Title: **Understanding and reducing aggression using pre-exposure, when sows are mixed in a grouped gestation system – NPB #07-128** **revised**

Investigator: J.N. Marchant-Forde[1]

Co-Investigators: J.P. Garner[2], D.C. Lay Jr.[1], A.K. Johnson[3] and R.M. Marchant-Forde[1]

Institutions: [1]USDA-ARS, Livestock Behavior Research Unit, Purdue University, West Lafayette, IN 47907
[2]Department of Animal Sciences, Purdue University, West Lafayette, IN 47907
[3]Department of Animal Sciences, Iowa State University, Ames, IA 47907

Date Submitted: **01/05/2011**

Table of contents

Industry summary:

The largest single challenge of keeping sows in groups is that of inter-sow aggression. We know that sows will fight when mixed and when having to compete for access to resources. However, there is little information on the effects of pre-exposure when sows are mixed together. This project aimed to investigate whether housing sows next to each other in the service house (pre-exposure) would influence the amount of aggression observed when they were subsequently moved into group gestation pens. Our first experiment compared lesion scores, production and behavior of 20 groups of 3 sows from mixing to farrowing, having previously been housed in service crates for 35 days post-service. In one treatment, groups of three pen-mates were housed in adjacent crates; in our other treatment, groups of three pen-mates were randomly formed from non-neighbors. In our second experiment, the treatments were the same, except the post-service time period prior to grouping was only 7 days. Total body lesion scores were significantly higher for pre-exposed sows in the 35-day experiment and numerically higher in the 7-day experiment. In both experiments, significantly more lesions were seen around the head, neck and shoulders of the sows, indicative of pre-exposed sows engaging in more reciprocal fighting behavior. Detailed analysis of the behavioral data is ongoing, but time-budgets indicated no effect of treatment during the early post-mixing period. Closer examination of aggressive behavior so far has shown no significant differences between treatments in aggression, but many of the measures show numerically higher numbers for pre-exposed sows. There is also no effect of treatment on production, with sows in both experiments having similar total litter sizes and numbers born alive and dead. Overall, the study has shown that pre-exposing sows to each other in service crates prior to mixing appears to be disadvantageous at subsequent mixing. Although neighboring sows will acquire some information and familiarity about their neighbors, it seems possible that the inability to resolve aggressive interactions within the service crates actually promotes aggressive behavior when the sows are placed into an environment in which aggression can be resolved. Therefore, we recommend that when sows are selected to from a group from the service crates, non-neighbors should be selected.

Scientific Abstract:

The largest single challenge of keeping sows in groups is that of inter-sow aggression. We know that sows will fight when mixed and when having to compete for access to resources. However, there is little information on the effects of pre-exposure when sows are mixed together. This project aimed to investigate whether housing sows next to each other in the service house (pre-exposure – or Grouped treatment [G]) would influence the amount of aggression observed when they were subsequently moved into fully-slatted, group gestation pens (2.9 m × 1.7 m), compared to sows that were randomly selected from non-neighbors (Random treatment [R]). Experiment 1 compared lesion scores, production and behavior of 20 groups of 3 purebred Yorkshire and/or Landrace sows from mixing to farrowing, having previously been housed in service crates for 35 days post-service. Experiment 2 compared lesion scores, production and behavior of 20 groups of 3 purebred Yorkshire and/or Landrace sows from mixing to farrowing, having previously been housed in service crates for 7 days post-service. Individual sow data were averaged to give a pen mean, with pen as the experimental unit. Data were analyzed using GLM with Treatment as fixed effect and pen and replicate as random effects. For analysis of the production data, parity was included as a co-variate. The results show that pre-exposure actually appeared to heighten aggression on subsequent mixing. Immediately post-mixing, total body lesion scores were significantly higher for G sows in the 35-day experiment. This difference was due to differences in lesion score for head, neck and shoulders ($G = 2.42$, $R = 1.77$, $F_{1,19} = 7.70$, $P < 0.05$) and mid-body and udder ($G = 2.42$, $R = 1.90$, $F_{1,19} = 4.37$, $P = 0.05$). In the 7-day experiment, more lesions were also seen around the head, neck and shoulders of the G sows post-mixing ($G = 2.25$, $R = 1.71$, $F_{1,14} = 6.61$, $P < 0.05$). These lesions are indicative of pre-exposed sows engaging in more reciprocal fighting behavior. Detailed analysis of the behavioral data is ongoing, but time-budgets indicated no effect of treatment during the early post-mixing period. Closer examination of aggressive behavior so far has shown no significant differences between treatments in aggression, but many of the measures show numerically higher numbers for pre-exposed sows. There is also no effect of treatment on production, with sows in both experiments having similar total litter sizes and numbers born alive and dead. Overall, the study has shown that pre-exposing sows to each other in service crates prior to mixing appears to be disadvantageous at subsequent mixing. Although neighboring sows will acquire some information and familiarity about their neighbors, it seems possible that the inability to resolve aggressive interactions within the service crates actually promotes aggressive behavior when the sows are placed into an environment in which aggression can be resolved. Therefore, we recommend that when sows are selected to from a group from the service crates, non-neighbors should be selected.

Introduction

Pigs are social animals. From an evolutionary perspective, being social conveys a number of benefits, but potentially some disadvantages, especially for certain individuals within the group. Living in a social group can reduce predation, improve successful foraging, improve rearing of offspring, increase chances of mating and help thermoregulation. On the flip side, a group can be more conspicuous to a predator, competition within the group can reduce access to resources for some individuals, and may increase the risk of disease (Mendl & Held, 2001). By definition, "social behavior is comprised of those patterns of behavior that involve two or more members of a species" (Banks & Heisey, 1977). Thus, social behavior includes sexual behavior and parental behavior. However, social behavior also includes those behaviors that relate to formation and maintenance of social organization in swine, namely those centered on aggression and social dominance. These are the aspects of social behavior in swine that have garnered most attention in relation to the animal's welfare.

Aggression is a major challenge when group-housing pigs (Marchant-Forde & Marchant-Forde, 2005). Pigs will fight when mixed and when competing for access to resources. The most immediate and obvious physical impact of aggression can be increased injuries (O'Connell et al., 2003). Persistent aggression can activate both the sympathetic-adrenal-medullary axis and the hypothalamic-pituitary-adrenal axis and can decrease an individual pig's welfare in terms of increased stress hormone concentrations (Otten et al., 1999) and increased heart rates (Marchant et al., 1995). With activation of the stress axes also comes a negative impact on immunity and thus disease incidence and rate of healing of any injury may be impacted. Persistent aggression can also decrease sow productivity (Mendl et al., 1992) and restrict access to resources (O'Connell et al., 2003). If individuals are unable to access enough food to meet their requirements, then growth can be reduced (Stookey & Gonyou, 1994) and this can increase the weight variability within the pen and can become self-reinforcing, with the smaller pigs getting smaller and smaller relative to their pen-mates. Within the breeding herd, the timing of group formation and any post-service mixing can be critical. It is widely acknowledged that mixing around the time of embryonic attachment/implantation should be avoided and thus mixing at weaning and/or 5-6 weeks post-service are recommended to maximize farrowing rate (Kirkwood & Zanella, 2005). Finally, there is recent evidence that for the breeding sow, the stress due to aggression that she encounters during gestation can impact both the behavior and stress-reactivity of her offspring (Ison et al., 2010).

Gestation sow housing remains a contentious issue in the U.S. and legislation has now been passed in Florida (2002) and Arizona (2006) to move sows out of gestation stalls and into gestation groups, followed this year by unilateral decisions by major North American pork producers (Smithfield, Maple Leaf, Cargill) to only use group housing. However, without adequate management of aggression, group housing can severely impact the welfare of subordinate sows (Mendl et al. 1992), especially when groups consist of multi-parity. Although aggression at mixing is unavoidable, it is usually intense only over the first few hours as social hierarchies are being established

(Pritchard, 1996). Aggression levels should decrease quickly over the first few hours post-mixing, reaching basal levels within 1-2 days (Pritchard, 1996). A number of different system design and management methods have been used to reduce aggression (see review by Marchant-Forde & Marchant-Forde, 2005) with variable results. In terms of system design, pen shape can affect aggression in the short-term. Circular pens cause higher levels of aggression (Weigand et al., 1994) than square or rectangular pens. A solid barrier within the pen reduces post-mixing aggression in sows (Edwards et al., 1993) and weaners (Olesen et al., 1996). In dynamic systems, dividing the pen into distinct lying bays, with one assigned to each sub-group on introduction, may have long-term advantages in reducing aggression by giving each sub-group its own "territory" (Bünger & Kallweit, 1994).

