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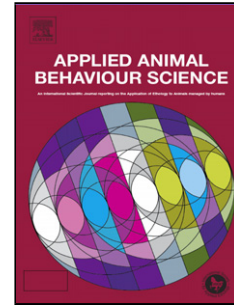
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Socialising piglets in lactation positively affects their post-weaning behaviour

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Abstract

Although commercial farrowing sheds keep individual litters separated, previous studies have
15 suggested that housing systems that allow socialisation of piglets pre-weaning can reduce
aggression after weaning. This study tested whether pigs socialised with non-litter mates pre-
weaning would show less aggression during mixing at weaning (when piglets are taken from their
sows and mixed in group housing), and whether socialisation influenced the time budgets or
behavioural expression of piglets at weaning. In total, 353 piglets were followed from birth through
20 to one week after weaning. Piglets from 24 sows were allowed to socialise in groups of four litters
(‘socialised’ treatment group) from 10 d of age; litters from nine sows were followed as controls.
Socialised piglets were monitored to determine the prevalence of cross-suckling. Body weight was
recorded at birth, prior to weaning and one week after weaning. Continuous video footage was
collected for 1.5 days after weaning for behavioural analyses. There was no difference in the body
25 weight of socialised pigs compared to control pigs at weaning or one week after weaning.
Quantitative scoring of behaviour revealed no significant difference in aggression displayed
between treatment groups or between the sexes; however, compared with overall averages, a
greater proportion of socialised males spent time lying (57% of time compared with an average of
43% for the other sex-treatment groups, $P < 0.001$; but less eating/drinking 4% cf. average 8%, $P <$
30 0.001), and a greater proportion of socialised females were investigating (17% cf. average 12%, $P <$
 0.001 with less lying 40% cf. 48%, $P < 0.001$). Qualitative Behavioural Assessment (QBA) was used to
assess the body language of pigs during an active period (the middle of the day after weaning).
Observers reached consensus in regard to their assessments of pig behavioural expression ($P <$
 0.001). Two main dimensions of behavioural expression were identified, which accounted for 41%
and 19% of the correlation between pigs. There were significant socialisation treatment effect ($P =$
35 0.002 and $P = 0.007$) on both dimensions, with socialised pigs more likely to be described as
‘sleepy’/‘tired’ or ‘content’/‘relaxed’ than control pigs (described as more ‘active’/‘curious’ or
‘aggressive’/‘dominant’). Because socialising piglets had no effect on body weight pre-weaning, and
there was a low occurrence of cross-suckling (2.9 ± 6.5 % of piglets recorded suckling), socialisation
40 was not disadvantageous. On the contrary, the behavioural difference at weaning suggests
socialising piglets may be beneficial from a welfare perspective.

Keywords: behavioural expression; cross-suckling; Free Choice Profiling; piglet; Qualitative
Behavioural Assessment; weaning; pre-weaning socialisation.

45

45 1 Introduction

Under commercial conditions, young pigs removed from their dams at weaning are generally sorted by weight and sex and then placed into pens in dedicated nursery facilities. Unfortunately, the mixing of non-littermates at weaning causes aggression that is of welfare concern (Parratt et al., 2006). Increased fighting due to mixing (Ewbank and Bryant, 1972) may lead to wounds, infection and abscesses (Teague and Grifo, 1961), and coupled with the challenges of dietary change at weaning, there is generally decreased disease resistance, growth performance as well as increased mortality recorded at weaning (Gross, 1972; Gross and Colmano, 1969). Increased fighting also contributes to reduced post-weaning feed intake through reduced time spent eating (Friend et al., 1983; but see Sherritt et al., 1974).

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A number of methods have been tested to reduce aggression when mixing unfamiliar pigs. For example, Pluske and Williams (1996) showed that the psychotropic drug amperozide reduced the incidence of aggressive behaviours following mixing of newly-weaned pigs, while lithium added to the diet reduced aggressive behaviours (but also caused vomiting and reduced feed intake, McGlone et al., 1980). A review of the use of pheromones, masking odours and tranquilisers found no notable success of any of these methods (Petherick and Blackshaw, 1987). Increasing dietary tryptophan levels to modulate brain serotonin levels, and hence behaviour, did not reduce stress responses in pigs (Li et al., 2006), and decreased shed illumination (which reduced cannibalism in broiler chickens, Christison et al., 1995), failed to reduce aggression in pigs (Dechamps and Nicks, 1989).

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An alternative approach to reduce fighting at weaning is to familiarise piglets with non-litter mates pre-weaning ('socialising'). Socialising piglets has been reported to reduce agonistic behaviour at weaning under intensive pork production conditions (Pluske and Williams, 1996; Weary et al., 2002). Piglets may be more predisposed to accept non-familiar piglets at a younger age (Pitts et al., 2000), since it is during this period of socialisation after leaving the nest that piglets learn to form social relationships through non-aggressive and playful interactions (Petersen et al., 1989). Pre-weaning is clearly an important time for piglets to develop behavioural flexibility and therefore the capacity to adapt to new challenges (Cox and Cooper, 2001), and hence is a time when piglets establish behavioural responses which they later rely on in life (Fagan, 1981). Additionally, although piglets still fight when socialised pre-weaning, fighting is of shorter duration (Pitts et al., 2000) and injuries are less severe because the piglets are smaller (Jensen et al., 1994). Pre-weaning socialisation therefore allows piglets to develop important social skills (Chaloupková et al., 2007)

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that can not only improve the young pigs' abilities to adapt to the post-weaning environment (Cox
80 and Cooper, 2001), but also benefit them during the grower/finisher period (D'Eath, 2005; Hillmann
et al., 2003; Kutzer et al., 2009).

