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### **Behaviour of pre-pubertal gilts and its relationship to farrowing behaviour in conventional farrowing crates and loose-housed pens**

Ison, SH; Wood, CM; Baxter, EM

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1 **Highlights**

- 2 • The ability to select gilts to perform well in free-farrowing systems would be a major advantage.
- 3 • This study investigated gilt behaviour in pre-pubertal temperament tests (human interaction  
4 and startle/novel object tests) and farrowing behaviour in a loose-farrowing system and  
5 conventional farrowing crates.
- 6 • Gilt behaviour in pre-pubertal tests was influenced by first test type experienced.
- 7 • Piglet-directed aggression at farrowing was lower in loose-farrowing pens compared with  
8 conventional crates.
- 9 • Gilts showing severe piglet-directed aggression at farrowing tended to make more contact with  
10 the human and the object during the first pre-pubertal test.
- 11 • Gilts that crushed one or more piglets were slower to contact the human and the object during  
12 the first pre-pubertal test.

13

14 **Behaviour of pre-pubertal gilts and its relationship to farrowing behaviour in conventional farrowing**  
15 **crates and loose-housed pens**

16 Sarah H. Ison<sup>a,\*</sup>, Cynthia M. Wood<sup>b</sup> and Emma M. Baxter<sup>a</sup>

17 <sup>a</sup>Scotland's Rural College (SRUC), Animal Behaviour & Welfare, Animal & Veterinary Sciences Group,  
18 Roslin Institute Building, Easter Bush, Midlothian EH25 9RG

19 <sup>b</sup>Virginia Polytechnic Institute and State University, Department of Animal and Poultry Sciences,  
20 Blacksburg 24061

21 \*Corresponding author:

22 Email: [Sarah.Ison@sruc.ac.uk](mailto:Sarah.Ison@sruc.ac.uk)

23 Tel: +44 (0)131 6519292

24 Fax: +44 (0)131 5353121

25 ABSTRACT

26 Individual variation in the reproductive performance of sows has the potential for greater negative  
27 impacts in loose-farrowing systems. Therefore, the ability to select gilts that will perform well would be  
28 a major advantage. This study investigated the behaviour of gilts during pre-pubertal tests and farrowing  
29 behaviour in conventional crates and PigSAFE (Piglet and Sow Alternative Farrowing Environment) pens.  
30 Gilts underwent two phases of behavioural testing. Firstly, gilts were subjected to three individual  
31 human interaction and three startle object tests randomly allocated to test sessions over 3 days (i.e. gilts  
32 had either a human or startle test first). Three weeks later, gilts underwent three human interaction and  
33 three novel object tests, in their stable group of six. Gilts farrowed in individual PigSAFE pens or  
34 conventional crates and behaviour was observed for 8 hours from the first piglet birth. Data were  
35 analysed using linear mixed models and Spearman's rank correlations. A novel finding was the effect of  
36 individual test order: gilts that had the human interaction or startle object test first behaved differently.  
37 The first test was different whichever test type, with a higher latency to interact with the object or  
38 human, and gilts experiencing the startle test first interacted more with the human in all three  
39 subsequent tests. Gilts farrowing in crates and pens showed differences in behaviour, most notably, a  
40 lower frequency of piglet-directed aggression was seen in pens ( $P < 0.05$ ). Piglet-directed aggression was  
41 studied further by comparing gilts that exhibited no aggression, to those showing aggressive behaviour,  
42 but no injurious biting, to those causing injury or death. This latter severely aggressive group spent more  
43 time alert, piglet focused and standing ( $P < 0.05$ ) compared with the other two groups and tended to  
44 show greater ( $P < 0.1$ ) contact duration in the first individual pre-pubertal test. Gilts that crushed one or  
45 more piglets were slower ( $P = 0.038$ ) to contact either the human or startle object in the first individual  
46 test, than those that did not crush. The impact of first individual test on behaviour in subsequent tests  
47 indicates that previous test experience could be influencing subsequent behaviour. Differences in gilts

48 showing severe piglet-directed aggression and between 'crushers' and 'non-crushers' suggests that it  
49 could be possible to use pre-pubertal behaviour to predict maternal ability.

50

51 *Keywords:* Pigs; Behavioural tests; Free farrowing; Maternal behaviour; Savaging; Temperament

## 52 1. Introduction

53 Enclosing sows in crates during farrowing and lactation remains a welfare issue. Despite a  
54 growing body of research into alternatives (for reviews see: Baxter et al., 2012; Edwards and Fraser,  
55 1997), no large-scale commercial uptake of crate-free systems on indoor pig farms has occurred, other  
56 than in countries where the farrowing crate is banned (Sweden, Switzerland and Norway). The piglet  
57 and sow alternative farrowing environment or PigSAFE pen is a crate-free system, designed to improve  
58 sow welfare, whilst ensuring ease of management, piglet survival and commercial viability (Baxter et al.,  
59 2015, 2011). Results show that the PigSAFE pen produces production figures comparable to those of  
60 conventional farrowing crates (Edwards et al., 2012). However, individual variation in sow performance  
61 is evident with some individuals performing well, with no pre-weaning losses, whereas others produce  
62 high losses (Baxter et al., 2015).

63 Loose farrowing systems for sows have to be robust enough to cope with individual variation or  
64 sensitivity. Thodberg et al. (2002) showed that behaviour during nest-building and farrowing is related  
65 to the general reaction pattern during stress, especially in inexperienced gilts. They also showed that the  
66 performance reflects an innate pattern of reaction in the individual that can be modified by the  
67 environment and previous experience. Another study demonstrated that gilts that savaged their piglets  
68 during farrowing were more likely to show 'shy' behaviour during a pre-farrowing human approach test  
69 (Marchant-Forde, 2002). Sow behaviour during gestation has been related to farrowing behaviour and  
70 piglet survival (Lensink et al., 2009a) and gilt behaviour at six months old was shown to be related to  
71 farrowing and performance (Lensink et al., 2009b). However, in these studies several correlations were  
72 performed and those that were significant were low, ranging in  $r_s$  value from -0.19 to 0.29 between  
73 behaviour during gestation and farrowing (Lensink et al., 2009b) and -0.27 and 0.41 between behaviour  
74 at six months old with farrowing behaviour and performance (Lensink et al., 2009a). Therefore, the

75 authors of these studies concluded that the value of pre-parturition behaviour in predicting farrowing  
76 success was not clear and further study is needed. In order to accurately assess temperament, the  
77 criteria outlined by Jensen (1995) need to be fulfilled, individuals must: 1) show consistency in reaction  
78 when exposed to the same situation; 2) show consistency in reaction across different situations; 3) show  
79 a bimodal distribution of responses; and 4) a genetic basis for differences in response must be  
80 demonstrated.