Among some management techniques showing short-term benefits are time of day, chemical intervention and boar presence. If sows are mixed after sunset, aggressive interactions are decreased over the short-term (90 minutes post-mixing) but by the next morning, aggression levels are the same as if pigs are mixed during daylight (Barnett et al., 1996). Similar effects have been found using anti-aggression (amperozide – Barnett et al., 1996) and sedative (azaperone – Luescher et al. 1990) drugs. With both of these, aggression only appears to be reduced whilst the drug is efficacious. With boar presence, it was found that aggressive interactions, skin damage and flight distance were all reduced by at least 28% over a 28-h post-mixing period by the presence of a boar (Docking et al., 2001).

For longer-term solutions to reduce aggression at mixing, influencing the early social experience of the sows may be effective. Piglets mixed prior to weaning are able to form stable dominance hierarchies during future encounters with unfamiliar pigs quicker than piglets mixed after weaning (D'Eath, 2005) and show more consistent behavior during social encounters (D'Eath, 2004). However, the amount of aggression at mixing can still be reduced later in life by practicing repeated mixing, pre-mixing or pre-exposure. With repeated mixing, gilts that are re-mixed three or four times post-weaning subsequently show reduced aggression when mixed at 5 months of age, compared to pigs mixed just once or twice (van Putten & Buré, 1997). With dynamic systems, pre-mixing is commonly practiced, whereby, rather than introducing several individual sows into a large group at once, the individual sows are grouped first, and then mixed as a sub-group into the large group. This practice strengthens sub-group behavior and reduces aggression between new and resident sows (Durrell et al., 2003). ***Lastly, and with largely untested potential, is the practice of pre-exposing pigs prior to mixing.*** Kennedy (1999) placed groups of 5 gilts in a small pen within a large pen and let the resident sows have olfactory, auditory, visual and limited physical contact with them for 5 days before mixing. Once mixed, aggression was consistently reduced by 60% over the course of the mixing day and the following 2-week period compared with gilts that were mixed into the resident group without pre-exposure. Kennedy (1999) further exposed a resident pair of pigs to olfactory and/or auditory stimuli from a single pig to be mixed in, by transferring bedding and relaying real-time vocalizations from the single pig to the pair. He found that both of these methods of pre-exposure also reduced aggression compared to direct mixing. Jensen & Yngvesson (1998) have also reported a pre-exposure effect on aggression in nursery pigs and a reduction in interaction nosing phase.

The other interesting facet of aggression at mixing is that stability of the social hierarchy is established without the need for all pigs to fight with each other. For example, Mendl & Erhard (1997) mixed 4 pigs from one established group with four pigs from another group 11 times and in no single case did all 16 possible unacquainted pairs fight before stability was reached (range 2 pairs – 10 pairs fought). Therefore, there is a mechanism by which domestic pigs are able to assess their relative fighting ability or relative place in the hierarchy based upon information gained from their own interactions and probably from interactions of other pairs. If pigs were able to gain as much information as possible, prior to being introduced to each other, this may well result in fewer fights and less intense interactions, when they are finally mixed. The type of information available may well consist of a mixture of visual (e.g. physical size), auditory (e.g. frequency or duration characteristics of vocalizations) and olfactory (e.g. information conveyed by pheromones (McGlone, 1985) – all of which pre-exposure could allow.

As producers move towards group housing of sows during gestation, however, many are continuing to use crates in the service house. Sows are often assigned randomly to service crates at weaning and groups are formed some days post-service by selecting, from among the rows of crates, sows with similar characteristics, such as body size, condition, parity, etc. These sows are then moved from the crates into the group pens, which is the first time that they encounter each other. Our hypothesis is that pre-sorting the sows at weaning, so that potential group mates are placed into service crates next to each other, may enable sows to become pre-exposed to each other during the service period, thereby reducing the amount of aggression seen when the group is subsequently formed in the group gestation pens.

Objective:

The objective of this study is:

1. To determine whether pre-exposing sows to each other, by placing them next to each other in the service crates prior to mixing, reduces aggression

We wish to determine if pre-exposing sows to each other before group formation, influences the amount of aggression and/or the detailed behavioral components within that aggression. Furthermore, does the length of time that pre-exposure occurs over have an effect on the amount of aggression and/or the detailed behavioral components of that aggression.

Materials and Methods

Animals, Housing and Husbandry

Animals were housed in accordance with the *Guide for the Care and Use of Agricultural Animals Used in Agricultural Research and Teaching* (FASS, 1999) and the project was approved by the Purdue Animal Care and Use Committee.

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

This experiment was carried out using Yorkshire and Landrace sows at Whiteshire Hamroc LLC's Whiteshire Farm, Albion, IN. Whiteshire Farm is a 550-sow nucleus herd farrowing 20+ sows per week.

A total of 40 Yorkshire and 20 Landrace sows with mean parity 4.56 ± 0.27 (range 1 to 9) were used for this study, forming 20 groups of 3 pigs. At each weekly weaning, over 5 consecutive weeks, 20 sows were weighed, had body condition assessed and were moved from the farrowing house to the service house. From these, 12 sows were chosen as experimental animals, matched for weight, parity and body condition and assigned to one of two treatments: 1) R - random (n = 27 sows or 9 subsequent groups of 3 sows), or 2) G - grouped (n = 33 sows or 11 subsequent groups of 3 sows). Random sows were moved to the service crates (1.98 m × 0.61 m) and placed so that neither of their neighboring sows would become subsequent group-mates on grouping (see orange and green sows in Figure 1). Grouped sows were assigned to a group of 3, and moved to the service crates together so that the middle sow had 2 subsequent group mates as neighbors, and each outer sow had the middle sow as one neighbor and a random sow as the other neighbor (see blue and pink sows in Figure 1).

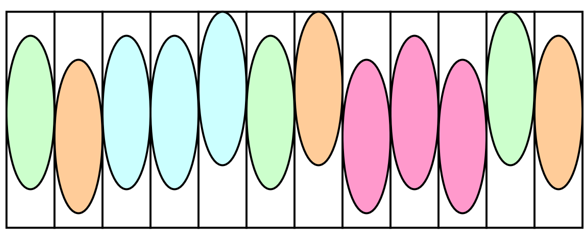

Figure 1: Diagrammatic representation of Random (R – green and orange) sows and Grouped (G – blue and pink) sows on placement into the service crates.

At estrus, which usually happened 3-5 days after weaning, sows were served using artificial insemination. At 35 days post-service, sows were pregnancy-checked and then moved to the gestation house. The gestation house (23.8 m × 11.6 m) contained 3 rows of 13 pens (2.9 m × 1.8 m), with a fully-slatted floor, and a feeding trough at the front of the pen (1.8 m wide), subdivided by ¾ body-length stalls into three feeding spaces (0.6 m wide) and one nipple drinker located at the rear of the pen. Sows were fed simultaneously once per day.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

This experiment was carried out using Yorkshire and Landrace sows at Whiteshire Hamroc LLC's Home Farm, Albion, IN. Home Farm is a 1000-sow nucleus herd farrowing 36-48 sows per week.

A total of 30 Yorkshire and 30 Landrace sows with mean parity 8.15 ± 0.45 (range 4 to 15) were used for this study, forming 20 groups of 3 pigs. At each weekly weaning, over 5 consecutive weeks, 20 sows were weighed, had body condition assessed and were moved from the farrowing house to the combined service/gestation house. From these, 12 sows were chosen as experimental animals, matched for weight, parity and body condition and assigned to one of two treatments: 1) R - random (n = 30 sows or 10 subsequent groups of 3 sows), or 2) G - grouped (n = 30 sows or 10 subsequent groups of 3 sows). Random sows were moved to the service crates (1.87 m × 0.56 m) and placed so that neither of their neighboring sows would become subsequent group-mates on grouping (see orange and green sows in Figure 1). Grouped sows were assigned to a group of 3, and moved to the service crates together so that the middle sow had 2 subsequent group mates as neighbors, and each outer sow had the middle sow as one neighbor and a random sow as the other neighbor (see blue and pink sows in Figure 1).

