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The influence of neonatal environment on piglet play behaviour and post-weaning social and cognitive development

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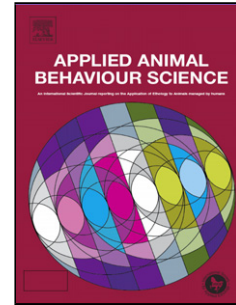
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1 The influence of neonatal environment on piglet play behaviour and post-weaning social and
2 cognitive development.

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11

12 Highlights:

- 13 • Compared piglet play behaviour in two neonatal environments pre- and post-weaning.
- 14 • Play behaviour is greater in piglets housed in complex and enriched environments.
- 15 • More playful piglets perform better in Spontaneous Object Recognition Tests.
- 16 • Play is dependent on present environmental stimulus.
- 17 • Direct and indirect effects on welfare e.g. reduced chronic aggression and stress.

18

19

20

21

22 Abstract

23 Research has shown that the domestic pig is highly playful throughout its development and that play is
24 an important aspect of social and cognitive development. Therefore the neonatal environment is
25 fundamental to successful stimulation of play in neonatal pigs, which could have indirect and direct
26 socio-cognitive effects on pigs post-weaning and therefore influence social interactions known to cause
27 welfare concerns (e.g. aggression during mixing). This study investigated how play pre- and post-
28 weaning developed in two neonatal environments (NE); the conventional farrowing crate (NEC) and a
29 more environmentally complex alternative PigSAFE pen (NEP) and to discover whether this had an effect
30 on piglet' cognitive abilities in Spontaneous Object Recognition Tests for two retention times (15 and 60
31 minutes) post-weaning. Hourly focal sampling was used to record play behaviours pre- and post-
32 weaning in 72 piglets of mixed sex (36 per NE) from a total population of 117 piglets from 12 litters. Out
33 of the 72 piglets, 24 were used in the cognitive Spontaneous Object Recognition tests five weeks post-
34 weaning. Linear mixed models showed that NEP piglets displayed play behaviours quicker after birth
35 than NEC piglets: locomotor ($F = 7.62_{(1,11)}$, $P = 0.020$); sow interaction ($F = 5.27_{(1,11)}$, $P = 0.045$); and social
36 interaction ($F = 23.61_{(1,11)}$, $P < 0.001$). NEP piglets played more pre-weaning than NEC piglets ($F =$
37 $5.06_{(1,71)}$, $P = 0.051$) and despite initial higher levels of aggression at weaning, displayed less chronic
38 aggression post-weaning as indicated by lesion scores of all piglets ($F = 27.05_{(1,116)}$, $P < 0.001$). NE was
39 shown to have a significant effect on the 15 minute cognitive retention test; with NEP piglets spending
40 more time interacting with the novel object than the familiar, compared to NEC piglets ($F = 5.39_{(1,23)}$, $P =$
41 0.045). There was no NE effect for the 60 minute retention test. It was concluded that play is
42 fundamental to successful socio-cognitive development (e.g. aggressive conflicts) and relates to play
43 function theories of training for the unexpected. Its effect on play behaviours are short-term and highly

44 dependent on present environmental stimulus, suggesting that any long-term benefits play may have on
45 an animal's welfare can only be achieved by regular stimulation throughout its life (e.g. constant
46 enrichment).

47 Keywords: Play, alternative housing, farrowing, enrichment

48

49 1. Introduction

50 Research into play behaviour has shown it to be fundamental for the physical, physiological and
51 psychological development of mammals, particularly the development of cognitive and social abilities
52 (Fagen, 1981; Špinka et al., 2001). As a result play behaviour (or the lack thereof) has been used as a
53 welfare 'iceberg indicator' to highlight concerns for captive animals, e.g. boredom (Held and Špinka,
54 2011; Dybkjaer, 1992). Mammalian play is a cognitively demanding activity and is concentrated during
55 neonatal development (Špinka et al., 2001).

56

57 The domestic pig (*Sus scrofa domesticus*) is a social, intelligent mammal (D'Eath and Turner, 2009;
58 Gieling et al., 2011). The pig's commercial environment, whether indoor or outdoor, imposes physical
59 and behavioural restrictions, and subjects it to several stressful events during its production life (e.g.
60 weaning) (Marchant-Forde, 2009). Several studies on pigs, involving object recognition, spatial memory
61 and problem-solving, have demonstrated a high level of cognitive skill (Gieling et al., 2011; Moustgaard
62 et al., 2002). Research also shows that pig play behaviour extends across all play behaviour categories;
63 locomotor, social and object, and that it has sex and age dependent aspects (Donaldson et al., 2002;
64 Newberry et al., 1988).

65

66 Interactions between sow and piglet within the neonatal environment (NE) are critical for piglet survival
67 (English and Smith, 1975; Marchant et al., 2000), but also for socio-cognitive development. Research
68 indicates that several factors are influenced by the NE, including sow/piglet behaviour (e.g. Bolhuis et
69 al., 2005, 2006; Cronin et al., 1996; De Jonge et al., 1996; Melotti et al., 2011; Olsson et al., 1999;
70 Siegford et al., 2008). Lack of understanding on how influential these effects on piglet development are
71 may mask just how important the NE is. Research has shown that restriction in this environment can
72 disturb development of social skills and stress coping mechanisms, resulting in higher stress and
73 aggression levels in adult pigs (e.g. Peterson et al., 2005). This supports the theory that play acts as
74 training for the future (e.g. responses to novelty and social interactions; including aggressive conflicts)
75 (Špinka et al., 2001).

76

77 The aims of this study were to investigate whether piglets reared in conventional farrowing crates (NEC)
78 or more environmentally complex alternative farrowing pens (PigSAFE pen - NEP) show different play
79 behaviour and development pre- and post-weaning, and whether this results in variation of cognitive
80 abilities post-weaning. It was hypothesised that if play behaviour is key to successful socio-cognitive
81 development of neonates, then the NE must have an indirect significant impact, as play behaviour can
82 be stimulated or restricted by the environment. Therefore, piglets reared in a more complex
83 environment should show greater socio-cognitive development than piglets reared in a standard
84 commercial NE.

85

86 2. Material and methods

87 2.1 Animals and Housing

88 Data were collected at the SRUC Pig Unit (Midlothian, Scotland) between March and June 2011. A total
89 of 117 piglets, bred from commercial cross-bred dams (Large White x Landrace) and sired by Pietrain
90 boars were used. Of the 117, 57 were born in the first NE, the standard farrowing crate (NEC), and 60
91 were born in the second NE, the PigSAFE pen (NEP). Piglets were produced from 12 sows, with six sows
92 per NE of equally varying parity. Litter size was not equalised and was dependent on natural biological
93 variation. However cross-fostering was permitted as per normal husbandry routines to improve piglet
94 survival. This was done within NE. The pig unit was managed on a batch system, involving a group of
95 sows farrowing simultaneously at three week intervals. As a result of all-in-all-out management,
96 farrowing system type was alternating, so comparisons of the NEs could not be run simultaneously.

97

98 The standard farrowing crate (NEC) was used to represent a barren environment as it is a restrictive
99 environment to both sow and piglets in terms of physical movement and mental stimulation (Figure 1a).
100 The crate had a solid concrete floor, apart from a small dunging area to the rear of the sow (0.5 x 0.5
101 m²). Natural light was provided by windows in the farrowing house. In addition artificial lighting was on
102 between 0700-1600 daily, with permanent lighting on in the creep area. Both the sow and her piglets
103 were physically isolated from other pigs. Two handfuls of long-stemmed straw were given daily, which
104 both the sow and piglets had access to, as this was standard farm practise for the NEC. The sow is
105 restricted to the central area via parallel bars, and her piglets are able to move around her and have
106 access to a heated and lit creep area at the front of the crate.

107

108 The newly developed Piglet and Sow Alternative Farrowing Environment, or PigSAFE (NEP), was
109 developed based on the design criteria proposed by Baxter et al. (2011) and described in Edwards et al.
110 (2012). Flooring was solid, insulated concrete with a slatted dunging area (Triband metal slats, 9mm

111 void). Lighting was provided artificially between 0700-1600 daily, with night lights remaining on at a
112 lower lux. Sows were provided with 2kg long-stemmed straw pre-farrowing which was replenished daily
113 if needed. Approximately 24h post-farrowing straw was removed if dirty and two handfuls of additional
114 long-stemmed straw was provided daily until weaning. NEP provides visual and some physical
115 interaction with neighbouring sows and piglets through the barred windows, and also has sloped walls,
116 which protect piglets from crushing and, inadvertently, add complexity to the environment (Figure 1b).