81           If temperament can be successfully assessed and associated with farrowing behaviour, it could  
82 be a useful tool in selecting breeding animals for loose-farrowing systems. This study investigated  
83 behaviour of gilts during a set of pre-pubertal tests, and then farrowing behaviour was studied as gilts  
84 went on to farrow in either conventional farrowing crates or PigSAFE pens.

## 85 **2. Materials and Methods**

### 86 *2.1. Animals and experimental procedure*

87           All experimental procedures were carried out in compliance with EU Directive 86/609/EEC and  
88 were approved by the SRUC Animal Welfare Ethical Review Body (AWERB) before any experiments took  
89 place. Twenty-four home bred Large White x Landrace primiparous sows (hereafter, gilts), housed in  
90 four groups of six at the SRUC pig research farm in Midlothian, UK were used for this experiment.  
91 Initially gilts were housed in their stable groups of six individuals in the commercial finisher shed where  
92 they underwent two phases of behavioural testing. The first of these consisted of six tests where the gilt  
93 was tested alone (hereafter referred to as individual tests), including three human interaction and three  
94 startle object tests, with two tests per day; one in a morning and one in an afternoon session on three  
95 days at approximately 20 weeks of age. The second phase consisted of six tests which the gilts  
96 underwent in their stable group of six (hereafter referred to as stable group tests), again with two tests  
97 per day; one in a morning and one in an afternoon session on three days at approximately 23 weeks of

98 age. At around 25 weeks old, gilts were moved in their groups of six to dry sow accommodation  
99 consisting of a straw-bedded area, a dunging passageway and six individual feeding stalls. At around 8  
100 months old, the gilts were artificially inseminated and farrowed in either PigSAFE pens (groups 1 and 4,  
101 n = 10) or conventional farrowing crates (groups 2 and 3, n = 11) (for full pen specifications, see Baxter  
102 et al., 2015). Of the 24 gilts tested, two did not hold service (i.e. were not pregnant), so did not go on to  
103 the second part of the study and due to a power failure, farrowing behaviour is missing for one gilt.

## 104 *2.2 Individual Tests*

105           Groups 1 and 2, and groups 3 and 4 were tested in two separate batches in October 2009 and  
106 January 2010 respectively. Gilts underwent three human interaction and three startle object tests  
107 randomly split across three days of the week with a day off in between test days, i.e. each gilt had one  
108 test in the morning and one in the afternoon on all of the test days (two tests per day), with a random  
109 order of test type (e.g. human-startle-human-startle-startle-human, or any other combination in the six  
110 test sessions). Therefore, gilts either had a human interaction (n = 15) or startle object (n = 9) test first  
111 on the morning of the first test day. In both morning and afternoon sessions across the three days gilts  
112 from either groups' 1 or 2, or 3 or 4 depending on the test session were alternated for consecutive tests.  
113 The test pen for both tests consisted of an empty finisher pen (solid on 3 sides, with metal bars at the  
114 back, with no view of other pigs, measuring 3.75 × 2.35 m) located in the same room in the finisher  
115 house where the gilts were initially housed. Prior to testing, gilts were habituated to a camera and  
116 tripod placed outside their home pen in the days preceding the tests, but gilts were not habituated to  
117 the test pen or testing routine. Muck was removed and the pen swept down between each test.

118           For the human interaction test, the individual gilt was moved into the test pen, the human  
119 interactor then climbed into the pen and knelt down in a central position. The test was started when the  
120 human was in position and lasted five minutes, before the gilt was returned to her home pen. Evidence



121 suggests that pigs discriminate between familiar and unfamiliar humans using visual cues, including the  
122 colour of overalls worn (Koba and Tanida, 1999). Therefore, the human interactor in this study wore red  
123 overalls, which was different from the blue overalls routinely worn by stock-people and research staff  
124 on the farm.

125 For the startle object test, an orange bucket was hung on a rope from a pulley system above the  
126 centre of the pen. The bucket was pulled towards the ceiling for the start of the test. When ready to  
127 start, the test gilt was moved from the home pen towards the test pen and as she crossed into the pen,  
128 the bucket was dropped to hit the floor after which, it was immediately raised slightly and the rope tied  
129 to leave the bucket hanging approximately 30 centimetres from the floor. The rope was marked to  
130 indicate the height at which to hang the bucket. When the bucket was dropped, the stopwatch was  
131 started and timed for five minutes after which, the bucket was raised and the gilt returned to her home  
132 pen.

### 133 *2.3. Stable Group Tests*

134 Two weeks later, gilts underwent stable-group testing, again consisting of three test days across  
135 a week with a day off in between each test day as before. Gilts underwent three human interaction and  
136 three novel object tests randomly split over the three days. The same test pen was used and the tests  
137 were video recorded as before.

138 The human interaction test was similar to the individual tests. Each group of gilts was moved  
139 into the test pen, the human interactor then climbed in from the neighbouring pen, and stayed in a  
140 kneeling position in the centre. After five minutes, the human left the pen, and the gilts were returned  
141 to their home pen. For the novel object test, an orange and white life-saving ring was attached using  
142 chains to the bars at the back of the pen, before the gilts were moved into the test pen. The gilts were

143 then moved into the test pen for five minutes and then returned to their home pen. The novel object  
144 was cleaned between tests.

#### 145 *2.4. Test Behaviour*

146 All five minute tests were recorded onto DV tape or SD card using either a Canon XM2 or Canon  
147 Legria placed on a tripod behind the test pen. Continuous focal observations of gilt behaviour during  
148 tests were conducted using The Observer 9.0 XT (Noldus Information Technology, Wageningen, The  
149 Netherlands). The duration of contact with the human or object, the latency to contact, and the  
150 frequency of contacts were recorded, along with the frequency to contact (nose or root) other parts of  
151 the test pen.