At estrus, which usually happened 3-5 days after weaning, sows were served using artificial insemination. At 7 days post-service, groups of 3 sows were moved across the alleyway to one of ten gestation pens. The gestation pens (2.9 m × 1.7 m) had a fully-slatted floor, and a feeding trough at the front of the pen (1.7 m wide), subdivided by ¾ body-length stalls into three feeding spaces (0.57 m wide) and one nipple drinker located at the rear of the pen. Sows were fed simultaneously once per day. Two groups from each treatment had a sow return to service and were dropped from the experiment, resulting in a total of 8 R pens and 8 G pens remaining on trial.

Lesion scoring

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

Sows were lesion scored prior to being mixed into the group pen and again at 48h, 1 week, 2 weeks, 3 weeks, 4 weeks and 8 weeks post-mixing by one trained observer. A lesion scoring scale (Elmore et al., 2010), adapted from Arey (1999) and Boyle et al. (2000) was used. The adapted scale included the visual evaluation of seven different regions of the animal including the head, body, legs and feet. The animals were given a score of 1 (no lesion to mild lesion) to 3 (severe lesion) for each region of the body. Swelling within the legs and feet was defined as an "enlargement of the skin or joint" and was classified in comparison to the opposite appendage. If an animal had both a mild lesion and a severe lesion in one location, the highest assigned score was recorded. The animals could receive a lesion score between 7 and 21 in total (see Table 1).

Table 1: Description of lesion scoring scale[a]

Region	Head and body	Region	Feet and legs
A B C	Head, Neck and shoulders Mid-body and udder Rump, tail and vulva	D E F G	Hoof and toes Dewclaws Lower leg and Upper leg
Score		**Score**	
Mild (1)	No blemishes Callus or redness <10 scatches[b]	Mild (1)	No blemishes Alopecia or callus Redness
Moderate (2)	<5 cuts[c] Mild wound[d] or abcess >10 scratches	Moderate (2)	Mild wound Mild swelling Abcess
Severe (3)	>5 large cuts Severe wound[e] Multiple abscesses	Severe (3)	Severe wound Severe swelling Multiple abscesses

[a] Adapted from Arey (1999) and Boyle et al. (2000).

[b] Scratches - skin unbroken.

[c] Cuts - skin broken.

[d] Mild wound: ~less than 2 cm in diameter.

[e] Severe wound: ~greater than 2 cm in diameter.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.
Sows were lesion scored prior to being mixed into the group pen and again at 24h, 2 weeks, 4 weeks, 5 weeks, 6 weeks, 8 weeks and 12 weeks post-mixing by one trained observer. The lesion scoring scale (Elmore et al., 2010), adapted from Arey (1999) and Boyle et al. (2000) was used, as described above.

Production

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.
Production indicators recorded included the total litter size, number of piglets born alive, number of piglets born dead. Also recorded was the number of piglets weaned and the average piglet weaning

weight. However, as a commercial operation, we were unable to mandate cross-fostering practices and fostering did occur within and across some experimental litters.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

Production indicators recorded included the total litter size, number of piglets born alive, number of piglets born dead. Also recorded was the number of piglets weaned and the average piglet weaning weight. However, as a commercial operation, we were unable to mandate cross-fostering practices and fostering did occur within and across some experimental litters.

Behavior – time budgets

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

The behavior of all sows was recorded using ceiling-mounted cameras (Panasonic WV-CD110AE, Matsushita Electric Industrial Co. Ltd., Osaka, Japan) attached to 16-channel digital video recording system (IPD-DVR816, Inter-Pacific, Inc., Northbrook, IL) recording in real-time mode. Scan sampling of behavior every 5 minutes was used to extract time-budget data into a Microsoft Excel worksheet, using the ethogram shown in Table 2. The recording schedule included a 12-h period (daytime) prior to grouping, the whole 24-h period post-grouping, a 12-h period (daytime) on the second day post-grouping and 3-h periods beginning 30 minutes prior to morning feeding at 1 week, 2 weeks, 4 weeks and 8 weeks post-grouping.

Table 2: Ethogram of behavioral components

Posture	**Description**
Stand:	Upright with at least three feet in contact with the ground
Sit:	Dog-sitting with front feet and ‘buttocks’ are in contact with ground
Lie Sternal:	Lying on sternum with belly in contact with the ground
Lie Lateral:	Lying on side with belly exposed
Behaviour	**Description**
Inactive:	No discernible behaviour, pig motionless
Feed:	Head in or close to feeder with oral manipulation of feed
Drink:	Mouth in contact with nipple drinker
Root/Nose:	Investigatory behaviour where nose is moving in contact with floor, pen walls or fixtures
Non-Aggressive Interaction	Social interaction not involving aggression
Ano-genital nosing	Snout moving in contact with ano-genital region of another sow
Aggressive Interaction	Social interaction containing threat, push, knock or bite.

Behavior – time budgets

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

The behavior of all sows was recorded using ceiling-mounted cameras (Panasonic WV-CD110AE, Matsushita Electric Industrial Co. Ltd., Osaka, Japan) attached to 16-channel digital video recording system (IPD-DVR816, Inter-Pacific, Inc., Northbrook, IL) recording in real-time mode. Scan sampling of behavior every 5 minutes was used to extract time-budget data into a Microsoft Excel worksheet, using the ethogram shown in Table 2. The recording schedule included a 12-h period (daytime) prior to grouping, the whole 24-h period post-grouping, a 12-h period (daytime) on the second day post-grouping and 3-h periods beginning 30 minutes prior to morning feeding at 1 week, 2 weeks, 4 weeks, 8 weeks and 12 weeks post-grouping.

Behavior – aggressive interactions

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

The behavior data, as collected above, was also subject to more detailed extraction focusing on aggressive interactions. Using all-occurrences sampling, the total number of social interactions was determined, together with the number including aggressive components of threat, push, bite and knock, the number including threat components only and the number of fights (interactions containing more than 10 reciprocated aggressive components). The extraction schedule included the 3-h periods immediately post-grouping and 3-h periods beginning 30 minutes prior to morning feeding at 24-h, 1 week, 2 weeks, 4 weeks and 8 weeks post-grouping. All-occurrences sampling was also used to extract each social interaction into an Microsoft Access database, using the ethogram shown in Table 3, with each behavioral component carried out by the initiator sow being followed by a behavioral component carried out in response by the recipient sow, thereby giving a sequence of reciprocated behaviors from the beginning to the end of the interaction.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

The behavior data, as collected above, was also subject to more detailed extraction focusing on aggressive interactions. Using all-occurrences sampling, the total number of social interactions was determined, together with the number including aggressive components of threat, push, bite and knock, the number including threat components only and the number of fights (interactions containing more than 10 reciprocated aggressive components). The extraction schedule included the 3-h periods immediately post-grouping and 3-h periods beginning 30 minutes prior to morning feeding at 24-h, 1 week, 2 weeks, 4 weeks, 8 weeks and 12 weeks post-grouping. All-occurrences sampling was also used to extract each social interaction into an Microsoft Access database, using the ethogram shown in Table 3, with each behavioral component carried out by the initiator sow being followed by a behavioral component carried out in response by the recipient sow, thereby giving a sequence of reciprocated behaviors from the beginning to the end of the interaction.