Socialising can also increase feed consumption by piglets, both before and after weaning (Weary et
al., 2002), which may lead to increased weight gain pre- and post-weaning (but see Rantzer et al.,
85 1995; Weary et al., 2002). Pre-weaning socialisation therefore potentially has production benefits
in addition to reducing the chance of injury at weaning (Pitts et al., 2000). Nevertheless, one of the
concerns regarding allowing mixing of suckling piglets is the incidence of cross-suckling and
competitive exclusion of subordinate piglets. Although it can be considered a natural phenomenon
(Maletinska and Spinka, 2001), cross-suckling is generally avoided under industry conditions due to
90 fears of suckling disruption (preventing some piglets from suckling) and potential injury to both the
sow and the piglets. Reduced milk intake and weight gain in the presence of cross-suckling has
been reported in some studies (Algers et al., 1990; Pedersen et al., 1998), while cross-suckling may
also lead to increased fighting for udder position which can lead to teat and udder damage (Brown
et al., 2005; Olsen et al., 1998). Mixing and cross-suckling can also agitate the sow (Pedersen et al.,
95 1998). It is understood that sows can distinguish between their own and alien piglets by odour
(Horrell and Hodgson, 1992); in a multi-suckling system a sow has limited possibilities of allowing
only her own piglets to suckle and not alien piglets, and as a result she may terminate suckling bouts
(e.g. by standing) where alien piglets are present (Pedersen et al., 1998). Depending on the housing
system, anecdotal reports suggest that some sows can become aggressive and attack the alien
100 piglets, or withhold and/or terminate suckling bouts for anything up to a day or more, unless
sedated (Blackshaw, 1986; Harper, 2001; White, 2013). However, published studies suggest that
any disturbances to lactation only last for a few hours (Jensen, 1986) or days (Weary et al., 2002)
and have no follow-on effects on growth rates (Maletinska and Spinka, 2001; Wattanakul et al.,
1997). It should also be noted that not all studies on multi-suckling systems observed cross-suckling
105 (Kutzer et al., 2009), and giving the piglets sufficient time to bond to their own sow (including
recognising her lactation call) and establish a teat order may reduce the incidence of cross-suckling
(D'Eath, 2005; Newberry and Wood-Gush, 1985).

The aims of the present study were to investigate the effects of pre-weaning socialisation on
110 behaviour pre-weaning (cross-suckling and body weight gain), as well as post-weaning observations
(time budgets for 1.5 days after weaning, and assessment of behavioural expression of pigs through
Qualitative Behavioural Assessment; QBA).

2 Methods

115 2.1 Animals and experimental design

This study was carried out at a large commercial piggery in Western Australia under approval of the
Animal Ethics Committee at Murdoch University (Permit number R2412/11) and the farm
owners/managers (who wish to remain anonymous). We examined the effects of pre-weaning
socialisation on behaviour during mixing at weaning, which was achieved without interfering with
120 the general piglet or sow management practices under the current farrowing system used at the
piggery. At the conclusion of the study, the pigs continued on within the farm's grower/finisher
facility.

A total of 353 piglets from 33 sows were marked individually, allowing them to be followed through
125 to post-weaning. Piglets from 24 sows were socialised pre-weaning ($n = 256$ piglets); for
comparison, litters from another nine sows were monitored as control animals ($n = 97$ piglets).
Sows used in the study were Large White x Landrace, mated to Large White x Landrace boars. The
average parity of the sows was 3.11 ± 0.37 (range 1-7) with an average gestation length of 114 ± 0.1
days. Litter sizes at birth averaged 11.6 ± 0.57 (range 5-16). All piglets included in this study were
130 born over a period of three days. Cross-fostering took place in the first 48 h after farrowing, as per
normal practice (redistributing some piglets from large litters to sows with fewer piglets). Piglets
were weighed (digital scales) within 24 h of birth, at the same time as tagging, ear notching and iron
injection. Creep feed (Kettridges, Picton, Western Australia; 21% crude protein, 1.35% available
lysine, 15.4 MJ DE/kg) was provided *ad libitum* from 8 d after farrowing.

135 Facilitation of socialisation of piglets was carried out from around 10 days of age (Fig. 1) by
removing sections of the farrowing crate walls, thereby allowing four litters access to a common
walkway and all four crates (Fig. 2). For the six socialised groups (i.e., six groups of four sows, to
make 24 sows and litters in total), each litter was marked with stock marker paint (a different colour
140 for each litter) to allow for behavioural monitoring. For the nine control litters, each litter was
allowed access to the walkway, providing the animals with additional space during pre-weaning. It

should be noted that because socialisation involves allowing piglets to roam into other pens or a communal space, this means inevitably increasing the space each piglet has access to and also increases the spatial complexity of their environment; it is therefore impossible to completely
145 separate the social and purely physical enrichment factors.

2.2 Pre-weaning observations

2.2.1 Cross-suckling

The 24 socialised litters were observed from the day of mixing through to weaning. For every sow,
150 $n = 15$ lactation events were recorded (total 360 lactation events). There are two types of cross-suckling piglets: some piglets will only occasionally cross-suckle (less than 5 times over all lactation events recorded for each sow), but habitual cross-sucklers will cross-suckle more than they suckle from their own mothers and, once established in the teat order, habitual cross-sucklers will usually be faithful to the sow that was not their mother (Olsen et al., 1998). Although we attempted to
155 follow individual piglets through all suckling bouts, we have greater confidence in our estimations of which sows allowed cross-suckling (sows that had one or more alien piglets suckling over at least three consecutive lactation events). The percentage of cross-suckling piglets was therefore calculated including and excluding these sows. We tested the influence of time (days post mixing) on the proportion of cross-suckling by mixed-model ANOVA, with mixed-group ID and sow ID
160 included as random factors. The percentage of cross-suckling piglets showed a Poisson distribution.

2.2.2 Body weight gain

Piglets were weighed within 24 h of birth, the day before weaning, and seven days after weaning. Body weight data were analysed by mixed-model ANOVA including treatment as a fixed effect, sow ID and sex as random factors, and piglet age and prior body weight readings of each piglet as
165 covariates. Body weight was normally distributed for each age group (Kolmogorov-Smirnov test).

2.3 Post-weaning behaviour

Piglets were weaned each Thursday at this farm, and therefore piglets ranged in age from 21-24 days at weaning. All piglets were weighed the day before weaning. On the day of weaning, sows were removed and taken to dry-sow housing. Piglets from each treatment group were then
170 grouped in a single pen sorted by sex and loaded onto a truck for transport to the grower facility (5 km away). Once at the grower facility, groups of 40 pigs were held in climate-controlled sheds (each

pen: 6.5 x 2.2 m, stocking rate: 0.36 m²/head). The animals for this experiment were retained in six pens (two adjacent pens of socialised females, two adjacent pens of socialised males, one pen of control females and one pen of control males). Each pen had two feeders with the same feed as used in the farrowing facility, and two drinking facilities: one nipple drinker and one bowl. Farm staff then went through the groups of pigs, sorting them further by size and removing lame or injured animals to a sick-pen for treatment. The total time from removal of the sows took ~6 h.

