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Christian Nawroth

*Martin Luther Universitat Halle-Wittenberg*

Mirjam Ebersbach

*University of Kassel*

Eberhard von Borell

*Martin Luther Universitat Halle-Wittenberg*

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

3 Christian Nawroth\*<sup>1</sup>, Mirjam Ebersbach<sup>2</sup>, Eberhard von Borell<sup>1</sup>

4 <sup>1</sup>*Department of Animal Husbandry & Ecology, Institute of Agricultural and Nutritional*  
5 *Sciences, Martin-Luther-University, Halle, GER*

6 <sup>2</sup>*Department of Developmental Psychology, Institute of Psychology, University of Kassel,*  
7 *Kassel, GER*

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10 **Corresponding author**

11 Christian Nawroth

12 Department of Animal Husbandry & Ecology

13 Institute of Agricultural and Nutritional Sciences

14 Theodor-Lieser-Str. 11

15 06120 Halle, Germany

16 Phone: +49-345-5522336

17 Fax: +49-345-5527106

18 Email address: nawroth.christian@gmail.com

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 =  $0.71 \pm 0.29$ ;  $N = 17$ ) 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<sup>®</sup>. 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.

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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  $.001$