Table 3: Ethogram of behavioral components used for sequential analysis

Behavior	**Description**	**Behavioral Group**
Ano-genital nosing	Nosing or sniffing at anal/genital area	AGN,SSB
Sniff sow's body	Nosing or sniffing at body	AGN,SSB
Bite at head	Biting at head in front of the ears	BT
Bite at ears	Biting at ears	BT
Bite at neck, shoulders	Biting at the region from the ears to the back of the shoulders	BT
Bite at body	Biting at the region between shoulders and hips	BT
Bite at rump	Biting at the region behind the hips	BT
Follow	Both sows moving, initiator following recipient	FO,APR
Approach	Initiator approaching stationary recipient sow	FO,APR
Head over head	Placing head over the head/neck of another sow	HO,MO
Head over body	Placing head over the shoulders/body/rump of another sow	HO,MO
Mount	Placing front feet up on body of another sow	HO,MO
Head knock to head	Use of head to hit the head/neck of another sow	K
Head knock to body	Use of head to hit the shoulders/body/rump of another sow	K
Nose to nose	Snouts of both sows touching or in close proximity, sniffing	NN
No Reaction	No change in behavior due to contact	NR,P
Pause	Break in behavior (less than or equal to 5 sec)	NR,P
Root/nose	Nosing or sniffing directed at floor, pen or objects in the pen	OTH
Eating	Head in feeder	OTH
Drinking	Mouthing at or in close proximity to the feeder	OTH
Head push to head	Head pushing or lifting the head	PU
Head push to body	Head pushing or lifting the body	PU
Withdraw/Avoid	Moving away from contact quickly	WD,HT
Threat	Sow moves head quickly towards other sow	T
Head Tilt	Lowering of head away from other sow	WD,HT
Walk	Walking as not to avoid another sow or contact	WLK
Break	Interaction finishes with no further behavioral component	BREAK
Switch	Third sow intervenes in interaction	SWITCH

Statistical analysis

Individual sow data were averaged to give a pen mean, with pen as the experimental unit. Data were analyzed using GLM with Treatment as fixed effect and pen and replicate as random effects. For analysis of the production data, parity was included as a co-variate.

Results

Lesion scoring

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

At movement to the gestation pen, there was no difference between G and R treatments in total body lesion score or lesion score for any of the 7 areas. However, by 48h post-grouping, sows in the G treatment had higher total lesion scores than sows in the R treatment ($F_{1,14} = 8.42$, $P < 0.05$ - see Figure 2). This difference was due to differences in lesion score for head, neck and shoulders (G = 2.42, R = 1.77, $F_{1,19} = 7.70$, $P < 0.05$) and mid-body and udder (G = 2.42, R = 1.90, $F_{1,19} = 4.37$, $P = 0.05$). However, by weeks 2 and 3, these differences were reversed and R treatment sows had higher lesion scores than G sows (2wk - $F_{1,14} = 5.64$, $P < 0.05$, 3wk - $F_{1,14} = 8.37$, $P < 0.05$). These differences were due to additive effects of numerical differences in head, neck and shoulders, mid-body and udder and rump, tail and vulva scores.

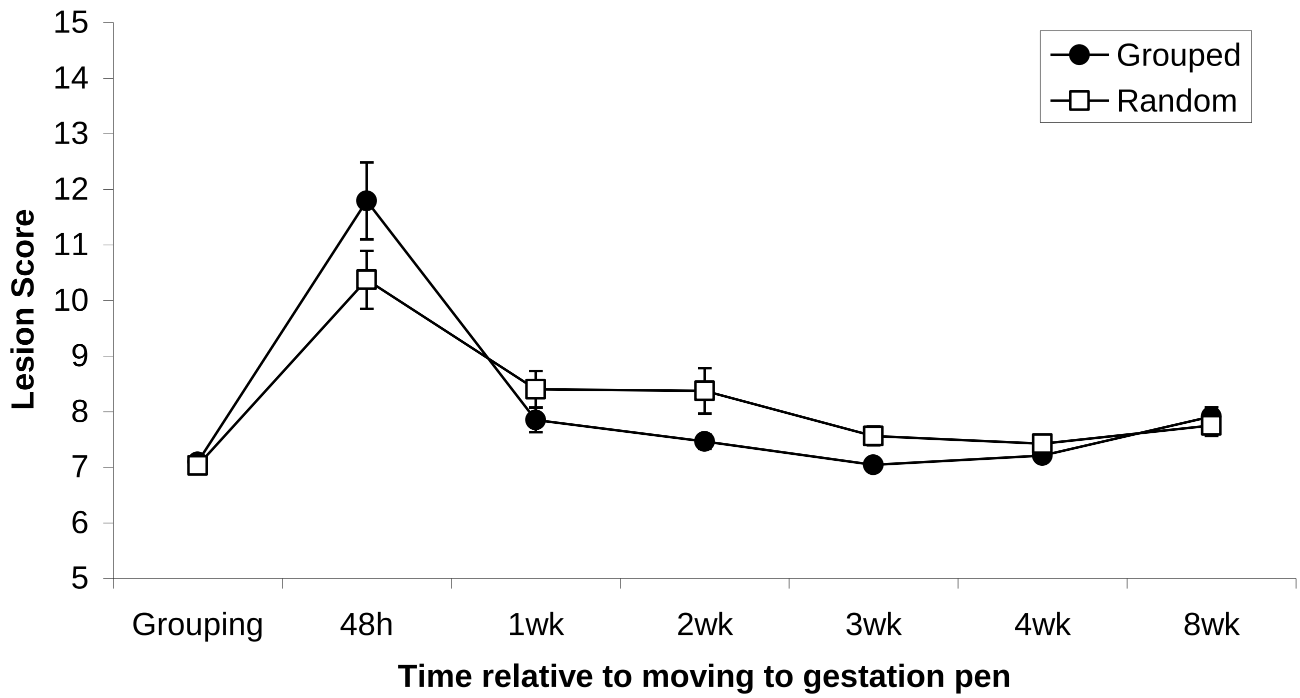

Figure 2: Total body lesion scores of sows housed in two service crate treatments for 35 days prior to grouping in a gestation pen.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

At movement to the gestation pen, there was no difference between G and R treatments in total body lesion score or lesion score for any of the 7 areas. Subsequently, there were also no significant differences between treatments in total body lesion score at any of the other time points (see Figure 3), but G sows had significantly higher lesion scores for the head, neck and shoulder region at 24h post-mixing (G = 2.25, R = 1.71, $F_{1,14} = 6.61$, $P < 0.05$).

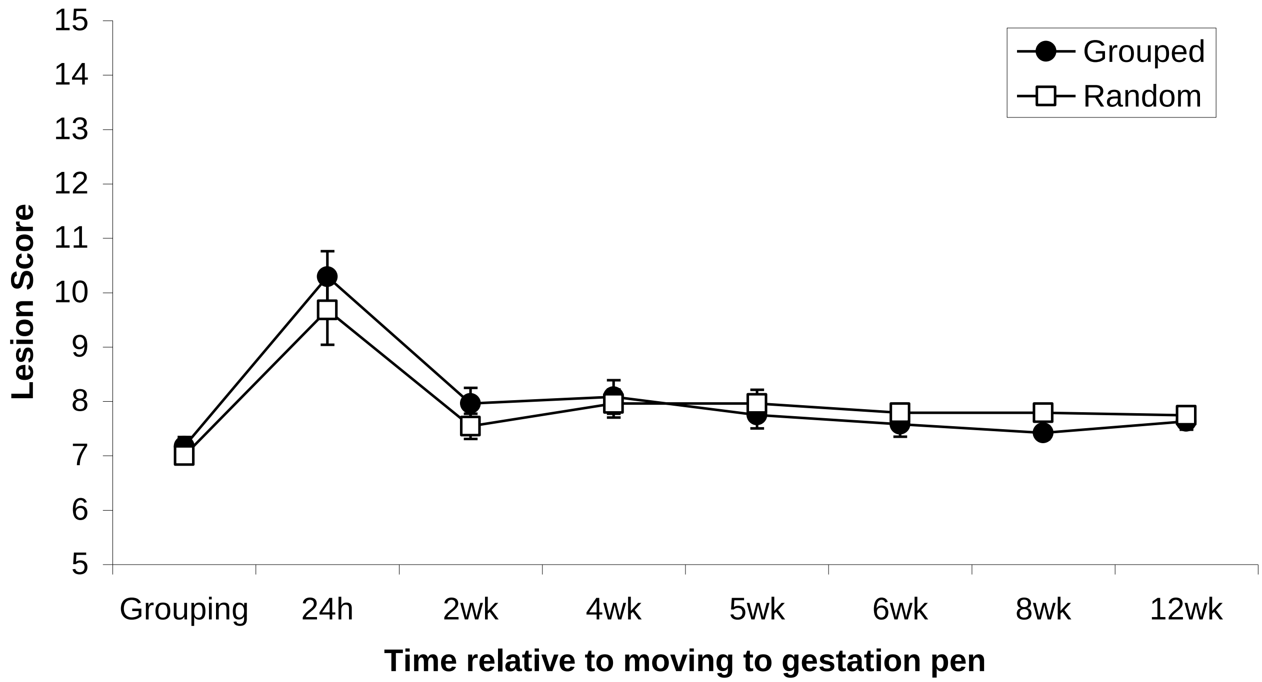

Figure 2: Total body lesion scores of sows housed in two service crate treatments for 7 days prior to grouping in a gestation pen.

