DEVELOPING WAYS TO MEASURE AND INCREASE SOW CONTENTMENT

Report prepared for the
Co-operative Research Centre for High Integrity Australian Pork

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Executive Summary

Optimising sow welfare and productivity throughout farrowing and lactation is a high priority for both Australian and international pig industries. Optimal sow welfare requires sows to experience positive affective states, which are pleasant experiences and emotions such as contentment. This study was designed to increase sow contentment during farrowing and lactation and quantify sow contentment in novel ways. There is limited research to show that preventing nesting during the farrowing period is stressful to sows. Long term confinement may also cause stress. While alternative, loose farrowing systems continue to be investigated, the most commercially-viable option is the farrowing crate, and will be for some time until loose farrowing and lactation systems can deliver similar production and piglet welfare outcomes. Providing enrichment for sows in farrowing crates may be one way to enhance sow welfare during the pre-farrowing, farrowing and lactation period. Traditionally, animal welfare science has focused on assessing poor welfare, which makes being able to measure signs of contentment difficult. New methods to assess sow contentment require investigation in both research and commercial settings.

This study aimed to identify indicators of contentment in sows, test their practicality in production settings, and assess how the provision of enrichment affects sow contentment, behaviour and performance in farrowing crates. This study was conducted as two experiments. Experiment 1 was conducted in a commercial research piggery. This involved best practice provision of enrichment (~1+ kg lucerne hay daily during farrowing and lactation) to test the effect of enrichment on sow contentment welfare indicators in detail. Experiment 2 took place at a commercial piggery to assess different types of enrichment (lucerne, straw and non-nutritive cotton rope; either only during farrowing or over the course of lactation) on sow contentment and performance and the practicality and robustness of welfare indicators under commercial conditions.

Providing enrichment during the confinement period promoted natural behaviours and improved biological functioning in sows, with fewer stillborn piglets occurring in sows that received enrichment for 2 days prior to farrowing and during lactation (Experiment 1 stillborn piglets: lucerne = 0.1 vs. control = 0.4, $p = 0.027$; Experiment 2 stillborn piglets: straw = 0.7, lucerne = 0.9, rope = 0.8, control = 1.0, $p = 0.053$). In Experiments 1 and 2, enrichment also changed the behavioural profiles of sows during farrowing and sows continued to use enrichments when they were provided after farrowing.

This study contributed substantially to the development of behavioural tests for positive affective state by assessing their feasibility in research and production settings. One new method of assessing affective state was developed (cognitive bias in confinement), a novel method for assessing affective state was tested in sows and piglets (startle response), and the feasibility of anticipatory behaviour was assessed. In terms of indicators of positive affective state, multiparous sows receiving enrichment showed more anticipatory behaviour toward food than gilts or control sows, suggesting more positive affect. No treatment effects for any other indicators were observed. Measures of positive affective state are in their infancy and this study has improved our understanding of how these indicators may be used in the future.

While loose farrowing and lactation systems continue to be investigated, sow confinement continues to be scrutinised by the community and animal welfare groups. Providing enrichment to sows in farrowing crates improved the welfare of sows as they interacted with the enrichment and this provided reproductive performance benefits that could offset the costs of providing enrichment.

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1. Introduction

Introduction

The assessment of animal welfare has recently expanded to include positive welfare indicators. There is a general understanding that being able to assess if a sow's welfare is positive is just as important as being able to assess if it's negative. Scientific tools exist to measure positive welfare in experimental settings, but as yet there are no measures available that can be conducted accurately and routinely at a farm level. This project assessed the contentment of sows during farrowing and lactation by using scientific indicators of positive welfare and then developing practical measures for use on farm. To better understand the factors that may impact sow contentment, and how these can be measured, these topics will be reviewed in the following sections.

The benefits of environmental enrichment for confined sows

Sows are strongly motivated to build nests prior to farrowing, and nest-building is considered to be a behavioural need for sows. Sows perform nest building behaviour in two phases (Wischner *et al.* 2009). The first phase involves searching for a suitable nest site, and is internally driven by hormonal changes such as the rise in prostaglandin approximately 12-16 hrs prior to farrowing (Jensen *et al.* 1993). The second phase is a construction phase, and is partially driven by external factors such as the presence of nesting material (Jensen *et al.* 1993). Once the sow is satisfied that the nest is complete, she will lie down in preparation for farrowing. If she is not satisfied that the nest is complete, she will continue to search for a suitable site and nesting material rather than resting (Jensen 1993; Thodberg *et al.* 1999). This thwarted motivation is indicated by the frequent position changes and pen-directed behaviours that sows in barren environments display prior to farrowing.