To avoid interfering with normal farm procedure, post-weaning video footage collection (under natural lighting conditions) commenced when farm staff had stopped moving through the pens, for 4 h (14:00h until dusk at 18:00h) and from dawn to dusk the following day (06:00h to 19:00h ~36 h since weaning). Two types of video footage were collected:

1. Continuous footage was collected for quantitative scoring of time budgets for four of the pens (one per sex/treatment combination). Four digital cameras (15 fps; Panasonic SDR-H250 camcorders, Belrose, NSW, Australia) were placed on tripods in the laneway between the pens, covering an estimated 90% of the pen area (there was a blind-spot immediately in front of the camera). This footage was used to compare behaviour between treatment groups and determine the most appropriate time point to conduct the QBA scoring.
2. Throughout the 1.5 days after weaning, a series of video clips (each 1-min in length) were collected for QBA using a hand-held camera (the same Panasonic SDR-H250 camcorder models), focussing on a randomly-selected individual in each pen and following this animal as it moved through the pen. The cameraman rotated past each of the six pens of pigs filming the animal closest to one of two grid-point locations in the pen (visualised as the centre of each half of the pen; these grid points were not marked in any way). A total of 110, 1-min clips were collected over the 1.5 days post-weaning. Analysis of time budgets (see results) indicated that the pigs were most active 21-24 h after mixing for weaning; the 1-min clips collected during this 3-h time window were used for QBA (all the clips within this 3-h period were used, meaning that there was no further selection process required).

2.3.1 Time budgets

Pig behaviour was scored using instantaneous scan sampling of the footage for 5-min intervals (similar to published studies of pig behaviour; e.g. Nakamura et al., 2011). Every 5 min, the footage was stopped and the behaviour of every individual (i.e. max. n = 40) within the field of view was

scored by one observer into one of seven behaviour categories (aggression, investigating,
205 eating/drinking, walking, standing, sitting, and lying ; see Table 1 for full description). Pearson's χ^2
analyses were performed with expected values calculated from the overall averages for each
behaviour (averaged across treatments, sexes and all time points). We used these quantitative
analyses to identify a 3-h window of peak activity (21-24 h after weaning) to carry out the QBA
analyses (since the greatest proportion of animals were active at this time, we maximised our
210 chances of determining treatment differences).

2.3.2 Behavioural expression (Qualitative Behavioural Assessment)

Qualitative Behavioural Assessment is a method of quantifying the behavioural expression of
animals. QBA has been used to study the behaviour of a number of species, including adult pigs
215 (Rutherford et al., 2012; Temple et al., 2011b; 2012; Wemelsfelder et al., 2000; 2001; 2009).

Fifteen volunteer observers (recruited by advertising across the university by word of mouth,
including people with a range of backgrounds but not pig experts) were required to attend two
sessions on the university campus or by correspondence. Observers were given detailed
220 instructions on completing the sessions but were not told about the experimental treatments. The
two sessions are detailed below:

Session 1: Term generation. Free Choice Profiling (FCP) has been used extensively in the field of
food science (Arnold and Williams, 1986). FCP is a powerful technique as it allows observers to
225 generate their own terms that they feel comfortable using. It also prevents observers from
projecting suggested criteria onto the animals or from being biased by the terms given to them
(Wemelsfelder, 2007; Wemelsfelder and Lawrence, 2001). Observers were shown 12 video clips of
pigs demonstrating a wide range of behaviour (collected by following individuals on an ad hoc basis
undertaking divergent behaviour; including both socialised and control piglets) to allow observers to
230 describe as many aspects of the pigs' expressive repertoire as possible. After watching each clip,
observers were given 2 min to write down any words that they thought described that animal's
behavioural expression. There was no limit imposed to the number of terms an observer could
generate, but terms needed to describe not *what* the animal was doing (i.e. physical descriptions of
the animal such as walking, chewing, drinking), but *how* the animal was doing it. The descriptive
235 terms were then edited to remove those that described actions (e.g. sitting, walking), and terms

that were in the negative form were transformed to the positive for ease of scoring (e.g. unhappy became happy). Each word for each observer was listed alphabetically (to effectively randomise the list) and attached to a 100-mm visual analogue scale ranging from minimum to maximum.

240 *Session 2: Quantification.* Observers watched the 1-min clips of the experimental pigs (n = 24 clips; six clips for each group). The experimental clips were ordered so that no two clips of the same treatment-sex combination were seen back-to-back. Observers used their own unique list of terms to quantify each term for each experimental pig. Their descriptive terms were sorted alphabetically (to effectively randomise the presentation order of terms), and presented to observers with a 100-
245 mm visual analogue scale adjacent to each term (Microsoft Excel). Observers scored animals by placing a mark on the visual analogue scale reflecting the intensity of the animal's expression on each descriptive term (i.e. somewhere between 0 = minimum and 100 = maximum for that term). Observers were given detailed instructions on completing the sessions but were not told about the experimental design or treatments.

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QBA analysis. The observer scores generated from the 24 video clips were analysed by Generalised Procrustes Analysis (GPA) using a specialised software edition written for Françoise Wemelsfelder; for a detailed description of its procedures, see Wemelsfelder *et al.* (2000). Briefly, GPA calculates a consensus or 'best fit' profile between observer assessments through complex pattern matching.
255 This consensus profile has several main dimensions (usually two or three) explaining the variation between animals. Each animal receives a quantitative score on each of these dimensions ('GPA dimension scores'), so that the animal's position in the consensus profile can be graphically represented in two- or three-dimensional plots. Each plot represents each pig in each treatment where the position of the pig indicates its scores on each GPA axis. To compare treatments, the
260 GPA scores for each dimension were analysed using a mixed-model ANOVA with socialisation treatment and sex as the fixed variables, observers as the random variables, and BoxCox-transformed GPA dimension scores as dependant variables (Kolmogorov-Smirnov test for normal distribution).

265 The GPA dimensions were interpreted by correlating the animals' scores to the observers' individual scoring patterns, producing word charts describing the consensus for individual observers that can be compared for linguistic consistency. From these word charts, a list of terms from all observers describing the consensus dimensions was produced. Those that correlated strongly with each GPA

dimension ($r > |0.6|$ on GPA dimension 1, $r > |0.5|$ on GPA dimension 2) were chosen to represent
 270 each GPA dimension.