117

118 Piglets were introduced to solid feed (Compound pellet creep feed, Scotlean Pigs Ltd., Primary Diets –
119 AB Abri Ltd., Yorks, UK) one week before weaning by floor scattering pellets within the creep area.
120 Weaning occurred at 27 days old, during which piglets were removed from sows and underwent several
121 management procedures (e.g. vaccination and ear tagging) before being moved to weaner pens.
122 Weaner pens were 3 x 6 m², with solid concrete floors and solid walls (1.5 m high) and deep-straw
123 bedding. Pens were mucked out and long-stemmed straw for bedding was replenished daily (4-5 kg as
124 required). Lighting regime was 10hrs of artificial light (07:00 – 17:00). Room temperature and ventilation
125 were mechanically controlled; room temperature was set at 25-27°C for the first few days, dropping to
126 21°C after one week. Piglets had ad libitum access to suitable feed and water. Handling of piglets was
127 performed as calmly and swiftly as possible to minimise stress. Approximately 20 piglets were housed
128 per pen, with two litters from the same NE being mixed to make a group (three pens per NE). Weaner
129 group sizes: NEC - pen A = 17, pen B = 20, and pen C = 20; NEP - pen D = 20, pen E = 20, and pen F =20.
130 Efforts were made to mix litters of similar size to minimise bullying (Francis et al., 1996).

131

132 This project was reviewed and approved by SRUC's ethical review committee and all routine animal
133 management procedures were adhered to by trained staff.

134

135 2.2 Experimental Design

136 The experimental study was split into three phases in order to address the hypothesis. Phase 1 (piglets
137 ≤ 27 days old) and Phase 2 (piglets aged $28 \leq 56$ days) involved investigating play behaviours pre- and
138 post-weaning, while Phase 3 involved the application of Spontaneous Object Recognition Tests to piglets
139 from both NEs post-weaning (approximately 56-70 days old).

140

141 A behavioural ethogram (Table 1) was developed and tested in pilot footage of digitally video recorded
142 piglets from farrowing to two weeks old in NECs from 2009. Play behaviours had been verified by
143 previous research (e.g. Blackshaw et al., 1997, Bolhius et al., 2005, Chaloupková et al., 2007, Donaldson
144 et al., 2002, Jensen et al., 2001, Newberry et al., 1988). As a result of this research, 'play fighting'
145 behaviours (e.g. biting) were excluded from the current study.

146

147 2.3 Phase 1: Comparisons of Pre-weaning Play Behaviours

148 All litters from each NE treatment were digitally video recorded (Low-lux B/W waterproof cameras: SK-
149 2020XC/SO, RF Concepts Ltd, Belfast, Ireland and Geovision GV-DVR, ezCCTV Ltd, Herts, UK)
150 continuously for four days post-farrowing. In order not to disrupt managerial procedures or maternal
151 behaviour, piglet handling was minimal during this period. Data were collected on the latency post-
152 farrowing for the first locomotor play behaviours to be performed by any piglet, within the four days for
153 each litter. At such an early age and using only video footage it was too difficult to distinguish definite

154 social play interactions and therefore latency for first sow-piglet interaction and other social physical
155 interactions (e.g. nudge – Table 1) were recorded but not specifically defined as social play.

156

157 Following the initial four days, using digitally recorded video footage, each litter underwent focal
158 sampling (Martin and Bateson, 2007) hourly for three minutes from 08:00 to 16:00 on Mondays,
159 Thursdays and Sundays up until weaning (4 – 27 days of age). Between 08:05 and 08:55 every day,
160 piglets were picked up daily and individually labelled with a number on their backs in black permanent
161 marker (Sharpie® Magnum chisel tip). The same markers were used across all piglets, litters and NEs to
162 ensure the smell of the marker did not have varying effects on behaviour. In each litter, six mix-sexed
163 focal piglets were randomly selected for the whole study; totalling 36 focal piglets per NE. During the
164 three minute focal samples all focal piglets from each litter were observed and any play behaviours were
165 tallied and any targets (object, piglet or sow) recorded. Some miscellaneous behaviours (e.g. 'active
166 fighting' and neighbouring pen contact) were also recorded. For the focal sampling, each focal piglet was
167 observed for a total of 243 minutes pre-weaning.

168

169 2.4 Phase 2: Comparisons of Post-weaning Play Behaviours

170 In order to quantify the intensity and duration of antagonistic interactions after weaning, each piglet (N
171 = 117) was lesion scored prior to litter mixing, by counting the number of lesions on each side of the
172 piglet in three sections (head, mid and rump to determine fighting and bullying respectively – Turner et
173 al., 2006; Baumgartner, 2007). These lesion scores acted as baseline lesion scores before entering the
174 weaner pens. Lesion scoring occurred again at 3 days and at 7 days post-weaning.

175

176 All weaner pens were continuously digitally video recorded for 24 hours from when the two litters per
177 pen were mixed at weaning. Latency of when first play behaviours from each play behaviour category
178 were recorded, as well as latency for first 'active fighting' (i.e. damaging fighting) to occur. Target piglets
179 and objects were also recorded.

180

181 Following the initial 24 hours, each pen was focal sampled using the same methodology as phase 1 as
182 well as the same focal piglets (6 per litter / 12 per weaner pen). Each focal piglet was observed for a
183 total of 270 minutes post-weaning.

184

185 2.5 Phase 3: Cognitive Tests

186 One of each sex was randomly selected from each litter to undergo the cognitive test phase, totalling 24
187 piglets (12 per NE). Consideration of different cognitive tests available resulted in the selection of the
188 Spontaneous Object Recognition Test (Gieling et al., 2011). For one week prior to testing, test piglets
189 were habituated to the hold pen and test pen several times, initially in pairs but later in isolation.

190

191 For this study, piglets from the two NEs were compared on object recognition abilities after two
192 different retention times (15 minutes and 60 minutes). For testing, selected piglets from one pen were
193 herded into the hold pen. The hold pen (pen size = 4.5m²) contained scattered saw-dust over a solid
194 concrete floor, two handfuls of straw and a mechanical drinker. The piglets were then left for 15
195 minutes to settle. The order of piglet and pen testing was systematically randomised via Latin Square
196 Design so that day, test order, pen and sex effects were minimised across NEs. The retention time order

197 involved all piglets from one NE being tested for the 15 minute retention time first and then being
198 tested for the 60 minute retention time.

199

200 For stage 1, a piglet was herded into the empty test pen (pen size = 4.5m², solid concrete floors and solid
201 1.5m high walls). Once the access gate was closed, two identical objects (blue square drinkers; approx.
202 H25cm x L30cm x W27cm) were simultaneously lowered into the pen; one centred on the right wall and
203 the other centred on the left wall. The piglet was exposed to the objects for 5 minutes, all digitally video
204 recorded, so that live observations were not necessary and did not interfere with the test subjects. At
205 the start, the piglet's location in the pen (pen quarter A, B, C or D), and head orientation (left/right)
206 were recorded as well as which object it touched first and the latency to do so. During the five minutes,
207 the piglet's time spent in each quarter was recorded as well as the time spent physically interacting with
208 either object. At the end of the test, the objects were removed and the piglet was returned to the hold
209 pen, where it remained for a specified retention time (15 or 60 minutes) before being retested following
210 the same methods and recordings for stage 1. The only difference being that one of the objects had
211 been replaced by a novel object (a small red/white traffic cone; approx. H35cm x L18cm x W18cm). The
212 side of the pen in which the novel object was placed was systematically randomised by time of day, pen,
213 litter and sex.

214

215 2.6 Statistical Application

216 For focal sampling the behaviour tallies for the three minute focal samples were totalled per sample day
217 and for pre-weaning and post-weaning as a whole. For lesion score data, body sections were added
218 together to generate totals for 0, 3 and 7 days post mixing for each piglet and then differences between

219 0-3 days and 3-7 days were calculated. Statistical comparisons were conducted through linear mixed
220 models (LLM) using the residual maximum likelihood method in Genstat (11th Edition). Litter was used as
221 the random factor (encompassing all individual piglet and litter variation). Fixed effects included NE,
222 piglet age, weaning weight, sex, number in litter, NE neighbour, litter order, foster piglet, number in
223 pen, and pen. Statistical significance of terms in the LLMs was tested using the F statistic and $P < 0.05$.
224 Any data that were shown to have skewed distribution were transformed by logbase10. Spearman's
225 rank correlations were performed on all behaviour totals pre- and post-weaning in order to establish
226 any significant relationships and their patterns.