#### 152 *2.5. Behaviour at Farrowing*

153 At no more than five days before the expected farrowing date, gilts were moved into their  
154 farrowing accommodation. Groups 1 and 4 farrowed in PigSAFE pens, and groups 2 and 3 in  
155 conventional farrowing crates. Closed-circuit television (CCTV) cameras (LL20, infra-red cameras, RF  
156 concepts, Ireland) were mounted above the pens or crates to record behaviour using GeoVision Digital  
157 Surveillance System software (ezCCTV Ltd, Herts, UK). Continuous focal observations were made of gilts  
158 for 8 hours from the birth of the first piglet using The Observer XT 9.0. Behaviour recorded included the  
159 duration of postures (stand, sit, kneel, lie lateral, lie ventral) and general behaviour, including alert, idle,  
160 piglet focused (head and/or ears orientated towards a piglet), straw/floor focused (nosing/rooting the  
161 floor/straw). Frequencies of attack/snap behaviour (aggressive interaction towards piglet, without  
162 damaging contact), bite (aggressive interaction towards piglet, with damaging contact) and nose (the  
163 snout makes contact with a piglet) were also recorded.

#### 164 *2.6. Data analysis*

165 Data were analysed using Genstat 11<sup>th</sup> Edition and Minitab 15. Results are considered  
166 statistically significant at  $P \leq 0.05$  and tendencies are discussed at  $P \leq 0.1$ . Behavioural variables were  
167 analysed using mixed models with the with the residual maximum likelihood method (REML) in Genstat.  
168 Normally distributed data were analysed using linear mixed models (LMM) and non-normally distributed  
169 data with generalised linear mixed models (GLMM) with a Poisson distribution and logarithm as the link  
170 function. All REML analyses had group/gilt in the random variation to account for pen level differences  
171 and repeated measures.

### 172 2.6.1. Behavioural tests

173 Due to randomisation of the test order for the gilts, some of the gilts had a human interaction (n  
174 = 15) and some had a startle object test (n = 9) first. This created an unexpected additional source of  
175 variation in the data, in that when observing the gilts' behaviour during these tests, it was noted that  
176 the gilts that had the startle object test first had a greater reaction to the startle object when it was their  
177 first time in the test arena. Therefore, type of first test (e.g. startle object or human interaction) has  
178 been included as a fixed factor, 'first test' in some of the analyses.

179 Test behaviour variables (contact duration, contact frequency, latency to contact) were first  
180 analysed for differences between stable group and individual tests, with 'test mode' (stable group or  
181 individual) as a fixed factor. Individual test behaviour was then analysed with 'test type' (human  
182 interaction or startle object) × 'test number' (1 to 3) as fixed factors, then startle object and human  
183 interaction tests were analysed separately with 'test number' × 'first test' (human or startle) as fixed  
184 factors. Stable group test behaviour was then analysed with 'test type' × 'test number' as fixed factors.  
185 Spearman's Rank correlation coefficients were calculated between all individual and stable group tests  
186 in Minitab for contact duration.

### 187 2.6.2. Farrowing behaviour

188           The gilts were split into three groups based on the aggressive behaviour they exhibited at  
189 farrowing: a group which attacked/snapped at, but did not bite piglets (attack, n = 7), a group which  
190 attacked/snapped at and bit piglets (bite, n = 5) and a group which did not show aggression towards  
191 piglets (none, n = 9). Gilts were also split into a two groups based on crushing behaviour, a groups which  
192 killed one or more piglets by crushing (yes, n = 10) and another that did not kill piglets by crushing (no, n  
193 = 11). Behaviour for the first eight hours after the birth of the first piglet was analysed with farrowing  
194 location (crate or PigSAFE) × piglet aggression (attack, bite, none) as fixed factors, then with crush (yes  
195 or no) as a fixed factor.

### 196 *2.6.3. Testing vs. farrowing*

197           Contact duration and latency to contact the human/startle object for the first individual pre-  
198 pubertal test (which was either a startle object or human interaction test) was analysed with piglet  
199 aggression group (attack, bite, none) and crush group (yes, no) as fixed factors. Spearman's rank  
200 correlations were conducted between gilt testing behaviour and farrowing behavioural variables in  
201 Minitab.

## 202 **3. Results**

### 203 *3.1. Behavioural Tests*

204           Overall, gilts spent a longer period of time interacting with the human or startle/novel object  
205 during the individual tests compared to the stable group tests, showed a higher frequency of contacts,  
206 but had a higher latency to contact the human or startle/novel object (Table 1).

207 *Insert Table 1*

#### 208 *3.1.1. Individual Tests*

209 Figure 1 shows the contact duration and latency to contact for the three individual human  
210 interaction and startle object tests, with individuals that had the startle object test first in grey and  
211 those that had the human interaction test first in white. No significant differences between contact  
212 duration or latency to contact the startle object or human were found ( $F_{1,142} = 0.46, P = 0.501$  and  $F_{1,142}$   
213  $= 0.52, P = 0.472$  respectively).

### 214 3.1.2. Individual Startle Object Tests

215 For the startle object test there was no significant difference in duration of contact across the  
216 three tests ( $F_{2,69} = 1.33, P = 0.275$ ) but a significant interaction was found for test number  $\times$  first test  
217 ( $F_{2,66} = 10.05, P < 0.001$ ). For gilts that had the startle object test first the contact duration during the  
218 first test was significantly lower than the next two, but gilts assigned to the human interaction test first  
219 showed a more consistent duration of contact across the three startle object tests. The latency to  
220 contact was significantly different between the three tests ( $F_{2,69} = 16.37, P < 0.001$ ), with the highest  
221 latency being for the first test. The contact latency was also significantly higher for pigs that had a startle  
222 test first, compared with the human interaction test first ( $F_{1,70} = 12.30, P = 0.002$ ). In addition, a  
223 significant interaction for test number  $\times$  first test was found ( $F_{2,66} = 12.98, P < 0.001$ ). For pigs that had  
224 the startle test first, the latency to contact the object was almost three times higher for the first test  
225 compared to the second and third, but for gilts that had the human interaction test first the latency was  
226 more consistent, with the highest latency for the first test, getting slightly lower on the second and third  
227 tests.