<u>Production</u>

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

Sows in the two treatments were of similar average parity (see Table 4). There was no effect of treatment on production measures, including total litter size, numbers born alive, dead and weaned, or average piglet weaning weight (see Table 4).

Table 4: Production measures from sows housed in two service crate treatments for 35 days prior to grouping in a gestation pen.

	Treatment		
Measure	**Grouped**	**Random**	**P-Value**
Parity	4.89 ± 0.47	4.33 ± 0.63	0.48
Total litter size	12.83 ± 0.44	12.62 ± 0.68	0.79
Number born alive	11.71 ± 0.41	11.32 ± 0.42	0.48
Number born dead	1.12 ± 0.19	1.33 ± 0.34	0.59
Number weaned	9.86 ± 0.31	8.75 ± 0.66	0.13
Average Piglet weaning weight (kg)	7.21 ± 0.12	7.03 ± 0.28	0.56

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

Sows in the two treatments were of similar average parity (see Table 5). There was no effect of treatment on production measures, including total litter size, numbers born alive, dead and weaned, or average piglet weaning weight (see Table 5).

Table 5: Production measures from sows housed in two service crate treatments for 7 days prior to grouping in a gestation pen.

Measure	Treatment		P-Value
	Grouped	**Random**	
Parity	8.69 ± 0.53	7.69 ± 0.72	0.25
Total litter size	9.77 ± 1.18	11.83 ± 0.76	0.16
Number born alive	8.37 ± 0.95	10.21 ± 0.59	0.12
Number born dead	1.39 ± 0.36	1.62 ± 0.35	0.66
Number weaned	8.61 ± 0.49	7.39 ± 0.68	0.17
Average Piglet weaning weight (kg)	6.54 ± 0.41	6.50 ± 0.54	0.96

Behavior – time budgets

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.
On the day of grouping into the gestation pen, there were no significant differences between treatments in the proportion of time spent engaged in the various behaviors or postures. Scan sampling is not ideal for determining the incidences of short-term behaviors such as social interactions, but on the day of grouping, ano-genital nosing and non-aggressive social interactions were numerically higher in R treatment, and aggression was numerically higher in the G treatment. During the day after mixing, aggression was still higher in the G treatment ($P<0.1$) and was numerically higher at 48h, 1wk and 1mo post-grouping (all non-significant). During the 3-h peri-feeding period, G treatment sows were less inactive (at 2wk – $P < 0.1$, at 1mo – $P < 0.05$, at 2mo – $P < 0.05$ – see Figure 3), spent more time standing (at 2wk – $P < 0.1$, at 1mo – $P < 0.05$, at 2mo – $P < 0.05$ – see Figure 4) and less time lying laterally (at 2wk – $P < 0.1$, at 1mo – $P < 0.05$ – see Figure 5). There were no other significant differences between treatments in behavior and postural elements at any of the time-points.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.
These data are still undergoing extraction and analysis.

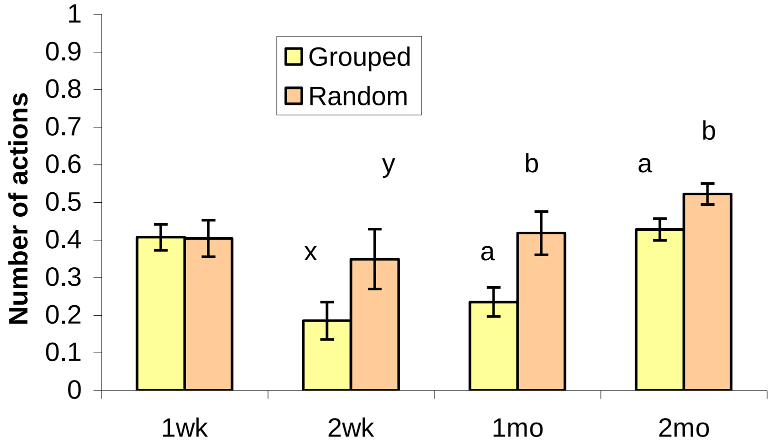

Figure 3: The mean ± s.e. proportion of time spent inactive during the 3-h peri-feeding period.
[a,b]Treatment means with different superscripts differ significantly ($P<0.05$).
[x,y]Treatment means with different superscripts tend to differ ($P<0.1$).

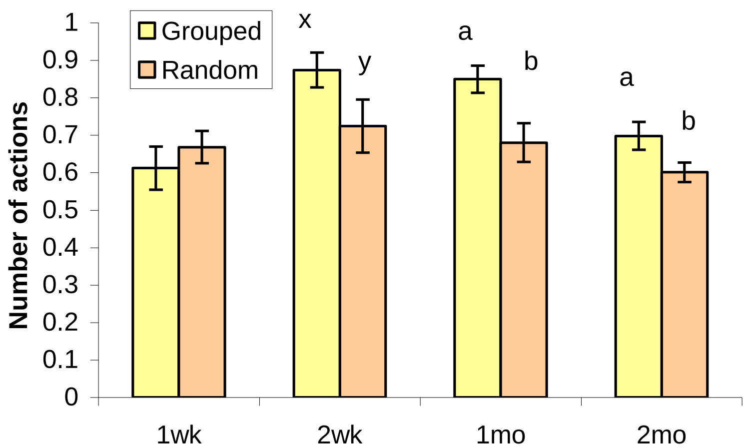

Figure 4: The mean ± s.e. proportion of time spent standing during the 3-h peri-feeding period.
[a,b]Treatment means with different superscripts differ significantly ($P<0.05$).
[x,y]Treatment means with different superscripts tend to differ ($P<0.1$).

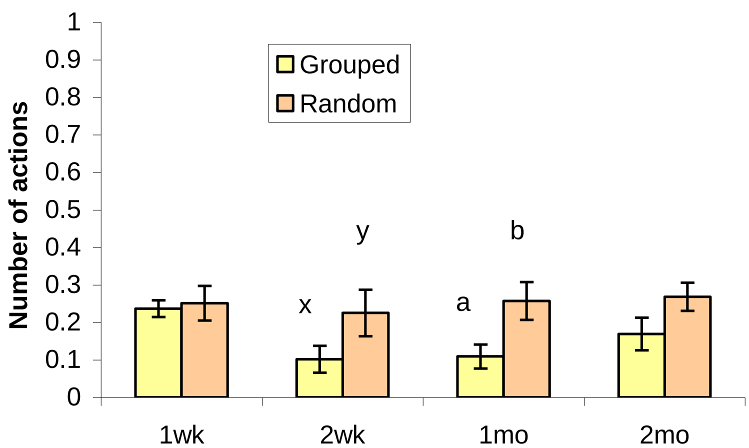

Figure 5: The mean ± s.e. proportion of time spent lying laterally during the 3-h peri-feeding period.
[a,b]Treatment means with different superscripts differ significantly ($P<0.05$).
[x,y]Treatment means with different superscripts tend to differ ($P<0.1$).

Behavior – aggressive interactions

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.

Partial results – R (n=4), G (n=4) for day of mixing and 24h post-mixing periods only.

There were no differences between treatments in the total number of interactions, the number or proportion of interactions that contain aggressive components, the number or proportion of interactions that contain threat components or the number of fights on either of the two days (see Table 5). However, results must be treated with caution due to interim nature.