This is a concern from more than just a welfare perspective, as expression of nesting behaviours have been correlated with subsequent measures of mothering ability and piglet survival. Thodberg et al.(1999) demonstrated that the provision of nesting materials to pen-housed sows not only increased full expression of natural nesting behaviours, but also decreased the time interval between piglets during farrowing and decreased the incidence of piglets crushed due to postural changes during farrowing. Cronin and van Amerongen (1991) similarly demonstrated that sows in an enriched farrowing crate environment that could more fully perform nesting behaviours subsequently showed greater interest in their piglets and were more responsive to their distress vocalizations, which lead to a reduction in overall piglet mortality.

Sows have also been reported to show signs of poor welfare during the lactation period from farrowing to weaning. Farrowing crates are restrictive in space not only for the sow, but also restricts the ability for her piglets to move away from the sow. Sows have a natural tendency to spend time away from their piglets as lactation progresses and gradually reduce suckling frequency, effectively creating a gradual weaning process (Jensen and Redbo 1987; Jensen 1988; Pajor *et al.* 1999). In the confined environment of the farrowing crate, the sow cannot escape her piglets and has minimal control over the amount of interaction, both positive and negative, that she has with them. Indeed, sows have been observed to "snap at" their piglets in late lactation, and Whatson and Bertram (1983) recorded an increase in this behaviour in the 4th week post-farrowing. Further, in an experiment by Cronin et al.(1991), the cortisol response of young sows was measured before farrowing and during lactation in conventional farrowing crates compared to open, straw-bedded pens. On day 28 of lactation, while the mean daily free cortisol concentrations of sows in both treatments were elevated relative to the previous weeks, concentrations were significantly higher for sows in crates than pens. These studies indicate that the continued confinement of sows with their litters during lactation may lead to poor welfare. It was hypothesised in the current experiment that providing enrichment during lactation may help alleviate poor welfare during this period.

The three frameworks of animal welfare science

There are three conceptual frameworks that animal welfare scientists use to understand animal welfare: biological functioning; affective states, and natural behaviours (Fraser 2003; Hemsworth *et al.* 2015). These three frameworks are closely interrelated. An animal's welfare is considered to be 'good' if it is healthy and reproducing successfully (good biological function), experiencing pleasant emotions and avoiding unpleasant emotions (positive affective states), and is able to perform species-specific behaviours that the animal finds rewarding, such as foraging and nest building in sows (satisfying natural behaviours). A combination of behavioural and physiological measures are often used to assess the welfare status of an animal in relation to these three frameworks.

The assessment of positive welfare

Animal welfare science has traditionally focused on assessing poor welfare, but there is an increasing understanding that good animal welfare is not simply the absence of negative experiences, but the presence of positive experiences (Boissy *et al.* 2007). Positive experiences contribute to good animal welfare, while negative experiences detract from it. Positive experiences for an animal can include pleasant physical sensations and emotional states, and result from obtaining access to a valued resource, positively interacting with the physical and social environment, and achieving their own goals (Yeates and Main 2008).The assessment of positive welfare should thus consider whether an animal has access to the resources that it wants, and how much the animal enjoys accessing that resource (Yeates and Main 2008).

Behavioural methods of assessing positive emotions in animals

It is now known that affective state alters cognitive processing, and cognition alters affective state (Boissy *et al.* 2007; Mendl *et al.* 2009). Thus, behavioural indicators of cognitive processing can provide information on the immediate affective state of the animal. The behavioural indicators of cognitive processes that were used to measure affect in this study were anticipatory behaviour, cognitive bias, and the startle response. These methods will be elaborated below.

Anticipatory behaviour

Animals are able to anticipate future events and can be trained to recognise cues that signal the arrival of a pleasant or aversive experience. The anticipation of a positive or negative event results in behavioural change that can be measured; animals will show withdrawal and reduced activity when anticipating an aversive experience, but will show increased activity and investigative behaviour when anticipating a pleasant experience (Spruijt *et al.* 2001). The value of the anticipated resource is dependent on the internal state of the animal, and thus the amount of anticipatory behaviour shown has been proposed as an indicator of positive affect in animals (Spruijt *et al.* 2001; Boissy *et al.* 2007). This means that positive affect can be indicated by increased activity in animals that are anticipating a reward, such as a feeding event.