General statistical treatments

Statistical analyses were performed using GenStat 10.2 (VSN International, Hemel Hempstead,
 Hertfordshire, UK) and Statistica 8.0 (StatSoft-Inc, Tulsa, OK, USA). Carrying out correlation analyses
 275 with quantitative data were limited since we only had four treatment groups (we used different
 footage for the quantitative and qualitative assessments and therefore were restricted to
 comparing group means). Data are presented as means \pm 1 SD and a statistical level of $\alpha \leq 0.05$ is
 used throughout to denote statistical significance.

280

3 Results

3.1 Pre-weaning behaviour

3.1.1 Cross-suckling

Alien piglets ('cross-sucklers') (average 2.9 ± 6.5 % of piglets suckling, range 0-45% over the 360
 285 lactation events recorded) were present at 22% of all suckling events. Sow ID had a strong effect on
 the proportion of cross-sucklers (sow: $F_{18,328} = 9.45$, $P < 0.001$), but there was no effect of group
 (mixed group ID: $F_{5,18} = 0.82$, $P = 0.550$) or time (days post mixing: $F_{8,328} = 1.13$, $P = 0.343$; Fig. 3). We
 identified two sows that never had alien piglets suckle, but six sows that allowed alien piglets to
 suckle over at least three consecutive lactation events. Excluding the six sows that habitually
 290 allowed cross-sucklers, the percentage of cross-suckling piglets reduced from 2.9% overall, to 1.2%.

3.1.2 Body weight

Males (1.65 ± 0.32 kg) were heavier than females (1.56 ± 0.30 kg) 1 day after birth ($F_{1,71} = 5.78$, $P =$
 0.019; Fig. 4a) and there was a strong effect of sow ID ($F_{31,275} = 14.64$, $P < 0.001$) on birth weight, but
 295 there was no effect of socialisation treatment at that point ($F_{1,31} = 0.01$, $P = 0.939$; piglets had been
 allocated to treatment groups but had not been socialised at that stage). The day before weaning
 (average weight of piglets 6.24 ± 1.09 kg) there was no treatment effect on body weight ($F_{1,29} =$
 0.40, $P = 0.534$), although there was still a strong effect of sow ID and birth weight (sow: $F_{30,273} =$
 4.37, $P < 0.001$; sex: $F_{1,272} = 0.29$, $P = 0.591$; covariates age: $F_{1,30} = 0.04$, $P = 0.852$, weight at birth:

300 $F_{1,38} = 48.21$, $P < 0.001$). Similarly, there was no treatment effect ($F_{1,27} = 0.14$, $P = 0.711$) on body weight 1 week after weaning (average weight of piglets 6.63 ± 0.96 kg), although there were effects of sow ID and a correlation with previous body weight measures (sow: $F_{30,129} = 1.77$, $P = 0.016$; sex: $F_{1,128} = 1.89$, $P = 0.172$; covariates age: $F_{1,27} = 0.15$, $P = 0.701$, weight at birth: $F_{1,45} = 192.95$, $P < 0.001$, weight at weaning: $F_{1,60} = 706.47$, $P < 0.001$).

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3.2 Post-weaning behaviour

3.2.1 Time budgets

For the ~150 time points that each pen was monitored over the 1.5 days post-weaning, we recorded an average of 33.5 ± 0.6 piglets per scan sample, which averaged 84% of the total number of
 310 animals ($n = 40$) in each pen. Overall average values for time budgets (averaged across all hours and all treatment groups) were aggression: 2.8%, investigating: 8.3%, eating/drinking: 4.0%, walking: 2.5%, standing: 16.2%, sitting: 0.4%, and lying: 65.8%; these average values were used for comparison with specific time points.

315 By the middle of the day (~21-24 h after mixing; Fig. 5), pigs were active compared with overall averages across the entire 1.5 day period (only 46% lying), showing more investigating (13%), standing immobile (26%), eating/drinking (6%), and interacting aggressively (4%). This 3-h period (hereafter 'peak activity period') was selected as the time window for QBA due to the amount of activity recorded. During this peak activity period (Table 2, Fig. 6), socialised males displayed more
 320 lying ($\chi^2_3 = 48.82$, $P < 0.001$), less standing ($\chi^2_3 = 27.19$, $P < 0.001$), and less eating/drinking ($\chi^2_3 = 18.78$, $P < 0.001$) compared to the averages summed across this 3-h time period for all treatments (χ^2 analysis). Control males displayed more standing ($\chi^2_3 = 12.14$, $P = 0.007$), eating/drinking ($\chi^2_3 = 40.95$, $P < 0.001$), and less lying ($\chi^2_3 = 19.69$, $P < 0.001$). Socialised females showed more investigative behaviour ($\chi^2_3 = 22.19$, $P < 0.001$) and less lying ($\chi^2_3 = 23.82$, $P < 0.001$). Control
 325 females showed no difference ($P > 0.05$) from overall averages for any behaviour.

3.2.2 Behavioural expression

The 15 observers generated a total of 117 unique terms to describe the pigs in the video clips, with an average of 19.5 (range 13-29) terms per observer. The Procrustes Statistic was 44.96% and this
 330 differed from a mean randomised profile ($t_{99} = 47.2$, $P < 0.001$). Two main GPA dimensions were

identified, explaining 40.6% and 19.4% of the variation between animals (GPA dimensions 1 and 2, respectively). Descriptive terms strongly correlated with each GPA dimension are shown in Table 3. Low values for GPA dimension 1 were associated with terms such as 'sleepy'/'tired' and high values with terms such as 'active'/'curious'. Low values for GPA dimension 2 were associated with terms such as 'content'/'relaxed', and high values were associated with terms such as 'aggressive'/'dominant'.

Positions of groups of pigs within their treatments on the two GPA dimensions are shown in Fig. 7. There was a treatment effect on GPA dimension 1 (y-axis in Fig. 7) ($F_{1,343} = 9.81$, $P = 0.002$), with socialised animals scored as more 'sleepy'/'tired' compared with control animals (more 'active'/'curious'). Neither sex ($F_{1,343} = 2.60$, $P = 0.107$) or observer ID ($F_{1,343} = 0.23$, $P = 0.998$) had an effect on GPA dimension 1 scores. There was also a treatment effect on GPA dimension 2 (x-axis in Fig. 7) ($F_{1,343} = 7.46$, $P = 0.007$), with socialised animals scored as more 'content'/'relaxed' compared with control animals (scored as more 'aggressive'/'dominant'). Neither sex ($F_{1,343} = 1.78$, $P = 0.183$) or observer ID ($F_{1,343} = 0.48$, $P = 0.943$) had an effect on GPA dimension 2 scores.