Table 5: Aggressive and non-aggressive interactions per pen for sows from two treatments mixed after 35 days in service crates

Measure	Treatment		P-Value
	Grouped	Random	
Day of Grouping			
Number of social interactions	107.3 ± 14.6	84.8 ± 16.3	0.34
Number of interactions that contain aggression	39.3 ± 15.9	34.3 ± 5.11	0.78
Proportion of interactions that contain aggression	0.33 ± 0.11	0.45 ± 0.10	0.43
Number of interactions that contain threats	17.00 ± 9.34	8.75 ± 1.03	0.41
Proportion of aggressive interactions that contain threats only	0.31 ± 0.11	0.26 ± 0.10	0.63
Interactions that are 2-sided fights	5.75 ± 4.46	6.25 ± 2.84	0.93
24h Post-grouping			
Number of social interactions	70.0 ± 13.2	47.8 ± 9.6	0.22
Number of interactions that contain aggression	23.3 ± 12.2	22.8 ± 3.22	0.97
Proportion of interactions` that contain aggression	0.28 ± 0.11	0.50 0.05	0.13
Number of interactions that contain threats	12.50 ± 6.74	8.75 ± 1.11	0.60
Proportion of aggressive interactions that contain threats only	0.61 ± 0.27	0.40 ± 0.10	0.22
Interactions that are 2-sided fights	0.75 ± 0.48	0.50 ± 0.50	0.73

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.

Partial results – R (n=3), G (n=3) for day of mixing only.

There were no differences between treatments in the total number of interactions, the number or proportion of interactions that contain aggressive components, the number or proportion of interactions that contain threat components or the number of fights on the day of mixing (see Table 6). However, results must be treated with caution due to interim nature.

Table 6: Aggressive and non-aggressive interactions per pen for sows from two treatments mixed after 7 days in service crates

Measure	Treatment		P-Value
	Grouped	Random	
Day of Grouping			
Number of social interactions	94.0 ± 21.4	88.0 ± 33.0	0.88
Number of interactions that contain aggression	46.3 ± 19.2	62.7 ± 25.7	0.64
Proportion of interactions that contain aggression	0.44 ± 0.14	0.70 ± 0.10	0.24
Number of interactions that contain threats	12.67 ± 7.51	37.00 ± 35.00	0.45
Proportion of aggressive interactions that contain threats only	0.19 ± 0.10	0.44 ± 0.38	0.49
Interactions that are 2-sided fights	7.00 ± 1.53	2.67 ± 2.67	0.19

Behavior – sequential analysis

Experiment 1. The effects of a 35-day post-service pre-exposure on subsequent aggression at grouping.
Extraction is complete for 5 pens so far, out to 2 months post-mixing. This is not enough data to carry out preliminary analysis at this stage.

Experiment 2. The effects of a 7-day post-service pre-exposure on subsequent aggression at grouping.
Extraction is complete for 3 pens so far, out to 3 months post-mixing. This is not enough data to carry out preliminary analysis at this stage.

Discussion and conclusions

In order to better understand the consequences of mixing pigs during commercial production, it is crucial to acknowledge the pig's origins and social behavior in a natural setting. The domestic pig is descended from the wild boar, but although they have changed greatly in terms of phenotype, their behavior, when given the opportunity, is extremely similar to their wild ancestors. The data from which we can conclude this comes from three main sources: 1) studies of wild boar in their natural habitat, 2) studies of feral populations of domestic pigs, and 3) studies of domestic pigs released into naturalistic enclosures. The natural social organization of pigs centers on a core group or 'sounder' of 2-4 related sows plus their associated offspring of different sizes and ages (Mauget, 1981; Graves, 1984; Gabor, et al. 1999). Sows in the group are likely to be sisters or mother and daughters. Group size will be influenced by habitat and resource availability (especially food), as will the size of the home range, but can be as large as 6000 hectares (Janeau & Spitz, 1984). Home ranges may overlap with other sounders, but even when sharing home ranges, sounders will tend to actively avoid open confrontation with each other (Gabor, et al. 1999).

As the offspring mature, the females split off to form their own sounders and the males split off to form adolescent bachelor groups, becoming solitary as mature boars. During the breeding season, mature boars may associate with sounders, becoming dominant to all sounder members. Within sounders, aggression is very rare. The group usually maintains a simple, linear social hierarchy, which is relatively stable over time. Position within the hierarchy is mostly determined by size and age, with large, mature, physically-strong sows being dominant over smaller sub-adults and juveniles (Mauget, 1981). Aggression does occur during competition for resources, especially food, but most often, subordinate animals actively avoid conflict with dominant animals (Jensen & Wood-Gush, 1984). Food will be scattered but available ad libitum in their complex environment, as long as the pigs forage. This social organization is such that pigs are not exposed to unrelated, unfamiliar pigs. New litters are integrated into the group early in life (7-14 days of age) when the sow returns to the group with her litter after isolation at farrowing, but no aggression has been observed during these interactions (Newberry & Wood-Gush, 1988; Petersen et al. 1989).

In contrast, pigs housed in commercial systems may be housed individually (but in close proximity to others) or in groups ranging from small (3) to large (200+). Regardless of group size, there will be relatively limited space and a relatively simple environment and they may encounter frequent remixing. Access to food may be ad libitum or restricted. Unsurprisingly, aggression will be much more prevalent under commercial conditions than under natural conditions. How prevalent will be largely influenced by: 1) the degree of mixing/remixing, 2) the method of feeding, and 3) the amount and quality of space. In general, when unacquainted pigs are mixed together, they often fight. The fight does not often break out immediately but can be a complex and gradual event as the pigs investigate each other using a series of specific and often reciprocal behaviors, characterized by nosing, sniffing and gentle nudging (McGlone, 1985). This may then escalate into more vigorous pushing and pressing, bites, head-knocks and mounting, which continues until one pig withdraws, with or without being pursued. Most fighting takes place within 2 h of mixing and by 24-48 h post-mixing, the level of aggressive interactions should be basal, and a hierarchy established. The hierarchy is then maintained by threats, avoidance and withdrawal, or short-lived aggressive interactions. However, this is a generalization. There does not appear to have been a fully-controlled study carried out that looks at variation in group size and environment, on the same swine unit, using the same management team, swine genetics, husbandry practices, etc.

The hypothesis behind our study was derived from previous work carried out in the U.K., in which sows being mixed into a dynamic ESF housing system were either mixed directly, or were placed into a small pen within a large pen, which enabled new and resident sows to be pre-exposed to each other and have a degree of contact and familiarization prior to mixing (Kennedy, 1999). Jensen & Yngvesson (1998) have also reported a pre-exposure effect on aggression in nursery pigs and a reduction in interaction nosing phase. We therefore hypothesized that sows that are held in service crates next to each other would show reduced aggression towards each other when grouped into a pen, compared to sows that are randomly chosen as non-neighbors and grouped into a pen. The results from the study so far show that grouping neighbors does not reduce aggression compared to grouping non-neighbors, and in fact, may actually increase aggression, especially in sows that are housed in service crates for 35 days.

The strongest evidence for this is offered with the lesion scores. Both experiments and both treatments show a post-grouping increase in body lesions, but this is greater for the G treatment sows than the R treatment sows, particularly in the 35-day crated experiment. The major areas showing an increase in lesion score are the head, neck and shoulders and the mid-body and udder regions. Previous studies have shown that lesions in these body areas are indicative of being involved in reciprocal fighting (Turner et al., 2006; Turner et al., 2009; Stukenborg et al., submitted). At this time, the behavioral data is insufficiently advanced to support the lesion score evidence with certainty, but the data reviewed so far would seem to suggest that aggression is more immediate, of higher intensity and more sustained between G treatment sows than R treatment sows.

We carried out a more fundamental study as a precursor to the current study and found interesting differences in aggressive behavior depending on the number of sows being mixed and the space into which they were mixed. When pairs of unacquainted sows were mixed indoors in a neutral pen, interactions involving aggression were relatively slow to develop and characterized by increasing intensity. The first aggressive actions involved pushing, next came head-knocks and finally came bites. In terms of overall budget, social interactions of indoor pairs contained higher proportions of pushing, head over/mounting behaviors and walking. Nearly half of all social interactions began with nose-to-nose behavior but both no response/pause and withdrawal/head tilt behaviors preceded significantly more bites than predicted indicating that ignoring or trying to avoid the other sow did not necessarily diffuse the interaction, given the limited space.