227

228 Phase 3 data were converted into percentages of time interacting with objects and latencies calculated.
229 Differences were calculated between percentage time interacting with objects for each trial and test
230 phase for the two retention test times. Linear mixed models were conducted using Litter as the random
231 effect and the fixed effects included NE, sex, age, pen, novel object, and novel object side. Spearman's
232 rank correlations were performed for percentage differences of object interactions for the two retention
233 times.

234

235 Spearman's rank correlation matrices were used to establish any relationships and patterns between
236 experimental phases.

237

238 3. Results

239 3.1 Phase 1: Comparisons of pre-weaning play behaviours

240 3.1.1 Initial four days post-farrowing

241 During the initial four days post farrowing NEP piglets were significantly quicker to perform first
242 locomotor play then NEC piglets (mean latencies: NEP = 430.0 ± 82.9 mins vs. NEC = 745.8 ± 78.8 mins; $F =$
243 $7.62_{(1,11)}$, $P = 0.020$). NE had a significant effect on latency of first piglet social interaction ($F = 23.61_{(1,11)}$,
244 $P < 0.001$), with piglets in NEP (84.2 ± 24.7 mins) interacting earlier with each other than piglets in NEC
245 (246.7 ± 22.5 mins). NE also had a significant effect on the first sow-piglet interaction ($F = 5.27_{(1,11)}$, $P =$
246 0.045), with piglets in NEP performing sow-piglet interactions sooner after farrowing than piglets from
247 NEC (mean latency: NEP = 85.5 ± 25.8 mins; NEC = 305.0 ± 74.4 mins). Farrowing length, mean piglet birth
248 weight, number born and sow parity had no significant effects on latencies for first locomotor play
249 behaviour and social interactions.

250

251 A Spearman's correlation matrix highlighted significantly strong positive correlations between
252 performance latency of first locomotor play behaviours and social ($r_s = 0.719$, $P = 0.008$) and sow-piglet
253 ($r_s = 0.619$, $P = 0.032$) interactions.

254

255 3.1.2 Pre-weaning focal sampling

256 NE had a tendency to affect total play behaviours pre-weaning, with NEP piglets on average performing
257 more play behaviours than NEC piglets (Table 2). Sex ($F = 13.92_{(1,71)}$, $P < 0.001$) and piglet age ($F =$
258 $5.49_{(1,71)}$, $P = 0.044$) had significant effects on total play behaviours pre-weaning. Older piglets on
259 average performed fewer play behaviours than younger piglets and females on average performed more
260 play behaviours than males.

261

262 NE showed a significant effect for total pre-weaning locomotor play behaviours; with NEP piglets on
263 average performing higher totals than NEC (Table 2). Sex also had a significant effect ($F = 12.08_{(1,71)}$, $P =$
264 0.011); with females performing higher totals than males irrespective of NE, although for NEC piglets the
265 difference was small. Foster piglets in NEC tended to have higher mean totals compared to non-fosters,
266 while the opposite was shown in NEP, but these differences were not significant. Weaning weight had
267 no significant effect on total pre-weaning locomotor play behaviours in the LLM analysis, however it did
268 have a significant relationship, shown by a negative correlation ($r_s = -0.25$, $P = 0.032$).

269
270 For object play totals NE had no significant effect (Table 2), however sex was highly significant ($F =$
271 $16.17_{(1,71)}$, $P < 0.001$), with females performing more object play behaviours than males in both NEs.
272 Foster status did not have a significant effect.

273
274 NE had no significant effect on social play behaviours pre-weaning (Table 2). Weaning weight ($F =$
275 $5.57_{(42,71)}$, $P < 0.001$) had a highly significant effect, with heavier piglets performing less social play
276 behaviours than lighter piglets ($r_s = -0.44$, $P < 0.001$). Foster status also had a highly significant effect ($F =$
277 $27.58_{(1,71)}$, $P < 0.001$), with fosters averaging less social play behaviours than non-fosters.

278
279 NE had a highly significant effect on total sow play behaviours pre-weaning (Table 2); with NEP piglets
280 interacting more with their mothers than NEC. Foster status also had a highly significant effect ($F =$
281 $8.89_{(1,71)}$, $P = 0.004$), with foster piglets interacting considerably less with the sow than non-fosters
282 irrespective of NE .

283

284 NE ($F = 4.38_{(1,71)}$, $P = 0.063$) and sex ($F = 3.42_{(1,71)}$, $P = 0.069$) both tended to affect active fighting
285 behaviour totals pre-weaning. NEP piglets on average fought more than NEC piglets, and females fought
286 more than males (Table 2). Total play invitations were significantly affected by NE; with NEP piglets
287 performing more than NEC piglets (Table 2). There was also a highly significant positive correlation
288 between totals of invitations and social play ($r_s = 0.40$, $P < 0.001$). However, no significant effect for NE
289 was shown for play rejections (Table 2), despite active fighting being significantly positively correlated
290 with play rejections ($r_s = 0.28$, $P = 0.017$).

291

292 3.2 Phase 2: Comparisons of post-weaning play behaviours

293 3.2.1 Post-weaning initial 24 hour

294 Data analysis showed no significant difference between NEs for the latency of first play behaviours in
295 the weaner pens ($F = 1.31_{(1,11)}$, $P = 0.285$): NEP = 9.17 ± 3.40 mins vs. NEC = 6.50 ± 1.23 mins. Pen, number
296 per pen, litter mixing order and average weaning weight were all shown to have no effect on latencies
297 for first play behaviours.

298

299 Analysis of latency to first fight per pen showed that NE had no effect ($F = 1.29_{(1,11)}$, $P = 0.288$), but the
300 number within each pen did ($F = 8.69_{(1,11)}$, $P = 0.018$), with the pen with fewer individuals showing longer
301 latency before first fighting behaviours occurred. Litters which were neighbours pre-weaning showed a
302 tendency to fight more quickly after mixing compared to non-neighbours ($F = 5.17_{(1,11)}$, $P = 0.053$). All
303 NEP litters only fought non littermates for the first fights after mixing, while NEC showed less
304 preference. Spearman's rank correlations showed that latency for first fight was not significantly
305 correlated with first play behaviours ($r_s = -0.128$, $P = 0.285$).

306

307 3.2.2 Lesion scoring

308 Lesion score data showed a significant difference between NEs for the amount of lesions counted
309 between 0-3 days ($F = 5.73_{(1,116)}$, $P = 0.038$) and 3-7 days ($F = 27.05_{(1,116)}$, $P < 0.001$) post-weaning. At 3
310 days post-weaning NEP piglets had a higher mean lesion score difference compared to NEC piglets,
311 however, at 7 days NEC piglets showed little change in lesion scores, while NEP piglets showed a sharp
312 decrease in their mean lesion scores (Figure 2).

313

314 3.2.3 Post-weaning focal sampling

315 NE was shown to have no significant effect on total play behaviours post-weaning (Table 3). Both sex (F
316 = $28.7_{(1,71)}$, $P < 0.001$) and weaning weight ($F = 34.58_{(42,71)}$, $P < 0.001$) were shown to have highly
317 significant effects; with males performing more play behaviours than females, irrespective of NE and
318 correlational analysis showing that heavier piglets performed less play behaviours than lighter piglets (r_s
319 = -0.46 , $P < 0.001$).

320

321 NE also had no effect on all total individual play behaviour categories post-weaning (Table 3): locomotor
322 play behaviours, object play and social play. However, Figure 3 demonstrates that total play behaviours
323 continue to linearly increase from pre- to post-weaning, despite a temporary reduction as a result of
324 weaning (between sample days 9 and 10).

325

326 Total active fighting behaviours and total play invitations were not significantly affected by NE (Table 3).
327 NE had no effect on total play rejections (Table 3), however weaning weight did have a significant effect
328 ($F = 2.82_{(42,71)}$, $P = 0.046$), with heavier piglets performing less play rejections than lighter piglets.

329

330 3.3 Phase 3 – Spontaneous Object Recognition Tests

331 Results for the trial stages of the tests (both objects identical) showed that NE had no significant effect
332 on the percentage time interacting with either object or latencies to approach them.

333

334 3.3.1 15-minute retention time

335 NE had a significant effect on the latency to touch the novel object in the 15 minute retention test ($F =$
336 $9.56_{(1,23)}$, $P = 0.012$), with NEP piglets approaching the object more quickly compared to NEC piglets (NEC
337 $= 94.0 \pm 14.1$ secs, NEP $= 43.7 \pm 6.8$ secs). Sex ($F = 1.03_{(1,23)}$, $P = 0.359$) and novel object side (left or right
338 wall) ($F = 0.00_{(1,23)}$, $P = 0.996$) were both shown to have no significant effect on latency to touch the novel
339 object.