4 Discussion

The present study showed pre-weaning socialisation positively influenced the behaviour of pigs. We recorded minimal cross-suckling (2.9%) and did not find any detrimental effects of socialising on body weight gain during lactation. Although there was no significant difference in the incidence of aggression between treatment groups or between the sexes, compared with overall averages, socialised males spent more time lying (but less eating/drinking), and socialised females were more active (less time lying) investigating. The behavioural expression of piglets suggested that they adapted quicker to the new environment at mixing, with socialised pigs scored higher for descriptive terms that implied they were perceived as more relaxed than control pigs.

4.1 Pre-weaning observations

The low evidence of cross-suckling found in this study (2.9%, or 1.2% when six sows that habitually allowed alien piglets to cross-suckle were excluded from the estimates) reflects similar findings for previous studies (0%, D'Eath, 2005; <2%, Weary et al., 2002; 0%, Weary et al., 1999). This low occurrence of cross-suckling may be due to nursing synchronisation by the sows in adjacent pens (piglets cannot simultaneously suckle from their own mother and an adjacent sow), or to the time at which socialisation commenced (day 10, by which time teat order is established). In contrast to the

view that cross-suckling is strictly a negative behaviour, piglets that may be undernourished (e.g.
365 due to suckling from a low milk-yielding teat) have the opportunity to seek additional nutrients from
another sow, which can be regarded as beneficial. In this case, the piglet would likely be better off
with additional suckling on a sow that was not their mother than if it had been faithful to its mother.

Literature emphasising negative impacts of pre-weaning socialisation mostly focuses on cross-
370 suckling and disruption to suckling (Pedersen et al., 1998). However, we found no significant
difference in body weight between socialised and control piglets at weaning, indicating that
socialised piglets were not adversely affected by any increase in competition at the udder. These
data support previous studies showing no effect of pre-weaning socialisation on overall piglet
growth rate (D'Eath, 2005; Kanaan et al., 2008; Parratt et al., 2006; Pluske and Williams, 1996;
375 Wattanakul et al., 1997; Weary et al., 1999). Another argument against pre-weaning socialisation
has been labour or other costs associated with changing housing. However, intensive indoor
production systems are highly controlled and intervention with litters (e.g. cross-fostering, keeping
below-weight piglets back a week or two on a foster sow) is commonplace. These practices could
continue in a multi-suckling system in the presence of litter-mixed housing of piglets.

380

4.2 Behaviour at mixing

There was no significant difference in aggression between socialised and control pigs over the 1.5
days mixing at weaning or during the 3-h 'active' period identified (21-24 h after mixing). This
finding contradicts published results reporting reduced aggression after weaning in piglets that
385 were socialised pre-weaning. Group size may influence the result, as many studies have used small
groups (e.g. three to six piglets Weary *et al.*, 1999; 2002), whereas we examined pens of 40 pigs
under commercial conditions. The method of assessing aggression may also have an effect.
Previous studies have used resident-intruder tests or social encounter tests (examining dominance
dynamics in pairs of pigs) or incidence of injuries (Kutzer et al., 2009; Pluske and Williams, 1996;
390 Wattanakul et al., 1997), which inform about hierarchy stabilisation (D'Eath, 2005; de Jonge et al.,
1996; Hillmann et al., 2003; Pitts et al., 2000) and also absolute levels of aggression (Erhard et al.,
1997). Alternatively, lesion scores (D'Eath, 2005) or fight length (Friend et al., 1983) have been
recorded. Play and aggression have been described as a continuum (Silerova et al., 2010), with
some authors identifying fighting separate from play when it includes 'serious' biting (Arey and
395 Sancha, 1996; Devillers and Farmer, 2009), head knocks (Chaloupková et al., 2007; Parratt et al.,
2006; Yuan et al., 2004) or pushing (Hessel et al., 2006; Mason et al., 2003). By contrast, we relied

on the pig's responses rather than *a priori* definitions, recording aggression as social interaction where one pig moved away from the other and did not find differences in levels of aggression.

400 By contrast with the wealth of studies that have quantified aggression around weaning (above), there are few data quantifying positive aspects of welfare. QBA has been used as one of 12 welfare assessments incorporated in the European Commission's Welfare Quality® assessments of sows, piglets and fattening pigs, where it is the only measure of positive welfare (Temple et al., 2011a; Wemelsfelder and Lawrence, 2001). In our study, observers reached consensus on their assessment
405 of the behavioural expression of piglets, supporting previous QBA studies in adult pigs (Rutherford et al., 2012; Temple et al., 2011b; 2012; Wemelsfelder et al., 2000; 2001; 2009). We also recorded a significant socialisation treatment effect on both GPA dimension 1 and 2, suggesting that enrichment of the social environment during lactation influenced the behavioural expression of pigs. Socialised pigs scored higher for descriptive terms that implied they were perceived as more
410 relaxed than control pigs - they were scored as more 'sleepy'/'tired' or 'content'/'relaxed' while control animals were more 'active'/'curious' or 'aggressive'/'dominant'. This finding supports the time budget data - socialised animals were also scored as spending more time lying (males), and while females were classified as standing or investigating, observers interpreted their body language as generally relaxed.

415 In conclusion, we showed positive behavioural responses at weaning for socialised piglets (time budgets and QBA) and support previous studies indicating that a piglet's experience pre-weaning influences their post-weaning behaviour (Cox and Cooper, 2001; Li and Wang, 2011). When piglets are mixed from 10 days of age, there was a low occurrence of cross-suckling and no difference in
420 their weight gain, providing evidence against misgivings about implementing a housing system that incorporates pre-weaning socialisation. Instead, pre-weaning socialisation may be beneficial to piglets from a welfare perspective, including expression of more relaxed behaviour.

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Fig. legends

570 Fig. 1. Timeline of this study. Socialisation of litters took place between 10 days of age and weaning (at 21-24 days). Body weight (mass m_b) was recorded <24 h after birth, 1 day before weaning, and 7 days after weaning.

Fig. 2. Diagrammatic representation of the layout of the pens. Piglets of 4 adjacent sows (A-D) were 'socialised' by allowing them access to the common corridor from ~10 days of age (left hand side shaded area). Control litters of other sows (E) were given access to the corridor but not allowed to mix with other litters (right hand panel shaded area). The farrowing crates measured 2 x 2.2 m with a sow confinement area 1.4 m wide, the corridors were 0.6m wide. The crates had a feeder for the sow and two nipple drinkers, one at sow height and one at piglet height.

Fig. 3. Percentage cross-suckling observed in the 24 socialised litters of piglets.