An aggressive interaction can result in injury to one or both parties and thus the potential cost of aggression can be high, particularly for the loser, both in terms of welfare of the pig but also economically for the producer. For the individual pig, the choice to engage in fight or not in the first place, or to know when to stop calls for the pig to be able to assess its fighting ability relative to the fighting ability of its opponent (Mendl & Erhard, 1997). Ordinarily in commercial practice, pigs are mixed in groups of varying sizes. Mixing of unacquainted pairs is not normal practice, but is rather more often used during experimental studies that focus on assessing aggressiveness of individuals (e.g. Poletto et al., 2010). In these instances, pairs are usually introduced in the home pen of one of the pigs – a resident-intruder test (Erhard & Mendl, 1997) – which is known to often elicit quite rapid attack on the intruder by the resident. In our situation, the mixing environment was neutral and both animals were introduced at the same time. In the limited space and without other pigs, the hierarchical relationship perhaps increases in relative importance and the 'cost' of losing the encounter and becoming the subordinate sow is heightened. The interactions are thereby typified by information-gathering, starting with gaining olfactory information through nose-to-nose contact, low grade physical information through pushing, followed by increasing intensity of interaction through knocking and biting. Adopting a strategy of non-response did not appear to prevent aggression, neither did withdrawal, as the limitations in space meant that the sow could not put sufficient distance between herself and her attacker to either prevent attack before it had started or stop attack once it had begun.

When pairs of unacquainted sows were mixed outdoors in a neutral paddock, interactions involving aggression were relatively quick to develop and characterized by immediate high intensity. Contrary to indoor pairs, the first aggressive actions involved bites, next came head-knocks and finally came pushes, indicating decreasing intensity over time. In terms of overall budget, social interactions of outdoor pairs contained higher proportions of following/approaching behavior. Nearly 90% of social interactions began with ano-genital nosing, following/approaching behavior or nose-to-nose behavior and nearly 90% of social interactions ended with withdrawal/head tilt behaviors and walking, indicating that sows used the available space to distance themselves from the other sow and that this was successful in ending the interaction.

Mixing two established and unacquainted sub-groups of three sows together in a neutral indoor pen resulted in the highest number of aggressive and non-aggressive social interactions. Indoor groups performed the most aggressive and non-aggressive component actions, and over 90% of all possible pair combinations interacted at some point within the 2 hours after mixing. Over 70% of unacquainted pairs interacted aggressively and over 40% of unacquainted pairs engaged in high intensity, reciprocated fights. Over 80% of all social interactions began with ano-genital nosing or nose-to-nose behavior and as with indoor pairs, both no response/pause and withdrawal/head tilt behaviors preceded a high number bites again indicating that ignoring or trying to avoid the other sow did not necessarily diffuse the interaction, given the limited space. Also probably due to the limited space, a third sow intervened in a number of interactions. When a third sow did become involved, her involvement was most often preceded by and followed by bites – i.e. high intensity aggression.

Although a high proportion of the possible pairs of sows interacted, the amount of serious aggression, or reciprocated fights was much lower. At around 40%, the number of unacquainted pairs fighting agrees with the 35% of pairs seen elsewhere (Mendl & Erhard, 1997). The reason hypothesized for this low number is that individuals can assess their relative chances of winning encounters without resorting to combat themselves, "based on direct assessment of others or by picking up on how their sub-group-mates are performing in fights with others and adjusting their behavior accordingly." The aggression itself, differed in form from the indoor pairs. Instead of gradually increasing intensity over time, sows were much quicker to use high intensity aggressive actions in the group situation and when a third sow intervened, biting was often recorded. Intervention was most likely incidental rather than planned, and happened as a result of being approached too closely by sows already engaged in an interaction, as seen elsewhere (McGlone, 1985). Some aggression was observed within sub-group pairs, and even one reciprocated fight. An increase in aggression is not unusual in a stable group being moved to a different environment (Friend et al., 1983; Stookey & Gonyou, 1994). Again, space (or lack of) would appear to be impacting behavior and the observation of biting being preceded by no response behavior or withdrawing indicates an inability to use distance to avoid aggression.

Sequential analysis of our current data set may well show subtle differences in the way the sows interacted on grouping. Our R treatment sows, on grouping, are starting with a 'blank page' in terms of information about the sows with which it has just been grouped. Our G treatment sows, however, already have some information about their pen-mates, having been housed beside them in the service crates. It is also probable that they have been involved in aggressive interactions that have not had clear outcomes and that may have escalated while they were in the crates. Several studies have shown that aggressive interaction between neighboring sows in gestation crates can be high (Jensen, 1984, Barnett et al., 1987, Broom et al., 1995). The initial attack is more often followed by retaliation in crates resulting in escalation in the intensity of aggression (Jensen, 1984, Barnett et al., 1987, Broom et al., 1995), rather than the withdrawal and cessation of interaction most often seen in group housed systems. Therefore, when mixed into a pen, G treatment sows are more ready to establish social hierarchy and hence are quicker to engage in more, high intensity aggression compared to sows from the R treatment that first need to gather initial information before deciding whether to engage in reciprocated fighting or not.

Overall, the study has shown that pre-exposing sows to each other in service crates prior to mixing appears to be disadvantageous at subsequent mixing. Although neighboring sows will acquire some information and familiarity about their neighbors, it seems possible that the inability to resolve aggressive interactions within the service crates actually promotes aggressive behavior when the sows are placed into an environment in which aggression can be resolved. Therefore, we recommend that when sows are selected to from a group from the service crates, non-neighbors should be selected.

Acknowledgements

We are grateful to the National Pork Board the partial funding this work. We also thank Dr. Mike Lemmon and Dr. Mark Brubaker at Whiteshire Hamroc LLC for enabling us to carry out the study on their units, and to Alexandre Baierle and the other staff at Whiteshire Farm and Home Farm for their help. Lastly, we thank the research technicians engaged on this project, Matt Horsman, Bill DeBoer and Lyndsey Jones who travelled to Albion, IN periodically to assist with data collection.

References cited

D.S. Arey, (1999) Time course for the formation and disruption of social organization in group-housed sows, *Appl. Anim. Behav. Sci.* 62: 199-207

Banks, E. M., Heisey, J. A. (1977). Animal Behavior. Educational Methods, Chicago. 200pp

Barnett, J.L.; Cronin, G.M.; McCallum, T.H.; Newman, E.A.; Hennessy, D.P. (1996) Effects of grouping unfamiliar adult pigs after dark, after treatment with amperozide and by using pens with stalls, on aggression, skin lesions and plasma cortisol concentrations. *Appl. Anim. Behav. Sci.* **50**, 121-133.

Barnett, J.L., Hemsworth, P.H. and Winfield, C.G. (1987) The effects of design of individual stalls on the social behaviour and physiological responses related to the welfare of pregnant pigs. Applied Animal Behaviour Science. 18, 133–142.

Boyle, L.A. Regan, D. Leonard, F.C. Lynch P.B. and Brophy, P. (2000) The effect of mats on the welfare of sows and piglets in the farrowing house, *Anim. Welf.* 9: 39–48

Broom, D.M., Mendl, M.T. and Zanella, A.J. (1995) A comparison of the welfare of sows in different housing systems. Animal Science 61, 369–385.

Bünger, B.; Kallweit, E. (1994) Ethological studies on pregnant sows in a dynamic group-housing system with rationed individual feeding by one electronic feeder station. *Landbauforschung Volkenrode* 44, 151-166.

D'Eath, R.B. (2004) Consistency of aggressive temperament in domestic pigs: the effects of social experience and social disruption. *Aggressive Behavior* 30, 435-448.

D'Eath, R.B. (2005) Socializing piglets before weaning improves social hierarchy formation when pigs are mixed post-weaning. *Appl. Anim. Behav. Sci.,* in press

Docking, C.M.; Kay, R.M.; Day, J.E.L.; Chamberlain, H.L. (2001) The effect of stocking density, group size and boar presence on the behaviour, aggression and skin damage of sows in a specialized mixing pen at weaning. In: *Proceedings of the British Society of Animal Science*. P46.