### 228 3.1.3. Individual Human Interaction Tests

229 There was no significant difference in contact duration across the three human interaction tests  
230 ( $F_{2,69} = 0.48, P = 0.620$ ). In contrast to the startle object test, significantly higher contact duration was  
231 found for gilts that had the startle test first ( $F_{1,70} = 7.54, P = 0.012$ ) and no test number  $\times$  first test

232 interaction ( $F_{2,66} = 1.89, P = 0.16$ ) indicates that this difference is consistent across the three tests. The  
233 latency to contact the human was significantly different across the three tests ( $F_{2,69} = 5.11, P = 0.010$ )  
234 and significantly higher if the first test was a human interaction test ( $F_{1,70} = 7.19, P = 0.015$ ) but there  
235 was no significant test number  $\times$  first test interaction ( $F_{2,66} = 2.30, P = 0.112$ ) because the first human  
236 interaction test was higher than the second and third whether the gilts had a startle object test or  
237 human interaction test first.

#### 238 *3.1.4. Stable Group Tests*

239 No significant difference in the contact duration or latency were found between the novel  
240 object or human interaction stable group tests ( $F_{1,142} = 0.35, P = 0.555$  and  $F_{1,142} = 0.80, P = 0.37$   
241 respectively) (Figure 2). A significant test type  $\times$  test number interaction was found for contact duration  
242 ( $F_{2,138} = 7.42, P < 0.001$ ) as the novel object test had a higher contact duration for test one compared to  
243 tests two and three, whereas contact duration was more consistent across the three human interaction  
244 tests.

#### 245 *3.1.5. Between test relationships*

246 Table 2 shows correlations between contact duration for the three individual human interaction  
247 and startle object tests, the three group human interaction and novel object tests, and between the  
248 individual and group tests. Gilts showed some consistency in the duration of contact in the human  
249 interaction tests, with significant positive correlations between the three individual tests, the group  
250 tests and between the individual and group tests.

251 *Insert Table 2*

#### 252 *3.2. Farrowing*

253 On average the gilts' had  $11.27 \pm 0.73$  piglets born alive ( $C = 12.72 \pm 0.43$ ,  $PS = 9.83 \pm 1.29$ ),  $0.64$   
254  $\pm 0.20$  born dead ( $C = 0.64 \pm 0.24$ ,  $PS = 0.64 \pm 0.34$ ) and live born mortality was  $16.91 \pm 3.21$  % ( $C = 17.31$   
255  $\pm 4.90$ ,  $PS = 16.50 \pm 4.37$ ).

### 256 3.2.1. Behaviour: Crates vs. PigSAFE pens

257 Crate gilts spent a higher percentage of time engaged in piglet focused behaviour ( $C = 11.0 \pm$   
258  $2.0$ ;  $PS = 4.4 \pm 1.1$ ,  $W_{1,19} = 9.33$ ,  $P = 0.038$ ) and PS gilts spent more time alert ( $C = 5.0 \pm 1.1$ ;  $PS = 9.2 \pm$   
259  $2.9$ ,  $W_{1,19} = 6.61$ ,  $P = 0.022$ ) and straw/floor focused ( $C = 1.0 \pm 0.3$ ;  $PS = 2.2 \pm 0.7$ ,  $W = 11.45$ ,  $P = 0.004$ ).  
260 PS gilts spent more time standing than C gilts ( $C = 3.1 \pm 1.2$ ;  $PS = 5.5 \pm 1.7$ ,  $W_{1,19} = 6.36$ ,  $P = 0.024$ ), with  
261 no other differences in posture. Crate gilts showed a higher frequency of attack/snap ( $C = 13.6 \pm 4.8$ ;  $PS$   
262  $= 6.2 \pm 2.4$ ,  $W_{1,19} = 10.37$ ,  $P = 0.006$ ) and biting behaviour ( $C = 4.0 \pm 2.4$ ;  $PS = 1.0 \pm 0.6$ ,  $W_{1,19} = 4.58$ ,  $P =$   
263  $0.05$ ). No other significant differences in the behaviour between C and PS gilts were found.

### 264 3.2.2. Savaging and crushing

265 Of the 22 gilts that went on to farrow, 10 killed one or more piglets by crushing (45.5 %) and 12  
266 did not kill any piglets by crushing. Twelve (57.1 %) out of the 21 gilts showed some kind of aggression,  
267 in the form of attacking/snapping at or biting piglets, six from crates and six from pens, five (23.8 %) of  
268 which killed one or more piglets ( $C = 3$ ,  $PS = 2$ ) and two (9.5 %) showed biting behaviour towards piglets,  
269 causing injuries but not mortality. Attack/snap behaviour was significantly more frequent in crates than  
270 PigSAFE pens (see previous section), and the frequencies of aggressive events reduced sooner in PigSAFE  
271 pens compared to crates (Figure 3), although a small peak in aggressive behaviour was seen in both  
272 environments at seven hours after the birth of the first piglet.

273 Farrowing behaviour was compared between the three aggression groups (attack, bite or none)  
274 (Table 3). Several significant differences in behaviour were observed for these three groups of gilts,

275 including the duration of time spent alert and piglet focused, which were higher for the bite group,  
276 compared to the other two groups and idle, which was lower for the bite group. Significant differences  
277 were also seen for the postures stand and sit, which were higher and lie lateral, which was lower for the  
278 bite group, compared to the attack/snap and no aggression groups. No significant differences in  
279 behaviour for the first eight hours after the birth of the first piglet were found between gilts which did  
280 or did not kill piglets by crushing, but there was a tendency for gilts that crushed piglets to spend less  
281 time in piglet focused behaviour (Table 3).

282 *Insert Table 3*

### 283 3.3. Testing vs. Farrowing

284 Gilts demonstrating different levels of aggression towards their piglets (attack, bite, none),  
285 tended to differ for contact duration ( $F_{2,18} = 2.75, P = 0.095$ ) during the first individual pre-pubertal test  
286 (startle object or human interaction). Post hoc analysis showed that the attack and no aggression group  
287 did not differ ( $T_{1,14} = 0.37, P = 0.744$ ), whereas the attack and bite and bite and no aggression group  
288 tended to differ ( $T_{1,10} = 2.04, P = 0.069$  and  $T_{1,12} = 2.00, P = 0.065$  respectively; Figure 4a). There was no  
289 significant difference between piglet aggression groups for the latency to contact the human/startle  
290 object during the first behavioural test ( $W_{2,18} = 3.56, P = 0.202$ ). For the gilts grouped on crushing, there  
291 was no significant difference in the duration of contact for the first individual behavioural test ( $F_{1,19} =$   
292  $2.45, P = 0.135$ ), but a significant difference for the latency to contact the human or startle object was  
293 found ( $W_{1,19} = 5.28, P = 0.038$ ; Figure 4b). Spearman's rank correlations between testing behaviour and  
294 farrowing behaviour showed no pattern of significant correlation.