580 Fig. 4 Effect of (a) sex and (b) socialisation treatment on piglet body weight (mass m_b) at three time points. Values are means $\pm 1SD$. * indicates significance ($P < 0.05$).

Fig. 5 Time budget of behaviour for all pigs (all treatment groups together). Footage was collected immediately after piglets were introduced to their weaning pens (between 2pm-6pm on day 1), and the entire following day for comparison. Footage could not be collected overnight (O/N) due to

585 poor lighting conditions.

Fig. 6. Summary of the time budgets for the three-hour time window analysed by qualitative assessment presented by the four treatment groups. \uparrow behaviour more prevalent than the average, \downarrow behavior less prevalent than the average.

Fig. 7: Positions of pigs within their treatments on GPA dimensions 1 and 2. Values are means $\pm 1 SD$

590 for the treatment group.

Table 1: Terms used to score behaviour in time budgets.

Category	Definition
Aggression	Pigs engaged in actions (e.g. fighting, biting, shoulder to shoulder aggressive stance, mounting, belly-nosing) which caused the recipient to react negatively. Where the recipient moved away, the event was scored as one pig behaving aggressively, where the recipient subsequently retaliated, it was scored as two aggressive pigs. If the recipient did not react negatively, the instigator was described as investigating.
Investigating	Instances of chewing, nosing and exploring the pen or penmates.
Eating/drinking	Pigs were deemed as eating/drinking if they were interacting with feed or water. Behaviour was described as investigating if the behaviour was not the food or water itself (e.g. a pig nosing the underside of the water bowl, trying to lift it).
Walking	Ambulation, movement without touching anything with nose or mouth.
Standing	All four legs supporting body with no ambulation or touching anything with their nose or mouth.
Sitting	Hind quarters on the floor, front legs supporting body.
Lying	Whole length of body on the floor or on other pigs, i.e. not supported by their legs.

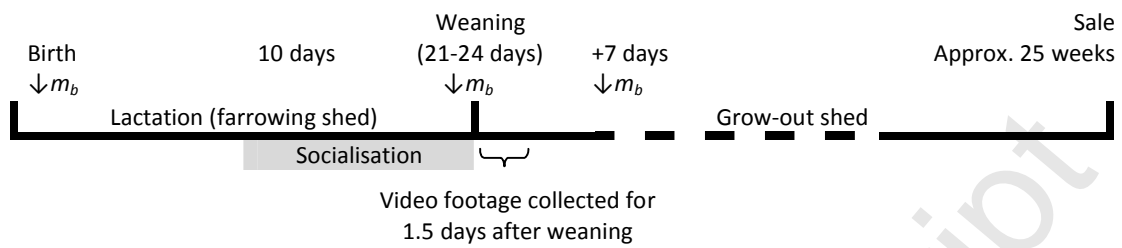
Table 2: Percentage of observations (total number of pigs observed within each treatment) for each of seven behavioural categories averaged across a 3-h time window the day after weaning (~21-24 h after weaning). Significant values (bold) indicated as: more (↑) or less (↓) than the overall average values ($P < 0.01$).

Behaviour	Socialised male	Control male	Socialised female	Control female
Aggression	4%	5%	4%	4%
Investigating	12%	12%	17% ↑	11%
Eating/drinking	4% ↓	11% ↑	7%	5%
Walking	3%	2%	3%	4%
Standing	20% ↓	32% ↑	28%	26%
Sitting	0%	0%	1%	1%
Lying	57% ↑	38% ↓	40% ↓	50%

595

595 Table 3: Terms used by observers to describe behaviour of piglets after weaning which were
 strongly correlated with the GPA consensus dimensions. The terms shown are those that were
 correlated with each end of each GPA dimension axis (% of variation in behavioural expression
 accounted for by each dimension). Term order is determined firstly by the number of observers to
 use each term (in brackets if greater than 1), and secondly by weighting of each term (i.e.
 600 correlation with the GPA consensus dimension). Terms in bold were used to describe the GPA
 dimensions in the text and graphs. The last column shows a summary of statistical analyses for each
 dimension.

GPA Dimension	Low Values	High Values	socialisation treatment effect
1 (40.6%)	Sleepy (13), Tired (7), Relaxed (4), Content (3), Snuggly (2), Dreamy (2), Comfortable (2), Peaceful, Seeking companionship, Still, Slothish, Wanting a cuddle, Cuddly, Quiet, Cold, Restful, Stable, Calm, Companionship.	Active (5), Curious (5), Investigative (3), Inquisitive (2), Restless (2), Depressed, Frustrated, Searching, Territorial.	$F_{1,343} = 9.81$ $P = 0.002$
2 (19.4%)	Content (2), Relaxed (2), Comfortable (2), Timid, Investigative, Observant, Curious, Happy, Inquisitive, Interested.	Aggressive (9), Dominant (5), Playful (5), Annoyed (5), Excited (4), Angry (3), Scared (3), Energetic (2), Irritated (2), Active (2), Fazed, Tetchy, Agitated, Feisty, Dominating, Bossy, Skittish, Bullied, Reactive, Pushy, Confident, Assertive Naughty, Forceful, Mischievous, Determined, Persistent, Consistent, Frustrated, Sexually Frustrated, Spooked.	$F_{1,343} = 7.46$, $P = 0.007$