340

341 NE was shown to have a significant effect on percentage time interacting with the novel object with NEP
342 pigs showing higher percentage time interacting with the novel object compared to the familiar object ($F =$
343 $5.39_{(1,23)}$, $P = 0.045$) (Figure 4). Sex also had an effect with males showing a higher percentage time
344 interacting with the novel object in both tests, but it was only significant for the 15 minute test ($F =$
345 $5.32_{(1,123)}$, $P = 0.043$).

346

347 3.3.2. 60-minute retention time

348 NE had no significant effect on the latency to touch the novel objects ($F = 0.54_{(1,23)}$, $P = 0.477$) or the
349 percentage time interacting with the novel objects ($F = 0.87_{(1,23)}$, $P = 0.373$). Both sex and novel object
350 side had no significant effects on latency or percentage time interacting with the novel object.

351

352 3.3.3 Relationships across experimental phases

353 Pre- and post-weaning total play behaviours did not significantly correlate with cognitive abilities in
354 phase 3 (higher interactions times with novel object than familiar object) for either retention times.
355 Interestingly pre-weaning sow-piglet play behaviours showed non-significant tendencies for positive
356 correlations with percentage difference interaction times (objects 1 and 2) for both retention times (15
357 mins test: $r_s = 0.40$, $P = 0.054$, 60 mins test: $r_s = 0.46$, $P = 0.024$).

358

359 4. Discussion

360 Overall NE was shown to influence pre-weaning but not post-weaning play behaviours, therefore
361 conservatively supporting the hypothesis that piglets reared in more complex NEs will play more than
362 piglets reared in less complex NEs. NEP piglets developed play behaviours earlier and showed a larger
363 repertoire of play behaviours pre-weaning than NEC piglets, indicating that the effects of NE on play
364 behaviour are short-term and are highly dependent on present environmental stimulus (e.g. more
365 straw, larger space). Previous research supports these findings by demonstrating that piglets reared in
366 more complex (enriched) environments perform more play and exploratory behaviours, being generally
367 more active than piglets reared in less complex (non-enriched) environments (Bolhuis et al., 2005;

368 Chaloupková et al., 2007; De Jonge et al., 1996; Oostindjer et al., 2011; Petersen et al., 1995; Weary et
369 al., 2002).

370

371 Links between play and exploration have also been demonstrated in several studies (e.g. Wood-Gush
372 and Vestergaard, 1991), thus it can be argued that a more complex (stimulating) environment
373 encourages greater exploration and eventual play within it and supports Špinka et al.'s (2001) theory of
374 training for the unexpected. Whilst Špinka et al.'s work supports the current study's findings pre-
375 weaning, once weaned there were no differences in play between the two treatment groups. Post-
376 weaning piglets were in identical environments, and all experienced the same stimulation and this is
377 likely the reason for no difference in play behaviours at this stage.

378

379 Pre-weaning NEP piglets may have been experiencing better welfare than NEC piglets if play behaviour
380 frequency is used as an indication of positive welfare; animals only play if they are in a 'relaxed state'
381 and as a result experience positive emotional states (Boissy et al., 2007; Burghardt, 2005; Špinka et al.,
382 2001; Manteuffel et al., 2009).

383

384 Play behaviours started earlier in the NEP compared to other 'enriched' environments from other
385 studies, with locomotor play behaviours starting at one day old, while Blackshaw (1997) observed these
386 behaviours not starting until 3-5 days old. Blackshaw (1997) also noted object play occurring during this
387 time, however, our study did not observe any object play behaviour during the four days post-farrowing.
388 NEP piglets showed much greater sow play behaviours compared to NEC piglets. Other studies have
389 observed similar results, with piglets reared in less restrictive environments and with greater access to

390 the sow, showing considerably higher sow play behaviours than piglets which were not (Blackshaw et
391 al., 1997). The sow and the piglets in NEP could interact more easily with each other in the larger and
392 non restrictive environment, compared to the NEC, therefore allowing play behaviours and other social
393 interactions to be performed. Blackshaw's (1997) results also supported our finding that sow
394 interactions occurred at around 1-2 days old and suggested this was fundamental for developing the
395 sow-piglet maternal bond.

396

397 The continuing increase in play behaviours during the pre-weaning period (0-4 weeks) has been
398 observed in other studies, although data from the present study do not show a peak between 2-6 weeks
399 old (Bolhuis et al., 2005; Newberry et al., 1988), but instead shows a continued increase until eight
400 weeks. Although there was a sharp decrease on the days when weaning occurred and play behaviours
401 remained lower than pre-weaning levels for the first week post-weaning. Several studies have
402 demonstrated how weaning results in a decrease in play behaviours (e.g. Donaldson et al., 2002). It is
403 suggested that this is due to the event being novel, and involving an abrupt change in environment,
404 including the withdrawal in milk, resulting in piglets being stressed, hungry and suffering from negative
405 emotional states (e.g. fear) (Boissy et al., 2007; Broom, 2008; Jensen and Stangel, 1992). Therefore the
406 motivation to play is hampered and supports the theories of the function of play being a luxury
407 behaviour only performed when an animal is in a 'relaxed state' (Špinka et al., 2001; Burghardt, 2005).

408

409 Weaning also involves piglets being mixed into novel groups; therefore motivations for establishing
410 group social hierarchies will become the priority until dominance is resolved. Lesion score data
411 demonstrated a sharp increase in fighting behaviours during this period, with the majority of individuals
412 all participating and receiving a high number of lesions particularly in the first three days. NEP piglets

413 showed higher aggression levels than NEC piglets; however this aggression was acute and sharply
414 decreased by day seven, while NEC piglets remained aggressive for the entire seven days, even though
415 the total lesions were lower than NEP piglets at three days. This suggests that piglets reared in more
416 complex environments, with basic access to neighbouring litters (through barred windows) may perhaps
417 resolve social hierarchy disputes quicker than piglets reared in litter-isolated and less complex
418 environments. However from these results we can only infer that environmental complexity and/or
419 access to other litters causes this and without measuring stress physiology, for example, we can only
420 assume that pro-longed aggressive encounters displayed in the NEC piglets cause a welfare detriment.
421 Other studies which have taken these measurements have shown that piglets mixed prior to weaning
422 appear to show decreased aggression and stress responses to mixing at weaning (D'Eath, 2005; De
423 Jonge et al., 1996; Parratt et al., 2006; Schaefer et al., 1990). However, resident-intruder tests (D'Eath,
424 2005) did demonstrate that socialised piglets were more aggressive to intruder piglets and engaged in
425 fighting more quickly than un-socialised piglets (D'Eath, 2005; Kanaan et al., 2008), therefore supporting
426 the present results. Perhaps piglets reared in more complex and sociable environments are able to
427 develop their social and fighting skills earlier than litter-isolated piglets in less complex environments
428 (D'Eath, 2005), thus providing them with the motivation and confidence to tackle hierarchal disputes
429 quickly and efficiently. If the function of play is to train for the unexpected (Špinka et al., 2001), then a
430 NE which provides greater novelty and complexity would allow for greater experience and play
431 development, and perhaps more successfully preparing piglets for novel social and aggressive
432 interactions at weaning.

433

434 Results for cognitive abilities across the two NEs showed that NEP piglets were better at discriminating
435 between familiar and novel objects after a retention time of 15 minutes, but there was no difference in

436 cognitive abilities for NEs after the 60 minute retention time, suggesting that pigs can discriminate
437 between objects. Pigs reared in more complex environments were more adept at object discrimination,
438 but there is a limit to their declarative memory (Bolhuis et al., 2004; Siegford et al., 2008; Winters et al.,
439 2008; Bracke and Spooler, 2008). Whilst these findings support our hypothesis that piglets reared in
440 more complex and stimulating NEs are able to develop their socio-cognitive abilities further than piglets
441 reared in less complex NEs, the fact that we found no significant correlations between play behaviour
442 (pre- and post-weaning) and interaction durations with novel objects means it cannot be confirmed
443 whether the increase of play behaviour or the more complex NE resulted in better object discrimination
444 post-weaning.