## 295 4. Discussion

### 296 4.1. Behavioural tests



297           The results from the individual tests indicate that gilts with the startle object test first and gilts  
298 that had the human interaction test first behaved differently in pre-pubertal tests, indicating that  
299 previous test experience is influencing behaviour in subsequent tests. In a previous study, pigs with  
300 regular exposure to humans were quicker to approach a novel object, although pigs with regular  
301 exposure to novel objects were not quicker to approach a human, compared with pigs which had no  
302 previous experience of either human contact or novel objects (Hemsworth et al., 1996). Gilts interacted  
303 with the novel object longer during the first stable group novel object test, compared to the remaining  
304 two tests, which is unsurprising given that the novel object was different for the stable group tests. As in  
305 this study, a previous study in which pigs underwent several behavioural tests also showed a habituation  
306 effect, as latency to contact decreased with subsequent tests (Brown et al., 2009).

307           Some consistency in behaviour was shown between individual and stable group human  
308 interaction tests. This is similar to previous studies, where correlations were found between tests with  
309 similar stimuli (Janczak et al., 2003b; Lawrence et al., 1991; Spooler et al., 1996). By contrast, a study of  
310 finisher pigs found consistency in response to different test types as well as over time (Brown et al.,  
311 2009) and prepubertal gilts showed a general reaction pattern across different non-social situations  
312 (Thodberg et al., 1999). In other situations, male and female growing pigs showed consistency in  
313 aggression and mounting behaviour (Clark and D'Eath, 2013) and at farrowing 14 % of sows that savaged  
314 as gilts, savaged on the second parity, compared with only 0.8 % of sows, which did not savage as gilts  
315 (Harris et al., 2003). Jensen et al. (1995), however, failed to find consistency in the undisturbed  
316 behaviour of piglets pre-weaning. Greater consistency in response to the tests used in the current study  
317 may have been found if the test order was not randomised and the gilts' were habituated to the test  
318 arena beforehand, so that they were responding to the novelty of the startle object and human, rather  
319 than the arena. However, according to the properties outlined by Jensen, (1995), the data in this study  
320 do not provide evidence of distinct coping strategies. In a critical evaluation of fear tests, Forkman et al.

321 (2007) concluded that fear tests for pigs are not well validated as inter-test correlations were low for the  
322 various tests that have been used, which is supported in this study.

#### 323 *4.2. Farrowing*

324 An interesting finding from this study is that gilts in PigSAFE pens showed fewer aggressive  
325 interactions towards piglets compared with gilts in crates. The consequences of piglet-directed  
326 aggression could be much more severe in loose-farrowing systems and a previous study found that more  
327 individuals exhibited piglet-directed aggression in farrowing pens compared to crates (Marchant-Forde,  
328 2002). Wild boar have been observed to exhibit piglet-directed aggression at high levels when farrowing  
329 in captivity suggesting that the environment, rather than the process of domestication may be  
330 influencing this unwanted behaviour (Harris et al., 2001). Reduced piglet-directed aggression was seen  
331 when gilts were provided with continuous light, which the authors suggested could enable the gilts to  
332 see the piglets better, reducing their alarm or fear as piglets approach (Harris and Gonyou, 2003). Stress,  
333 pain, or the inability to cope with confinement could also negatively affect gilts behaviour leading to  
334 piglet-directed aggression (Ahlström et al., 2002; Cronin et al., 1996; Jarvis et al., 1998). Perhaps the  
335 ability of the gilts housed in PigSAFE pens to interact properly with piglets, enabling the development of  
336 mother-young relationships to be faster than those in crates, could have reduced piglet-directed  
337 aggression. In this study PS gilts exhibited more nose contact with piglets, but had a lower duration of  
338 piglet-focused behaviour (where the gilts head and/or ears are orientated towards a piglet but with no  
339 physical contact), which could be an indication of the need, but inability of gilts in crates to interact  
340 properly with piglets.

341 A study of piglet-directed aggression in wild boar separated individuals into three groups based  
342 on aggression towards piglets, including none (0), moderate (1), where there was some aggression not  
343 resulting in injury and severe (2) where one or more piglets were killed or intervention was needed to

344 protect the piglets (Harris et al., 2001). An early study of sow parturition also observed aggressive  
345 behaviour, where the sows appeared defensive, backing away from piglets and attempting to bite, but  
346 also extreme aggression where sows actively attacked piglets in the farrowing pen (Randall, 1972). Gilts  
347 in this study were also grouped based on piglet-directed aggression. Another interesting outcome from  
348 this study is that gilts exhibiting severe aggression resulting in the death of piglets showed several  
349 differences in behaviour compared with the other two groups, although these results should be treated  
350 with some caution due to low numbers of animals. Harris et al. (2001) also found that wild boar gilts  
351 with a piglet aggression score of two, differed from those scoring one or zero. In other studies savaging  
352 sows have been shown to be more restless during parturition, exhibiting more posture changes,  
353 standing behaviour and were more responsive to their piglets (Ahlström et al., 2002; Chen et al., 2008).

354 Behaviour after the onset of farrowing was also compared between gilts that crushed one or  
355 more piglets to those that did not, but no clear behavioural differences were demonstrated. A previous  
356 study comparing 'crushers' with 'non-crushers' showed 'non-crushers' to have a better mothering style,  
357 including nosing the piglets more when changing posture and reacting sooner to piglet distress calls by  
358 directing attention towards piglets (Andersen et al., 2005). Crushing has not been directly related to  
359 posture or posture changes, but is related to the maternal ability of the sow to lie carefully and respond  
360 to piglet screams (e.g. Andersen et al., 2005; Wischner et al., 2010, 2009). Behavioural differences may  
361 have been seen in this study if more detailed maternal behaviour was measured.

#### 362 *4.3. Testing vs. farrowing*

363 No significant pattern of correlation was found between behaviour during the tests and at  
364 farrowing. However, when the contact duration and latency for the first individual behavioural test were  
365 compared between piglet aggression groups, and for 'crushers' versus 'non-crushers', some differences  
366 were found. Firstly, the group showing severe piglet-directed aggression tended to have longer contact

367 duration than the other two groups, and secondly, gilts that crushed piglets had a longer latency to  
368 contact the startle object or human in the first behavioural test, compared with those that did not crush.  
369 These differences are small and should be treated with caution, but will be discussed in relation to  
370 previous research.