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Fig. 1

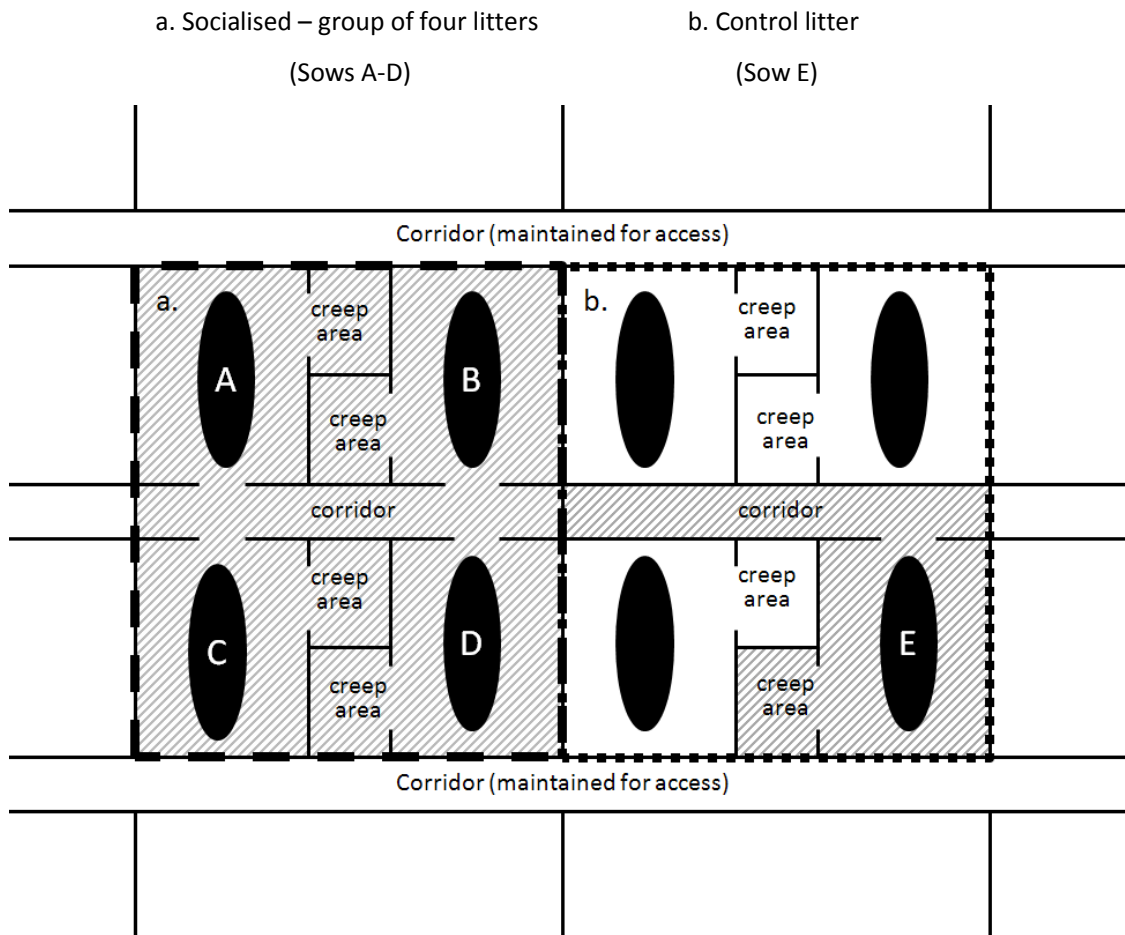


Fig. 2

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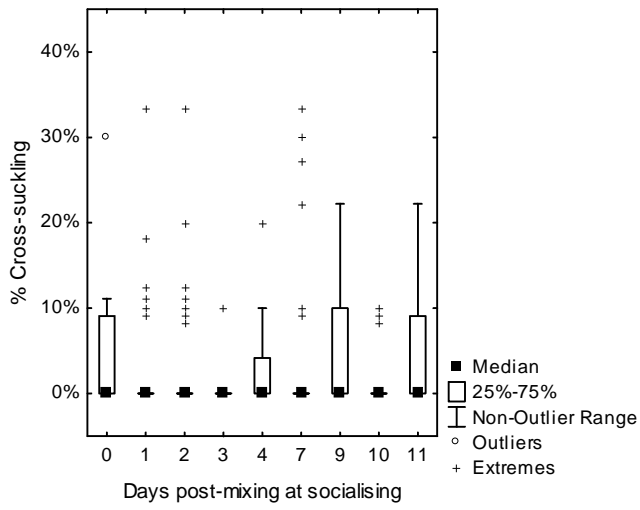


Fig. 3

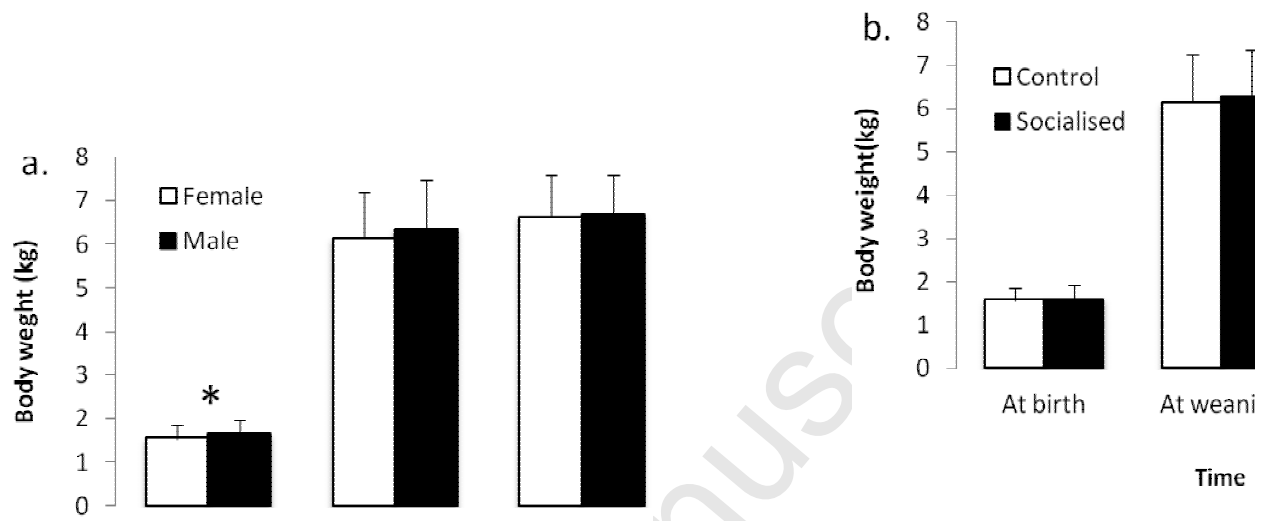
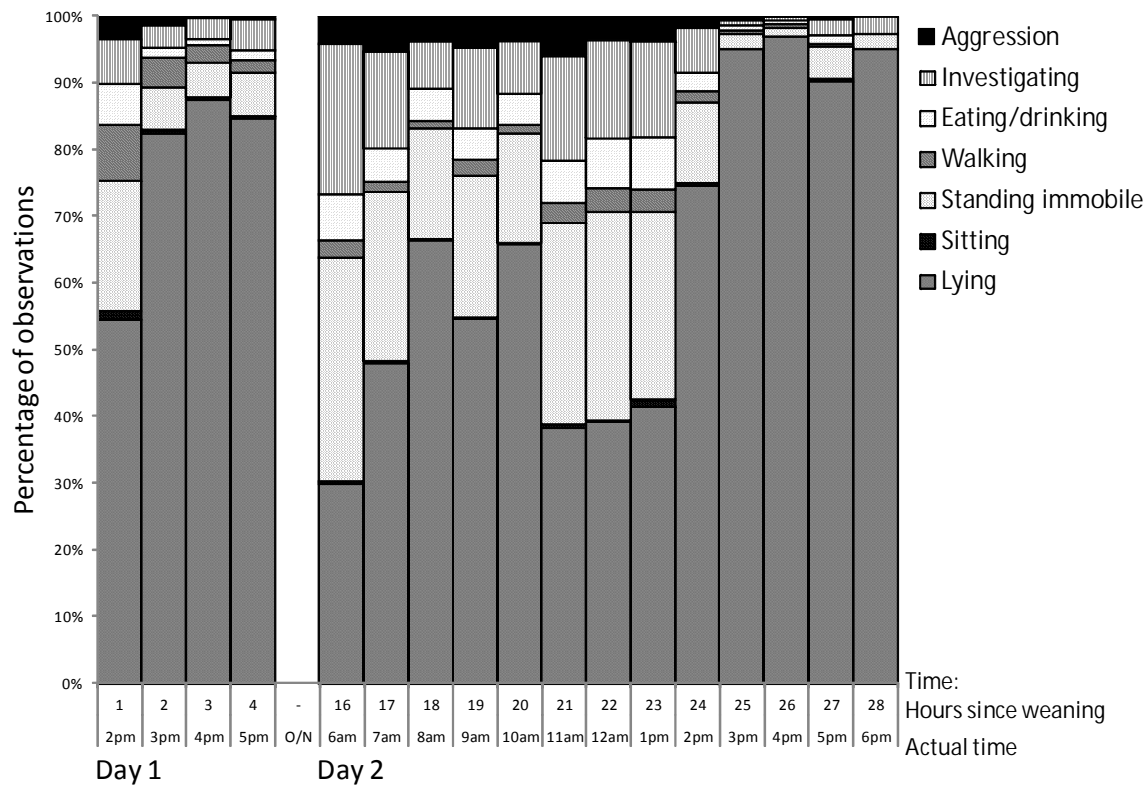