445

446 Similar results regarding retention times have been shown by Kornum and colleagues (2007), where pigs
447 demonstrated the ability to discriminate between objects in spontaneous object recognition tests after
448 10 minute retention times, but no discrimination was shown after one hour or 24 hours. The results for
449 the latencies to approach the novel object showed that NEP piglets for the 15 minute retention test did
450 approach the novel object more quickly, perhaps suggesting a more adept ability to cope with novelty
451 and being less fearful (e.g. less neophobic than NEC piglets). It could be argued that NEP piglets may not
452 be better at object recognition, but merely are less neophobic due to an optimistic cognitive bias
453 (Douglas et al., 2012), although they would have to show some cognitive understanding that one object
454 is novel. Although comparatively Olsson and colleagues (1999) demonstrated that pigs reared in
455 enriched environments were less likely to approach novel objects and even showed avoidance
456 behaviours compared to pigs reared in non-enriched environments, and they suggested that the lack of
457 stimulation and poor social development in a NE may be factors in developing poorer risk assessment
458 abilities. In the current study pigs from both NEs did comparably approach novel objects, but pigs from

459 the more complex NE showed more exploration and play behaviours perhaps due to extra stimulation
460 they received pre-weaning (Špinka et al., 2001; Bolhuis et al., 2004). Links between more complex play
461 behaviours and cognitive ability have been suggested (Held et al., 2009), therefore piglets reared in NEP
462 who did develop a broader play repertoire pre-weaning, may have developed their cognitive abilities
463 earlier, resulting in greater object play (seen pre- and post-weaning) as well as a better ability to
464 discriminate between objects in the novel object test and the motivation to explore, compared to NEC
465 piglets. However the results did show large individual variation for both NEs, which might be attributed
466 to individual variation in cognitive abilities (e.g. genetic pre-disposition to memory capacity (Gielsing et
467 al., 2011; Kornum et al., 2007) as well as temperament (Lind and Moustgaard, 2005; Spooler et al.,
468 1996; Wemelsfelder et al., 2000).

469
470 There is also the issue of interference during the cognitive tests; research by Mendl (1997),
471 demonstrated how pigs' spatial memory was reduced when disturbances (e.g. isolation or novel food
472 source) occurred during retention intervals. During this study, test pigs were held with two pen mates,
473 and were provided with saw dust and straw to reduce stress. However, perhaps the presence of these
474 items and other individuals acted as disturbances during the retention periods, therefore masking
475 cognitive ability in the 60 minute test, where discrimination may have been more subtle.

476
477 Irrespective of NE, sex was shown to have substantial effects on both play and socio-cognitive abilities
478 pre- and post-weaning. Pre-weaning, female piglets played more than males, but this was reversed post-
479 weaning, and in the cognitive tests, males appeared better at discriminating than females. Other
480 studies have shown that on the whole, males play more than females (Blackshaw et al., 1997; Houpt,
481 2005) and studies on maze tasks in pigs showed no significant sex effect (Gielsing et al., 2011; Siegford et

482 al., 2008). Perhaps the explanation is simply that females show neurological development earlier than
483 males (Short and Balaban, 1994) and that as exploration and play appear to be closely intertwined
484 (Špinka et al., 2001) the reason for the higher interaction with the novel object was not simply
485 discrimination capability, but the motivation to explore and play, which was starting to reduce in
486 females post-weaning. Perhaps the novel object test shows higher play motivations rather than ability to
487 discriminate, although play is heightened by the presence of novel stimuli (Fagen, 1981; Wood-Gush and
488 Vestergaard, 1991).

489

490 4.1 Conclusion

491 These findings have an impact on the way we house commercial pigs and their related welfare,
492 particularly during neonatal development. This study has suggested that piglets reared in enriched and
493 complex NEs develop greater socio-cognitive abilities which have long term direct and indirect effects on
494 their welfare e.g. reduced chronic aggression post-weaning, reduced stress and increased positive
495 emotional states as the result of play. The study also suggests that the pig's memory and cognitive
496 abilities although great, do have limits which perhaps should be considered in management practices
497 (e.g. fostering and mixing) in order to minimise stress and encourage good welfare.

498

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504

505 References

506 Baumgartner, J., 2007. How to deal with complex data of skin lesions in weaner pigs. *Animal Welfare* 16,
507 165-168

508 Baxter, E. M., Lawrence, A. B., Edwards, S. A., 2011. Alternative farrowing systems: design criteria for
509 farrowing systems based on the biological needs of sows and piglets. *Animal* 5(4), 580-600.

510 Blackshaw J. K., Swain A. J., Blackshaw A. W., Thomas F. J. M., Gillies, K. J. 1997. The development of
511 playful behaviour in piglets from birth to weaning in three farrowing environments. *Applied*
512 *Animal Behaviour Science* 55, 37-49.

513 Boissy A., Manteuffel G., Jensen M. B., Moe R. O., Spruijt B., Keeling L. J., Winckler C., Forkman B.,
514 Dimitrov I., Langbein J., Bakken M., Veissier I., Aubert A. 2007. Assessment of positive emotions in
515 animals to improve welfare. *Physiology and Behavior* 92, 375-397

516 Bolhuis, J. E., Schouten, W. G. P., de Leeuw, J. A., Schrama, J. W., Wiegant, V. M., 2004. Individual coping
517 characteristics, rearing conditions and behavioural flexibility in pigs. *Behavioural Brain Research*.
518 152, 351-360.

519 Bolhuis, J. E., Schouten, W. G. P., Schrama, J W., Wiegant, V. M., 2005. Behavioural development of pigs
520 with different coping characteristics in barren and substrate-enriched housing conditions. *Applied*
521 *Animal Behaviour Science* 93, 213-228.

522 Bolhuis, J. E., Schouten, W. G. P., Schrama, J W., Wiegant, V. M., 2006. Effects of rearing and housing
523 environment on behaviour and performance of pigs with different coping characteristics. *Applied*
524 *Animal Behaviour Science* 101, 68-85.

- 525 Bracke, M. B. M., Spoolder, H. A. M., 2008. Novel object test can detect marginal differences in
526 environmental enrichment in pigs. *Applied Animal Behaviour Science* 109, 39-48.
- 527 Broom, D. M., 2008. Welfare Concepts. In: *Welfare of Pigs from birth to slaughter*. Faucitano L., &
528 Schaefer A. L (Eds). Wageningen Academic Publishers. The Netherlands & Editions Quae,
529 Versailles, France. 15-27.
- 530 Broom, D. M., 2010. Cognitive ability and awareness in domestic animals and decisions about obligations
531 to animals. *Applied Animal Behaviour Science* 126(1-2), 1-11.
- 532 Chaloupková, H., Illman, G., Bartoš, L., Špinka, M., 2007. The effect of pre-weaning housing on play and
533 agnostic behaviour of domestic pigs. *Applied Animal Behaviour Science* 103, 25-34.
- 534 Cronin, G. M., Smith, J. A., 1992. Effects of accommodation type and straw bedding around parturition
535 and during lactation on the behaviour of primiparous sows and survival and growth of piglets to
536 weaning. *Applied Animal Behaviour Science* 33, 191-208.
- 537 D'Eath, R. B., 2005. Socialising piglets before weaning improves social hierarchy formation when pigs are
538 mixed post-weaning. *Applied Animal Behaviour Science* 93, 199-211.
- 539 D'Eath, R. B., Turner, S. P., 2009. The Natural behaviour of the Pig. In: Marchant-Forde, J. N. (Eds). *The*
540 *Welfare of Pigs*. *Animal Welfare* 7, 13-45.
- 541 Dawkins, M., 1990. From an Animal point of view – motivation, fitness and animal welfare. *Behavioral*
542 *and Brain Sciences*. 13, 1-61.
- 543 De Jonge, F. H., Bokkers, E. A. M., Schouten, W. G. P., Helmond, F. A., 1996. Rearing Piglets in a Poor
544 Environment: Development Aspects of Social Stress in Pigs. *Physiology and Behavior* 60 (2), 389-
545 396.

- 546 Donaldson, T. M., Newberry, R. C., Špinka, M., Cloutier, S., 2002. Effects of early play experience on play
547 behaviour of piglets after weaning. *Applied Animal Behaviour Science* 79, 221-231.
- 548 Douglas, C., Bateson, M., Walsh, C., Bédué, A., Edwards, S. A., 2012. Environmental enrichment induces
549 optimistic cognitive biases in pigs. *Applied Animal Behaviour Science* 139, 65-73.
- 550 Dybkjaer, L., 1992. The identification of behavioural indicators of 'stress' in early weaned piglets. *Applied*
551 *Animal Behaviour Science* 35, 135-147.
- 552 Edwards S.A., Brett M., Ison S., Jack M., Seddon Y.M., Baxter E.M. 2012. Design principles and practical
553 evaluation of the PigSAFE free farrowing pen. *Proceedings Proc 4th European Symposium on*
554 *Porcine Health Management, Brugges, Belgium.* p113.
- 555 English, P. R., Smith, W. J., 1975. Some causes of death in neonatal piglets. *Vet. Ann.* 15, 95-104.
- 556 Fagen R., 1981. *Animal Play behaviour.* Oxford University Press, New York.
- 557 Fiedler, I., Küchenmeister, U., Ender, K., Haider, W., Ernst, K., Puppe, B., 2005. Reactions of muscles to
558 stimulation – effects on the loin muscle (M. Longissimus) of Landrace pigs. *Dtsch Tierarztl*
559 *Wochenschr.* 112, 363-368.
- 560 Francis, D.A., Christison, G. I., Cymbaluk, N. F., 1996. Uniform or heterozygous weight groups as factors
561 in mixing weanling piglets. *Canadian Journal of Animal Science* 76, 171-176.
- 562 Gieling, E. T., Nordquist, R. E., van der Staay, F. J., 2011. Assessing learning and memory in pigs. *Animal*
563 *Cognition* 14, 151-173.
- 564 Grandin, T., 1980. The effect of stress on livestock and meat quality prior to and during slaughter.
565 *International Journal for the Study of Animal Problems.* 1(5), 313-337.