Durrell, J.L., Beattie, V.E., Sneddon, I.A. and Kilpatrick, D. (2003) Pre-mixing as a technique for facilitating subgroup formation and reducing sow aggression in large dynamic groups. Applied Animal Behaviour Science 84, 89–99.

Edwards, S.A.; Mauchline, S.; Stewart, A.H. (1993) Designing pens to minimize aggression when sows are mixed. *Farm Building Progress* 113, 20-23.

Elmore, M.R.P, Garner, J.P., Johnson, A.K., Richert, B.T. and Pajor, E.A. (2010) A flooring comparison: the impact of rubber mats on health, behavior and welfare of group-housed sows at breeding. *Appl. Anim. Behav. Sci.* 123**,** 7–15.

Erhard, H. W., Mendl., M. (1997) Measuring aggressiveness in growing pigs in a resident-intruder situation. *Appl. Anim. Behav. Sci.* 54**,** 123–136.

Friend, T. H., Knabe, D. A., Tanksley, Jr., T. D. (1983) Behavior and performance of pigs grouped by three different methods at weaning. *J. Anim. Sci.* 57, 1406.

Gabor, T. M., Hellgren, E. C., Van Den Bussche, R. A., Silvy, N. J. (1999) Demography, sociospatial behaviour and genetics of feral pigs (Sus scrofa) in a semi-arid environment. *J. Zool.* 247, 311–322.

Garner, J.P., Meehan, C.L., Mench, J.A. (2003) Stereotypies in caged parrots, schizophrenia and autism: evidence for a common mechanism. *Behav. Brain Res.* 145, 125-134.

Graves, H.B. (1984) Behavior and ecology of wild and feral swine (Sus scrofa) *J. Anim. Sci.* 58, 482–492.

Ison, S. H., D'Eath, R. B., Robson, S. K., Baxter, E. M., Ormandy, E., Douglas, A. J., Russell, J. A., Lawrence, A. B., Jarvis, S. (2010) 'Subordination style' in pigs? The response of pregnant sows to mixing stress affects their offspring's behaviour and stress reactivity. *Appl. Anim. Behav. Sci.* 124, 16-27.

Janeau, G., Spitz, F. (1984) L'espace chez le sanglier (Sus scrofa L.): Occupation et mode d'utilisation. *Gibier Faune Sauvage* **1**, 76–89.

Jensen, P. (1980) An ethogram of social interaction patterns in group-housed dry sows. *Appl. Anim. Ethol*. **6**, 341-350.

Jensen, P. (1982) An analysis of agonistic interaction patterns in group-housed dry sows – aggression regulation through an "avoidance order". *Appl. Anim. Ethol.* **9**, 47-61

Jensen, P. (1984) Effects of confinement on social-interaction patterns in dry sows. Applied Animal Behaviour Science 12, 93–101.

Jensen, P., Algers, B., Ekesbo, I.(1986) Methods of Sampling and Analysis of Data in Farm Animal Ethology. Berkhäuser Verlag, Basel. 86pp.

Jensen, P., Wood-Gush, D. G. M. (1984) Social interactions in a group of free-ranging sows. *Appl. Anim. Behav. Sci.* **12**, 327–337.

Jensen, P. & Yngvesson, J. (1998) Aggression between unacquainted pigs – sequential assessment and effects of familiarity and weight. *Appl. Anim. Behav. Sci.* 58, 49-61.

Kirkwood, R., Zanella, A. J. (2005) Influence of gestation housing on sow welfare and productivity. NPB Final Report.

Kennedy, M.J. (1999) The behaviour and welfare of pigs on the mixing of unfamiliar groups and on exposure to conventional and novel management techniques. PhD Thesis, University of Cambridge, UK.

Luescher, U.A.; Friendship, R.M.; McKeown, D.B. (1990) Evaluation of methods to reduce fighting among regrouped gilts. *Can. J. Anim. Sci.* **70**, 363-370.

Marchant-Forde, J.N. and Marchant-Forde, R.M. (2005) Methods to reduce aggression at mixing in swine. *Pig News & Information*, 26: 63N-73N.

Marchant, J.N., Mendl, M.T., Rudd, A.R., Broom, D.M. (1995) The effect of agonistic interactions on heart rate of group-housed sows. *Appl. Anim. Behav. Sci.* 46, 49-56

Mauget, R. (1981) Behavioural and reproductive strategies in wild forms of Sus scrofa (European wild boar and feral pigs) In. (ed. W. Sybesma). The Welfare of Pigs. The Hague, Martinus Nijhoff. 11, 3–13.

McGlone, J.J. (1985) A quantitative ethogram of aggressive and submissive behaviors in recently regrouped pigs. *J. Anim. Sci.* **61**, 559-565.

Mendl, M. T., Held, S. (2001) Living in groups: an evolutionary perspective. In. (eds. L. J. Keeling, H. W. Gonyou) Social Behaviour in Farm Animals, CABI Publishing, Wallingford, UK. pp7-36.

Mendl, M.T. & Erhard, H.W. (1997) Social choices in farm animals: to fight or not to fight? In: *Animal Choices. BSAS Occasional Publication* **20**, 45-53

Mendl., M.T.; Zanella, A.J.; Broom, D.M. (1992) Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Anim. Behav.* 44, 1107–1121.

Newberry, R. C., Wood-Gush, D. G. M. (1988) Development of some behaviour patterns in piglets under semi-natural conditions. *Anim. Prod.* 46, 103–109.

O'Connell, N.E.; Beattie, V.E.; Moss, B.W. (2003) Influence of social status on the welfare of sows in static and dynamic groups. *Anim. Welfare* 12, 239-249.

Oleson, L.S.; Nygaard, C.M.; Friend, T.H.; Bushong, D.; Knabe, D.A.; Vestergaard, K.S.; Vaughan, R.K. (1996) Effect of partitioning pens on aggressive behavior of pigs regrouped at weaning. *Appl. Anim. Behav. Sci.* 46, 167-174.

Otten, W.; Puppe, B.; Kanitz, E.; Schon, P.C.; Stabenow, B. (1999) Effects of dominance and familiarity on behaviour and plasma stress hormones in growing pigs during social confrontation. *J. Vet. Med. Series A – Physiol. Pathol. Clin. Med.* 46, 277-292.

Petersen, H. V., Vestergaard, K., Jensen, P. (1989) Integration of piglets into social groups of free-ranging domestic pigs. *Appl. Anim. Behav. Sci.* 23, 223–236.

Pritchard, V. (1996) Oestrous and mating behaviour in group housed sows and the effect of social dominance. MSc Thesis. University of Aberdeen, UK.

Stookey, J.M.; Gonyou, H.W. (1994) The effects of regrouping on behavioural and production parameters in finishing swine. *J. Anim. Sci.* 72, 2804-2811.

Stukenborg, A. Traulsen, I. Stamer, E. Puppe B., Presuhn U.And Krieter. J. The use of a lesion score as an indicator for agonistic behaviour in pigs. Submitted to Livestock Science.

Turner, S.P., Farnworth, M.J., White, I.M.S., Brotherstone, S., Mendl, M., Knap, P., Penny, P., Lawrence, A.B., 2006. The accumulation of skin lesions and their use as a predictor of individual aggressiveness in pigs. Appl. Anim. Behav. Sci. 96, 245-259.

Turner, S.P., Roehe, R., D'Eath, R.B., Ison, S.H., Farish, M., Jack, M.C., Lundeheim, N., Rydhmer, L., Lawrence, A.B., 2009. Genetic validation of postmixing skin injuries in pigs as an indicator of aggressiveness and the relationship with injuries under more stable socialconditions. J. Anim. Sci. 87, 3076-3082.

van Putten, G. and Bure´ , R.G. (1997) Preparing gilts for group housing by increasing their social skills. Applied Animal Behaviour Science 54, 173–183.

Wiegand, R.M.; Gonyou, H.W.; Curtis, S.E. (1994) Pen shape and size: effects on pig behavior and performance. *Appl. Anim. Behav. Sci.* 39, 49-61.