Fig. 4



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Fig. 5

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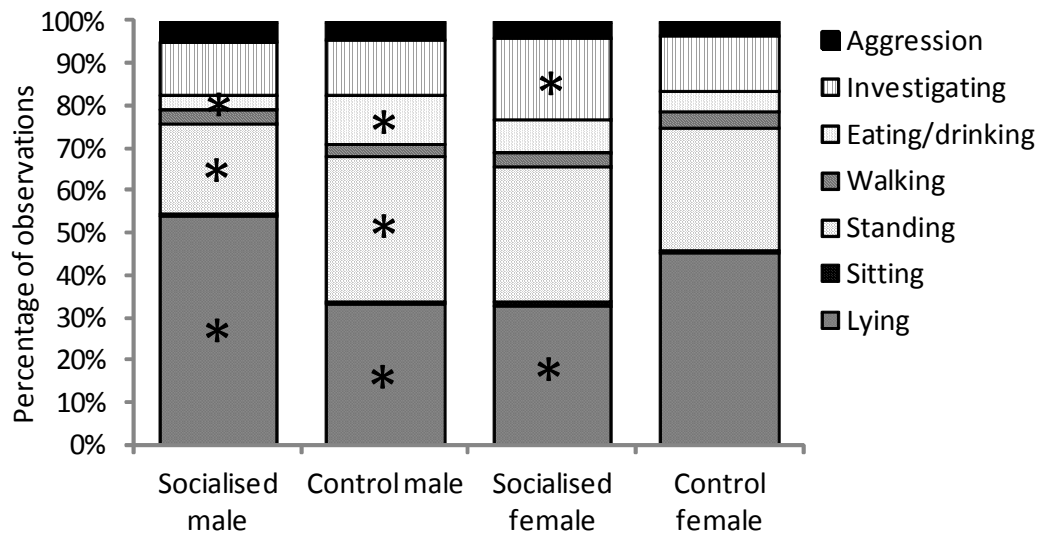


Fig. 6.

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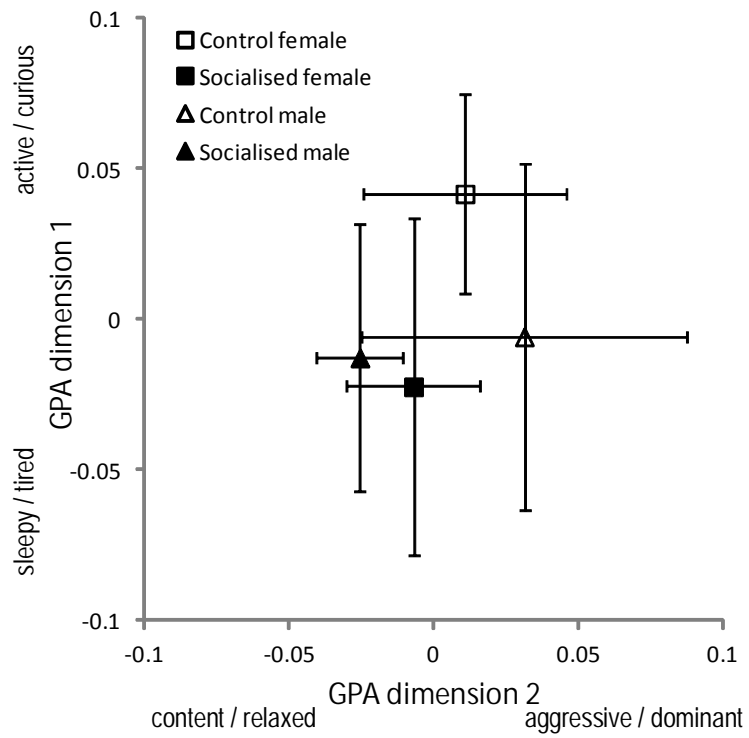


Fig. 7:

We have no conflict of interest to declare.

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Socialising piglets in lactation positively affects their post-weaning behaviour

5

Highlights

- Group housing piglets during lactation influences their social development
- Group housed ('socialised') piglets showed a low occurrence of cross-suckling
- 10 • Socialised pigs show different behaviour when mixed with unfamiliar pigs at weaning
- Male socialised pigs spent more time lying at weaning, females exploring
- Observers described socialised pigs as having more 'relaxed' behavioural expression

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