- 566 Held, S. D. E., Špinka, M., 2011. Animal Play and animal welfare. *Animal Behaviour* 81(5), 891-899. Held,
567 S., Cooper, J. J., Mendl, M. T., 2009. Advances in the Study of Cognition, behavioural Priorities and
568 Emotions. In: Marchant-Forde, J. N. (Eds). *The Welfare of Pigs. Animal Welfare* 7, 47-94.
- 569 Held, S., Mendl, M., Laughlin, K., Bryne, R. W., 2002. Cognition studies with pigs: Livestock cognition and
570 its implication for production. *Journal of Animal Science* 80(E. Suppl. 1), E10-E17.
- 571 Houpt, K. A., 2005. *Domestic Animal Behavior for Veterinarians and Animal Scientists*. 4th Edition.
572 Blackwell Publishing Professional Ltd. 256-267.
- 573 Jensen, M. B., Pedersen, L. J., Hansen, S. W., Munksgaard, L., Ladewig, J., Matthews, L. 2001. Effects of
574 interrupted social contact on the social behaviour of calves and piglets. *Behavioural Processes* 56,
575 23-29.
- 576 Jensen, P., Redbo, I., 1987. Behaviour during nest leaving in free-ranging domestic pigs. *Applied Animal*
577 *Behaviour Science* 18, 355-362
- 578 Jensen, P., Stangel, G., 1992. Behaviour of piglets during weaning in a semi-natural enclosure. *Applied*
579 *Animal Behaviour Science* 33, 227-238.
- 580 Kanaan, V. T., Pajor, E. A., Lay (Jr), D. C., Richert, B. T., Garner, J. P., 2008. A note on the effects of co-
581 mingling piglet litters on pre-weaning growth, injuries and responses to behavioural tests. *Applied*
582 *Animal Behaviour Science* 110, 386-391.
- 583 Kornum, B. R., Thygesen, K. S., Nielsen, T. R., Knudsen, G. M., Lind, N. M., 2007. The effect of the inter-
584 phase delay interval in the spontaneous object recognition test for pigs. *Behavioural Brain*
585 *Research* 181, 210-217.

- 586 Lind, N. M., Moustgaard, A., 2005. Response to Novelty Correlated with Learning Rate in s Go/No Go
587 Task in Göttingen Minipigs. *Neural Plasticity* 12, 341-345
- 588 Manteuffel, G., Langbein, J., Puppe, B., 2009. Increased farm animal welfare by positively motivated
589 instrumental behaviour. *Applied Animal Behaviour Science* 118, 191-198.
- 590 Marchant, J. N., Rudd, A. R., Mendl, M. T., Broom, D. M., Meredith, M. J., Corning, S., Simmins, P. H.,
591 2000. Timing and causes of piglet mortality and conventional farrowing systems. *Veterinary*
592 *Record* 147 (8), 209-214.
- 593 Marchant-Forde J. N. 2009. The Welfare of Pigs. *Animal Welfare* 7, 1-12.
- 594 Martin, P., Bateson, P., 2007. *Measuring Behaviour: An introductory guide*. 3rd Edition. Cambridge
595 University Press.
- 596 Melotti,L., Oostindjer,M., Bolhuis,E., Held, S., Mendl,M. 2011. Coping personality type and
597 environmental enrichment affect aggression at weaning in pigs. *Applied Animal Behaviour Science*
598 133, 144-153.
- 599 Mendl, M., Laughlin, K., Hitchcock, D., 1997. Pigs in space: spatial memory and its susceptibility to
600 interference. *Animal Behaviour* 54, 1491-1508.
- 601 Moustgaard, A., Lind, A. M., Hemmingsen, R., Hansen, A. K., 2002. Spontaneous Object recognition in
602 the Göttingen Minipig. *Neural Plasticity* 9(4), 255-259.
- 603 Newberry, R. C., Wood-Gush, D. G. M., Hall, J. W., 1988. Playful Behaviour of piglets. *Behavioural*
604 *Processes* 17, 205-216.

- 605 Olsson, I. A.S., de Jonge, F. H., Schuurman, T., Helmond, F. A., 1999. Poor rearing conditions and social
606 stress in pigs: repeated social challenge and the effect on behavioural and physiological responses
607 to stressors. *Behavioural Processes* 46. 201-215.
- 608 Oostindjer, M., Brand, H. V. D., Kemp, B. J., Bolhuis, E., 2011. Effects of environmental enrichment and
609 loose housing of lactating sows on piglet behaviour before and after weaning. *Applied Animal
610 Behaviour Science* 134(1-2), 31-41. In press.
- 611 Parratt, C. A., Chapman, K. J., Turner, C., Jones, P. H., Mendl, M. T., Miller, B. G., 2006. The fighting
612 behaviour of piglets mixed before and after weaning in the presence of absence of a sow. *Applied
613 Animal Behaviour Science* 101, 54-67.
- 614 Petersen, H. V., Simonsen H. B., Lawson L. G. 1995. The effect of environmental stimulation on the
615 development of behaviour in pigs. *Applied Animal Behaviour Science* 23, 223-226.
- 616 Schaefer, A. L., Salomons, M. O., Tong, A. K. W., Sather, A. P., Lepage, P., 1990. The effect of
617 environment enrichment on aggression in newly weaned piglets. *Applied Animal Behaviour
618 Science* 27, 41-52.
- 619 Short, R. V., Balaban, E., (Eds). 1994. *The Differences Between the Sexes*. Cambridge University Press.
620 203-300
- 621 Siegford, J. M., Rucker, G., Zanella, A. J., 2008. Effects of pre-weaning exposure to a maze on stress
622 responses in pigs at weaning and on subsequent performance in spatial memory and fear-related
623 tests. *Applied Animal Behaviour Science* 110, 189-202.
- 624 Špinko, M., Newberry, R. C., and Bekoff, M., 2001. *Mammalian Play: training for the unexpected*. The
625 *Quarterly Review of Biology* 76, 141-168.

- 626 Spoolder, H. A. M., Burbidge, J. A., Lawrence, A. B., Simmins, P. H., Edwards, S. A., 1996. Individual
627 behavioural differences in pigs: intra- and inter-test consistency. *Applied Animal Behaviour*
628 *Science* 49, 185-198.
- 629 Turner, S. P., Farnworth, M. J., White, I. M. S., Brotherstone, S., Mendl, M., Knap, P., Penny, P.,
630 Lawrence, A.B., 2006. The accumulation of skin lesions and their use as a predictor of individual
631 aggressiveness in pigs. *Applied Animal Behaviour Science* 96(3-4), 245-259.
- 632 Weary, D. M., Pajor, E. A., Bonenfant, M., Fraser, D., Kramer, D. L., 2002. Alternative housing for sows
633 and litters Part 4. Effects of sow-controlled housing combined with a communal piglet area on pre
634 and post-weaning behaviour and performance. *Applied Animal Behaviour Science* 76, 279-290.
- 635 Wemelsfelder, F., Haskell, M., Mendl, M. T., Calvert, S., Lawrence, A. B., 2000. Diversity of behaviour
636 during novel object tests is reduced in pigs housed in substrate-impooverished conditions. *Animal*
637 *Behaviour* 60(3), 385-394.
- 638 Winters, B. D., Saksida, L. M., Bussey, T. J., 2008. Object recognition memory: Neurological mechanisms
639 of encoding, consolidation and retrieval. *Neuroscience and Biobehavioral Reviews*. 32, 1055-1070.
- 640 Wood-Gush D. G. M., Vestergaard, K., 1991. The seeking of novelty and its relation to play. *Animal*
641 *Behaviour* 42, 599-606.
- 642

642 Figure Captions

643 Figure 1: Un-scaled diagrams of the two neonatal environments: a) standard farrowing crate; b) PigSAFE
644 pen with the approximate dimensions. In NEP, the swing door provides an enclosed nest area, but when
645 opened (after 7 days), changes and opens up the environment.

