and gazing at correct bowl; PDS = proximal dynamic-
802 sustained pointing; Body = dynamic-sustained body orientation; Head = dynamic-sustained head
803 orientation; dashed line represents chance level; error bars represent standard errors ; * P < .05, ** P <
804 .001