371 In contrast to the finding in this study, a previous study found that gilts which killed piglets by  
372 savaging showed more shy behaviours during a pre-farrowing human approach test, including a longer  
373 latency to interact with the human and with fewer interactions (Marchant-Forde, 2002). The same study  
374 found that gilts which were dangerously aggressive towards the stock-person showed more bold  
375 behaviours during this test. Behaviour was compared between savaging and non-savaging sows around  
376 parturition and results showed that savaging sows showed more posture changes from before farrowing  
377 and during the piglet expulsion phase (Chen et al., 2008). The authors suggested that although the  
378 aetiology of this abnormal behaviour remains to be found, it could be a more generalised behavioural  
379 pathology including increased excitability, which is not specifically piglet-related (Chen et al., 2008), this  
380 would fit with the increased contact duration during behavioural tests found in the current study. In a  
381 study of another abnormal, unwanted behavioural problem in pigs, tail biting, researchers found that  
382 biters interacted more with enrichment devices, compared with victims and control pigs (Zonderland et  
383 al., 2011). This again, fits with the theory of a behavioural pathology related to increased excitability.

384 Again, in contrast to the current study, a previous study found that the gilts with a shorter  
385 latency to interact with a novel object at six months of age crushed more piglets (Lensink et al., 2009b).  
386 However, this study also found that the escape behaviour from a human entering the home pen at six  
387 months old and the withdrawal response when sows were approached from the front of the farrowing  
388 crate tended to correlate positively with piglet crushing and nervousness around farrowing significantly  
389 correlated with crushing (Lensink et al., 2009b). Another study found that a high withdrawal response of

390 sows to being touched by a human during feeding, two weeks before farrowing positively correlated  
391 with the number of piglets crushed (Lensink et al., 2009a). In the latter study, the authors suggested that  
392 high fearfulness was associated with piglet crushing, which would fit with the data in this study, where  
393 crushers showed a longer latency to contact the human or startle object during the first pre-pubertal  
394 test.

395 Relationships between crushing of piglets and behaviour during a human interaction and novel  
396 object test at eight weeks old have not been found, however, 'fear of humans', but not 'novelty induced  
397 anxiety' was related to reproductive parameters, with less fearful sows demonstrating higher  
398 reproductive success (Janczak et al., 2003a), a result also found in earlier studies relating to fear of  
399 humans (Hemsworth et al., 1989, 1981). In another study where pre-pubertal gilts underwent  
400 behavioural tests, those which were calm during the stressful test situation, timed their nest building  
401 more optimally and behavioural activity during tests correlated with being active during farrowing  
402 (Thodberg et al., 2002). Andersen et al., (2005) found that non-crushers performed more nest building  
403 behaviour from 8 to 6 hours pre-farrowing compared with crushers, but the opposite was found in the  
404 last hour before farrowing when crushers tended to perform more nest-building activity.

405 As with previous work (Lensink et al., 2009a;b), the link between pre-pubertal and farrowing  
406 behaviour in this study is not completely clear and the unexpected additional source of variation created  
407 by the test regime used in this study and low sample size, limited the ability to explore these  
408 connections using multivariate statistical techniques (Budaev, 2010). A number of factors influence good  
409 maternal behaviour, but the results of this study, along with others (Lensink et al., 2009a, 2009b;  
410 Marchant-Forde, 2002; Thodberg et al., 2002), do indicate that it could be possible to predict good  
411 maternal behaviour and select gilts to optimise performance in loose-farrowing systems. However, more  
412 work is needed to provide additional information, perhaps using more carefully-selected measures,

413 larger sample sizes and multivariate statistical techniques, to better predict breeding sow performance.  
414 Information provided here gives a basis on which to build for future studies in this area of research.

## 415 **5. Conclusions**

416 Gilt behaviour during pre-pubertal individual tests was influenced by the test type first  
417 experienced; demonstrating that behavioural response to novel situations is likely to be sensitive to  
418 several factors. Lower frequencies of piglet-directed aggression seen in PigSAFE pens is an interesting  
419 result and could be due to a greater ability to display normal maternal behaviour. Correlation between  
420 pre-pubertal test behaviour and farrowing behaviour was not found. However, differences in behaviour  
421 for the first individual test were found for gilts showing severe piglet-directed aggression and between  
422 those that crushed or did not crush piglets, indicating that it could be possible to use pre-pubertal  
423 behaviour to predict maternal ability, but a better measure; perhaps using response to novelty and a  
424 multivariate approach is needed.

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- 514

515 **Table 1**

516 Mean ± Standard Error for variables measured in both individual human interaction and startle response

517 tests and group human interaction and novel object tests with group vs. individual effects and *P* values

Behaviour	Individual Test		Group Test		Group vs. Individual Effect, <i>P</i> value
	Human	Startle	Human	Novel Object	
Contact duration (s)	132.84 ± 6.97	126.57 ± 8.84	105.98 ± 6.66	110.97 ± 5.98	$F_{1,286} = 8.73, P = 0.003$
Contact frequency	9.86 ± 0.43	14.14 ± 0.96	7.82 ± 0.37	7.10 ± 0.31	$F_{1,286} = 59.03, P < 0.001$
Latency to contact (s)	18.73 ± 4.74	29.42 ± 14.29	7.78 ± 1.48	10.63 ± 2.53	$W_{1,286} = 6.55, P = 0.011$

518

519

520 **Table 2**

521 Spearman’s rank correlation coefficients ( $r_s$ ) and  $P$  values for contact durations between a) the three  
 522 individual human interaction (IH1, IH2, IH3) and startle object (S1, S2, S3) tests; b) the three group  
 523 human interaction (GH1, GH2, GH3) and novel object tests (NO1, NO2, NO3) and c) between the group  
 524 and individual tests.

a) Individual Tests :  $r_s, P$

IH1					
IH2	0.370, 0.075	IH2			
IH3	<b>0.438, 0.032</b>	<b>0.507, 0.012</b>	IH3		
S1	-0.354, 0.097	-0.339, 0.113	-0.213, 0.329	S1	
S2	-0.028, 0.896	-0.157, 0.464	-0.189, 0.377	0.359, 0.092	S2
S3	0.002, 0.993	-0.327, 0.127	0.091, 0.679	0.210, 0.348	0.397, 0.061

b) Group Tests:  $r_s, P$

GH1					
GH2	0.374, 0.126	GH2			
GH3	<b>0.638, 0.004</b>	<b>0.783, &lt;0.001</b>	GH3		
NO1	-0.029, 0.909	-0.177, 0.407	-0.250, 0.239	NO1	
NO2	0.364, 0.138	0.224, 0.293	0.025, 0.908	0.310, 0.140	NO2
NO3	-0.195, 0.433	<b>-0.456, 0.025</b>	<b>-0.445, 0.029</b>	0.282, 0.182	0.049, 0.818