646 Figure 2: Comparison of mean (\pm SE) lesion score differences (post weaning) for the two neonatal
647 environments.

648 Figure 3: Play behaviours from pre-weaning-sample days 1-9 (4-27 days of age) to post-weaning-sample
649 days 10-19 (28-56 days of age). Weaning occurred between sample days 9 and 10.

650 Figure 4: Mean (\pm SE) percentage differences for interaction durations with objects in spontaneous
651 object recognition trials (objects identical) and tests (introduction of a novel object) for 15 minute
652 retention time between trial and test for pigs from both neonatal environment treatments: farrowing
653 crate (NEC) and PigSAFE pen (NEP).

654

Table 1: Ethogram for piglet behaviours.

Play Category	Behaviour	Description
Locomotor/ Individual	Scamper	Two or more forward directed hops in quick succession of each other usually associated with excitability.
	Pivot	Twirling of body on the horizontal plane by a minimum of 90° usually associated with jumping on the spot.
	Toss head	Energetic movements of head and neck in quick succession, in both horizontal and vertical planes.
	Flop	Focal animal drops to the pen floor from a normal upright position to a sitting or lying position. There is no contact with an object or another individual (piglet or sow) which could cause the change in position.
	Hop	Focal animal has either its two front feet or all four feet off the pen floor at one time, through an energetic upwards jumping movement. The animal continues facing the same original direction for the whole of the behaviour.
	Rolling	Lying on back, while rocking entire body in side to side movements. Behaviour is terminated when focal animal returns to an upright position.

Gambolling Energetic running in forward motions within the pen environment. Normally associated with using large areas of the pen, and occasionally coming into marginal contact with other piglets (e.g. nudge).

Social	Pushing	Focal animal drives its head, neck or shoulders with minimal or moderate force into another piglet's body. Occasionally the behaviour results in the displacement of the target piglet.
	Nudging	Snout of focal piglet is used to gently touch another piglet's body, not including naso-naso contact. Usually occurs in bouts of behaviours in quick succession.
	Chase	Focal animal follows the locomotory movement and direction of another piglet vigorously e.g. running after a target piglet which is also running.
	Push-overs	The focal animal uses its head and shoulders to drive a substantial force at a target piglet, resulting in the target to lose balance and fall-over. A fall is identified by the target piglet losing its footing for at least two feet, resulting in its shoulders or hips coming into contact with the floor.
	Sow	Focal piglet uses its feet to elevate itself onto the body of the sow.
	Climbing	A minimum of two feet must be off the floor and on the sow. Any behaviour directed at the sow's udder is ignored, however attempts to clamber above the udder is included, although the majority will be targeted around the sow's head, neck and shoulders.

	Sow nudging	The snout of the focal piglet is used to gently touch the sow's body, not including naso-naso contact. The behaviour normally occurs in bouts, with the single behaviours occurring in quick succession.
Object	Shake object	While holding an item (e.g. straw) in its mouth, the focal animal energetically moves the item from side to side using its neck and head. This behaviour also includes manipulation of items in a similar fashion, which are fixed at one point (e.g. hooked chains). Item must be visible to the observer when being held in the piglet's mouth.
	Carry object	Animal securely holds an item in its mouth, while moving in a forward direction. Item must be visible to the observer when being held in the piglet's mouth.
Miscellaneous	Play Invite	Focal piglet performs locomotor or social play behaviours, which are directed through face-to-face body orientation to another non-playing piglet. The behaviours are often repeated rapidly and highly energetic.
	Play Reject	Focal piglet which is a target of play invite behaviours from another piglet, responds by turning its head and body a minimum of 90° away from the 'inviting' piglet, and does not reciprocate any play behaviours.
	Active fighting	Focal piglet strikes or bites another piglet with significant force or attempts to do so (e.g. head/shoulder knocks). Normally performed with aggressive vocalisations.

Out of sight Piglet was or has gone out of sight during the 3 minute focal sample. The majority of these incidences occurred when the focal piglet moved into the creep areas, as this was the only major blind spot in the digital recordings.

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Table 2: Means and standard errors (SE) for pre-weaning behaviour totals for NEs and their statistical comparisons. Degrees of freedom = 1,71 for all measures.

Pre-weaning behaviour totals	NEC		NEP		F statistic	P value
	Mean	SE	Mean	SE		
Play Behaviours	150.11	4.14	170.33	5.80	5.06	0.051
Locomotor play	56.81	2.33	68.75	3.12	7.71	0.020
Object play	16.25	1.05	17.92	1.37	1.36	0.268
Sow-piglet play	11.72	1.12	26.89	1.26	33.16	<0.001
Social (piglet- piglet) play	65.33	2.75	56.78	3.29	0.67	0.433
Active fighting	4.64	0.38	6.08	0.40	4.38	0.063
Play invitations	4.25	0.35	7.25	0.54	27.08	<0.001
Play rejections	4.61	0.35	4.89	0.38	0.20	0.661

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Table 3: Means and standard errors (SE) for post-weaning behaviour totals for NEs and their statistical comparisons. Degrees of freedom = 1,71 for all measures.

Post-weaning behaviour totals	NEC		NEP		F statistic	P value
	Mean	SE	Mean	SE		
Play Behaviours	281.19	9.30	294.25	6.16	1.65	0.232
Locomotor play	128.39	6.52	129.25	5.17	0.23	0.645
Object play	52.72	2.20	54.33	2.25	0.24	0.634
Social (piglet- piglet) play	100.08	4.26	110.67	3.80	1.6	0.237
Active fighting	20.72	0.91	18.31	1.20	0.78	0.397
Play invitations	14.86	0.98	14.42	0.87	0.31	0.588
Play rejections	9.33	0.90	6.69	0.54	1.48	0.249