525 c) Group vs. individual tests:  $r_s, P$

	GH1	GH2	GH3	NO1	NO2	NO3
IH1	0.225, 0.370	0.023, 0.917	-0.115, 0.594	0.021, 0.924	0.183, 0.391	0.259, 0.222

IH2	<b>0.577, 0.012</b>	0.111, 0.606	0.343, 0.101	-0.242, 0.254	-0.100, 0.642	0.150, 0.485
IH3	<b>0.486, 0.041</b>	<b>0.446, 0.029</b>	<b>0.515, 0.010</b>	-0.244, 0.251	0.030, 0.889	-0.145, 0.499
S1	-0.025, 0.924	0.030, 0.893	0.185, 0.398	-0.110, 0.618	0.006, 0.978	<b>-0.415, 0.049</b>
S2	0.057, 0.824	-0.165, 0.442	0.081, 0.708	-0.001, 0.998	-0.142, 0.509	-0.142, 0.508
S3	-0.147, 0.573	0.148, 0.499	0.018, 0.935	0.373, 0.080	0.044, 0.844	-0.237, 0.276

526

527 **Table 3**

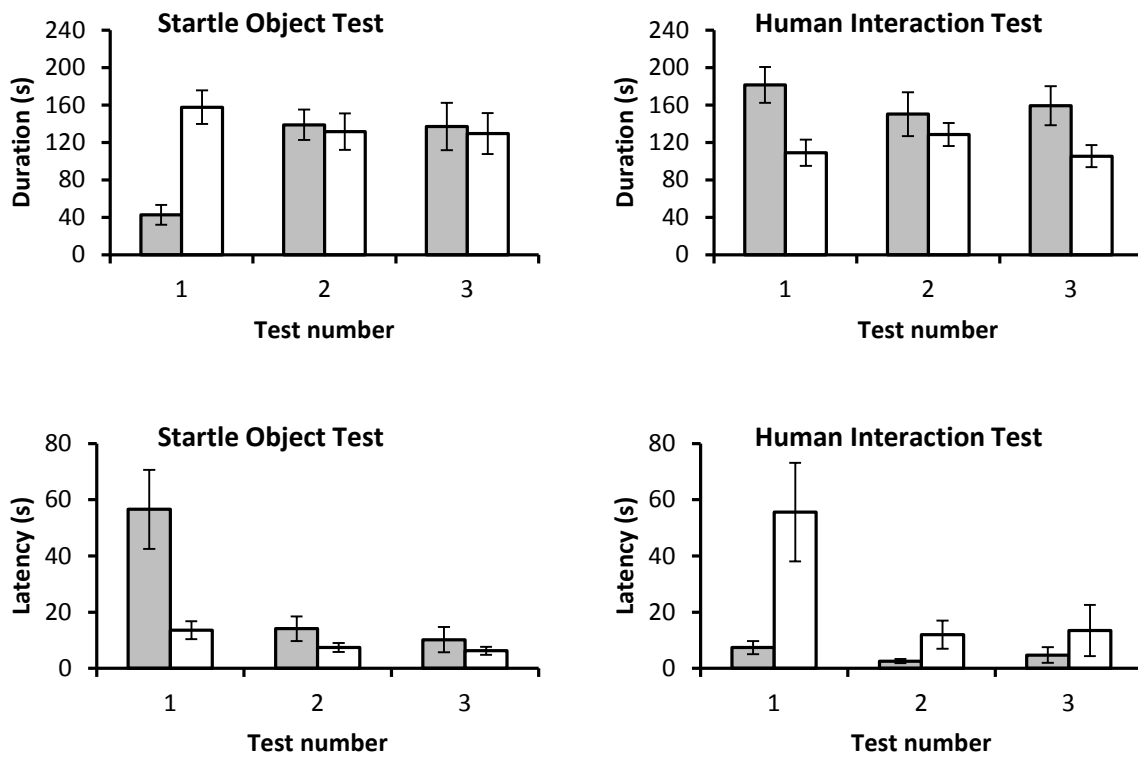
528 Mean  $\pm$  standard error for behavioural variables measured during farrowing, with gilts grouped by aggression towards piglets during farrowing

529 (attack, bite, none) and crushing (yes or no) effects and *P* values for differences between these groups

Behaviour	Piglet aggression			Effect, <i>P</i> value	Crushing		Effect, <i>P</i> value
	Attack (n = 5)	Bite (n = 7)	None (n = 9)		Yes (n = 10)	No (n = 11)	
Alert	5.79 $\pm$ 1.86	11.59 $\pm$ 3.77	4.18 $\pm$ 1.22	$W_{2,18} = 7.87, P = 0.044$	5.99 $\pm$ 2.53	7.82 $\pm$ 2.53	$W_{1,19} = 0.35, P = 0.56$
Idle	87.84 $\pm$ 2.98	73.32 $\pm$ 3.95	88.56 $\pm$ 2.10	$W_{2,18} = 15.87, P = 0.005$	85.49 $\pm$ 1.90	81.67 $\pm$ 3.76	$W_{1,19} = 0.66, P = 0.43$
Piglet focused	5.37 $\pm$ 1.49	12.67 $\pm$ 2.71	5.50 $\pm$ 1.56	$W_{2,18} = 11.17, P = 0.018$	6.38 $\pm$ 1.51	8.97 $\pm$ 2.09	$W_{1,19} = 3.73, P = 0.070$
Straw/floor focused	0.91 $\pm$ 0.52	2.19 $\pm$ 0.65	1.47 $\pm$ 0.63	$W_{2,18} = 2.34, P = 0.34$	1.79 $\pm$ 0.62	1.42 $\pm$ 0.46	$W_{1,19} = 0.04, P = 0.85$
Stand	1.90 $\pm$ 1.14	8.11 $\pm$ 2.26	2.54 $\pm$ 0.59	$W_{2,18} = 11.09, P = 0.017$	3.11 $\pm$ 0.69	5.09 $\pm$ 1.67	$W_{1,19} = 1.07, P = 0.32$
Sit	0.93 $\pm$ 0.24	3.57 $\pm$ 0.86	1.73 $\pm$ 0.62	$W_{2,18} = 5.29, P = 0.11$	1.81 $\pm$ 0.61	2.41 $\pm$ 0.64	$W_{1,19} = 0.43, P = 0.52$
Lie Lateral	88.71 $\pm$ 2.89	75.00 $\pm$ 4.36	89.51 $\pm$ 2.35	$W_{2,18} = 9.93, P = 0.022$	86.76 $\pm$ 3.74	82.78 $\pm$ 3.74	$W_{1,19} = 0.69, P = 0.42$
Lie Ventral	8.33 $\pm$ 1.99	13.10 $\pm$ 4.00	6.01 $\pm$ 1.59	$W_{2,18} = 3.45, P = 0.21$	8.10 $\pm$ 1.69	9.52 $\pm$ 2.63	$W_{1,19} = 0.18, P = 0.68$
Posture changes	73.60 $\pm$ 10.31	115.86 $\pm$ 16.29	83.44 $\pm$ 14.27	$W_{2,18} = 4.45, P = 0.15$	95.22 $\pm$ 11.36	89.42 $\pm$ 13.70	$W_{1,19} = 0.10, P = 0.67$

530

531 **Fig. 1.** Contact duration (s) and latency to contact (s) for the three individual startle response and three  
532 individual human interaction tests, separated by the gilts' first test: startle response (n = 9, grey) or  
533 human interaction (n = 15, white)

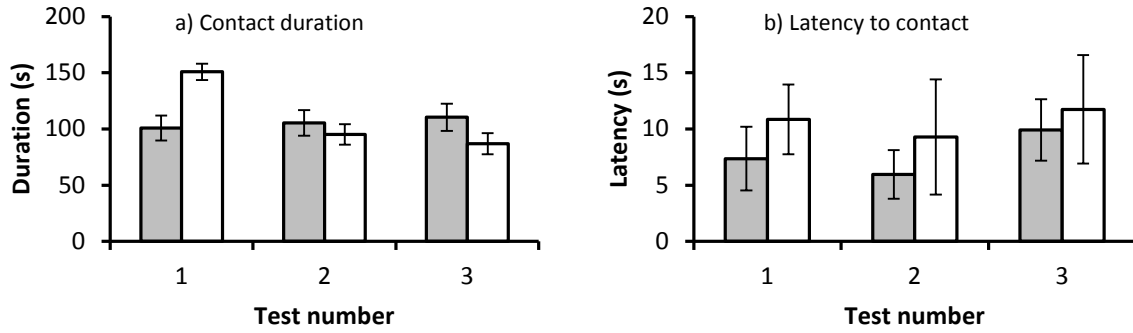


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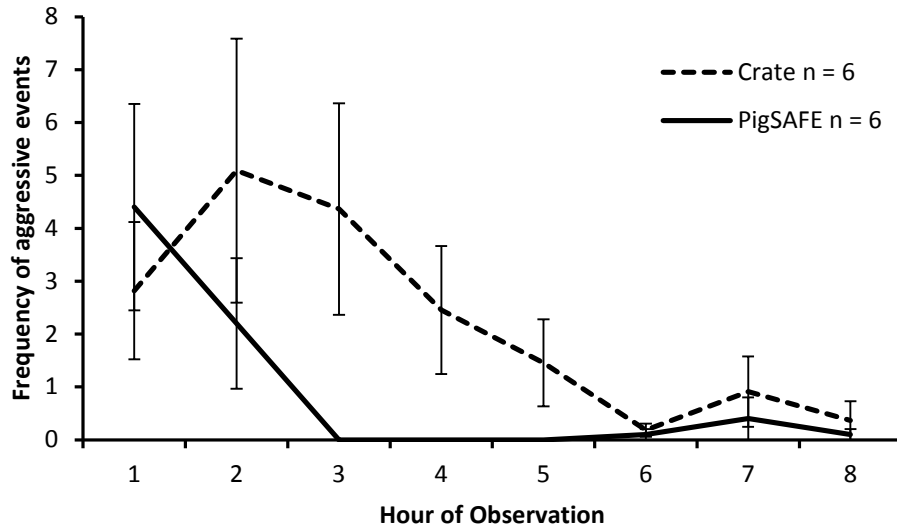
536

537 **Fig. 2.** Mean  $\pm$  SE for the duration of contact (a) and latency to contact (b) for the first, second, and third  
 538 group human interaction (grey) and novel object (white) tests



539

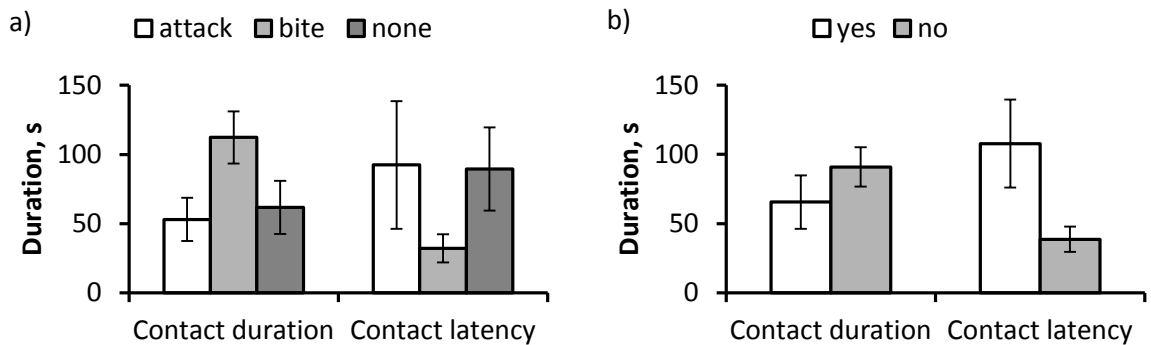
540 **Fig. 3.** Frequencies of aggressive events (attack/snap and bite) by hour of observation for gilts farrowing  
 541 in crates (n = 6) or PigSAFE pens (n = 6)



542

543

544 **Fig. 4.** Contact duration and the latency to contact (seconds) for the first individual behavioural test by  
 545 a) piglet aggression groups: attack (n = 5), bite (n = 7), and none (n = 9) and b) crush groups: yes (n = 10),  
 546 no (n = 12)



547

548