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Figure 1

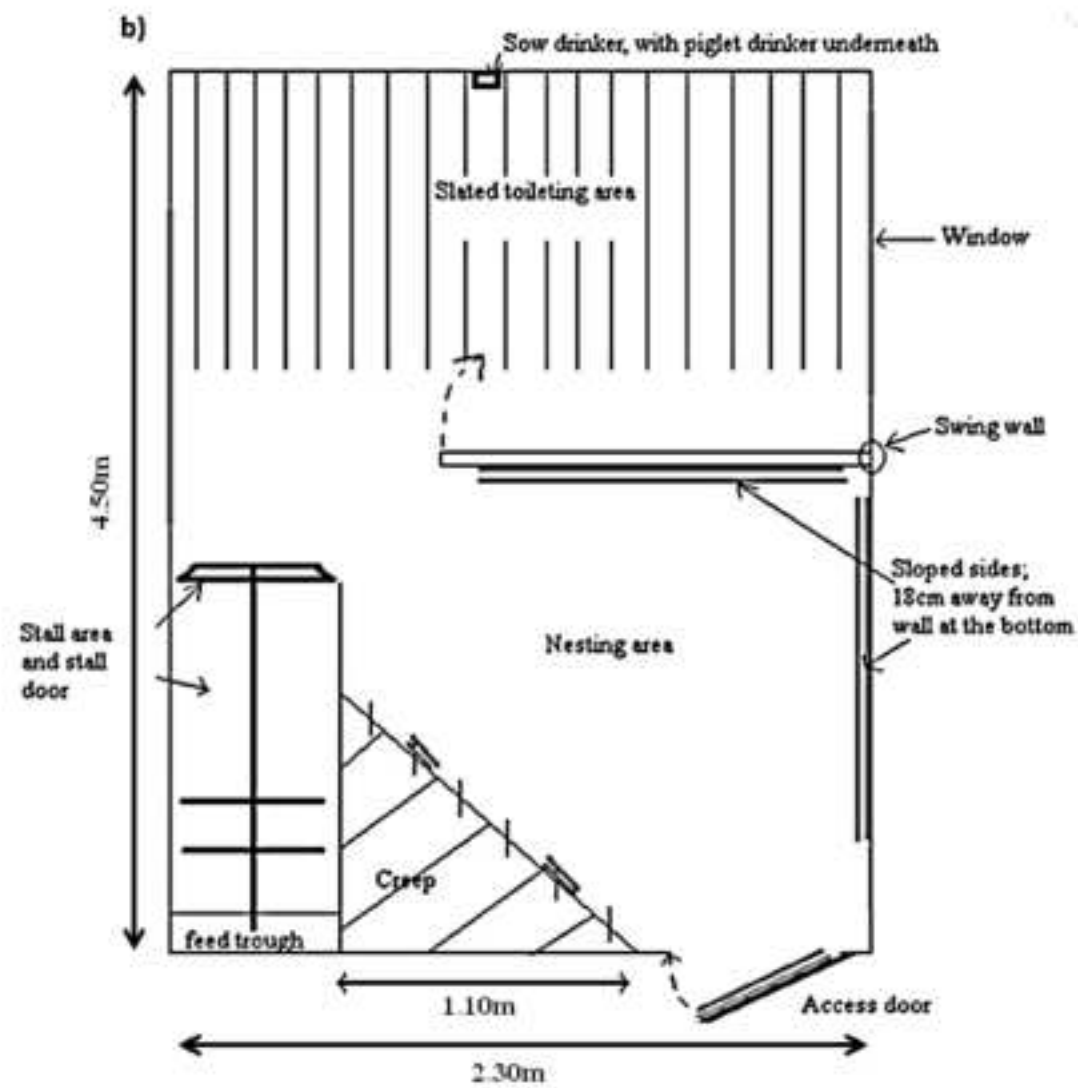
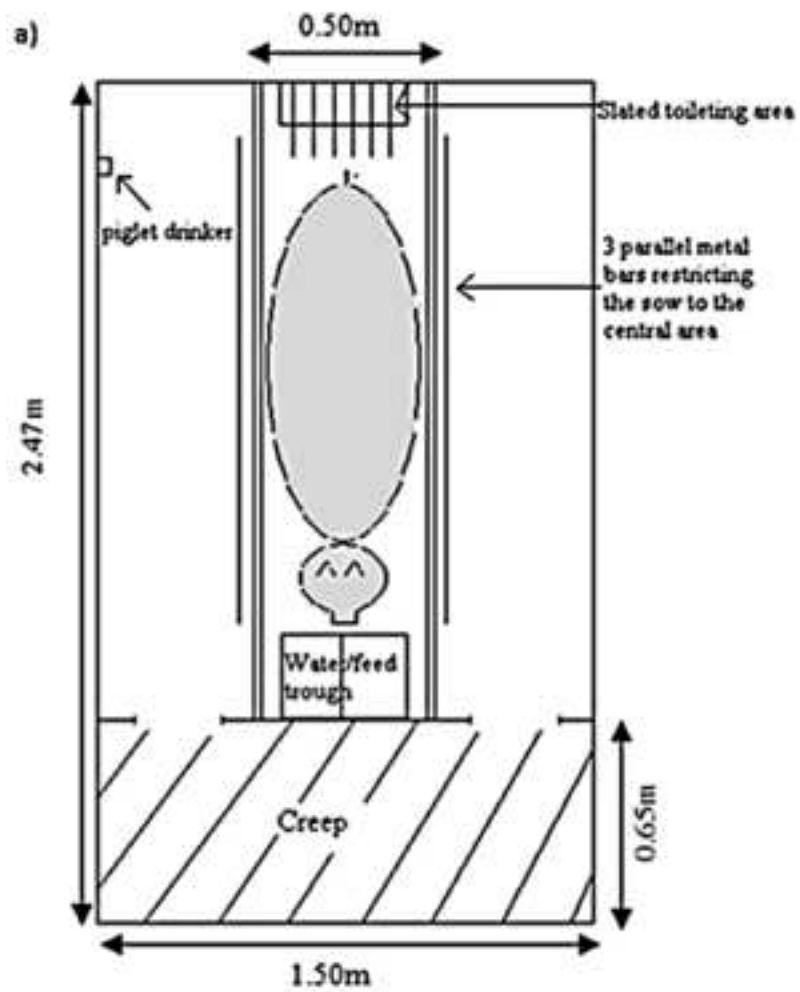


Figure 2

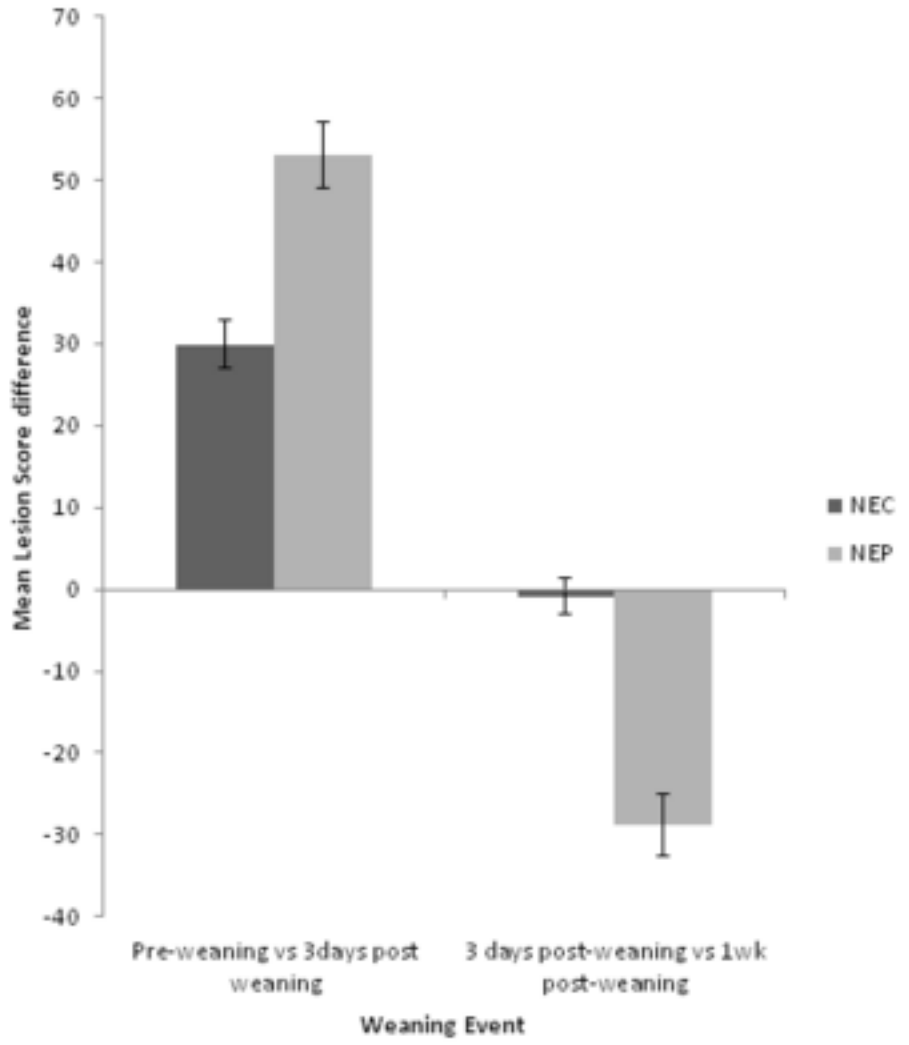


Figure 3

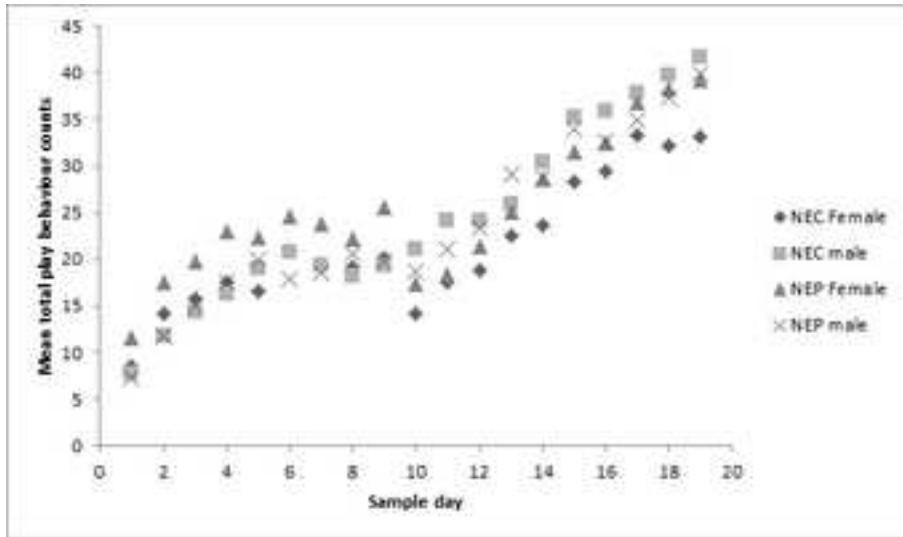


Figure 4

Script