Cognitive bias
Judgement processes in humans and animals are altered by affective state and can be used as an indicator of affective state. Animals experiencing a negative affective state are more likely to view an ambiguous stimulus as a threat, while animals experiencing a positive affective state are more likely to view it as an opportunity (Harding *et al.* 2004; Mendl *et al.* 2009). This cognitive bias in decision making can be assessed in animals by measuring whether or not they approach an ambiguous stimulus, with approach behaviour indicative of a positive affect and avoidance behaviour indicative of negative affect.

Startle response
The startle response is the reflexive movement of an organism to the sudden exposure of an unexpected stimulus, such as loud noise. The magnitude of the startle response varies in a linear manner with affective state in humans and animals, with a greater startle response associated with negative emotional states (Lang *et al.* 1990; Grillon and Baas 2003). This allows the magnitude of the startle response to be used as an immediate indicator of emotional valence.

To date there are few studies that investigate these cognitive measures of positive affect in pigs. This study represented unique research in that it compares multiple measures of positive affect in sows under laboratory and commercial conditions.

Aims and hypotheses
It was hypothesised that providing enrichment to sows during their confinement in the farrowing crate will improve their contentment. The aims of this experiment were:

1. To identify indicators of contentment in sows
2. To test the practicality of these measures in a large scale, production setting
3. To assess how the provision of enrichment affects sow contentment and sow performance in farrowing crates

This research was conducted as two experiments. The first experiment involved a proof of concept study at the Roseworthy facility, SA, to demonstrate that the indicators of positive welfare described above could be measured in confined sows. The second experiment took place at a commercial piggery at Rivalea Australia, NSW, to test the practicality and robustness of these measures under commercial conditions. The second experiment also introduced multiple new treatments, to determine if non-nutritional enrichments could deliver welfare and performance benefits. A third experiment was conducted alongside this project under the supervision of the key researchers at SunPork Farms South and is attached to this report as an appendix.

2. Methodology

Experiment 1 was approved by PIRSA Animal Ethics Committee (Project Number: 08-15), and Experiment 2 was approved by Rivalea Animal Ethics Committee (Animal Ethics Number: 16B072C). All animal procedures were conducted with prior institutional ethical approval under the requirement of the NSW Prevention of Cruelty to Animals Act 1985 in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organisation/Australian Animal Commission 'Australian code of practice for the care and use of animals for scientific purposes'.

Subjects, housing and treatments

Experiment 1

The experiment was conducted from March 2016 until August 2016, at the Roseworthy Piggery. 72 Large White x Landrace mixed parity sows (gilts-parity 2) were batch farrowed over six replicates (12 sows per replicate).

The farrowing shed was maintained at an optimal internal temperature using central controlled heating and ventilation system, and an evaporative cooling system. The rooms were lit with standard fluorescent lights, with a lighting schedule of 10 hours light, 14 hours dark. The farrowing shed held five separate rooms, each containing 12 industry standard farrowing crates. Sows were housed in the same room over all six replicates.

Sows were moved into the farrowing shed at 108 ± 2 days of gestation (approximately seven days before their predicted due date, Range = 4 - 11 days prior to farrowing). On loading into farrowing crates, sows were randomly allocated to either a Control or Enrichment treatment, with equal spread of treatment and parity. Sows in the enrichment treatment received 1kg of lucerne daily leading up to farrowing after feed delivery, and every second day following farrowing. The lucerne was provided after feed delivery on the floor directly in front of the feeder. The control treatment received standard husbandry with no access to nesting materials or enrichment. Video cameras were permanently installed above each farrowing crate to enable behaviour observations. Sows were fed a lactation pellet (13.8 MJ DE/kg) at 3kg/day until the day of farrowing, after which they received 5kg feed in the morning and a maximum of 5kg in the afternoon (adjusted according to left over morning feed). Piglet fostering was conducted by farm staff at 12-24h of age. Piglets were batch weaned at 17.2±0.4 days (mean±SEM) of age.

Production measurements

Production data were collected for the number of piglets born (total, born alive, born dead), the number of piglet deaths, and the number of piglets weaned per sow. Subsequent reproduction data for each sow was collected for: weaning to oestrus interval (days), mated next batch (%), pregnancy rate (%), farrowing rate (%), and total piglets born, piglets born alive, and piglets born dead in the subsequent litter. Piglet survival was calculated on a per sow basis, and included fostered piglets.

Experiment 2
This experiment was conducted from February 2017 until November 2017 at the Rivalea piggery, Corowa VIC, using 724 mixed parity sows (approx. n=120 per treatment group; gilts-parity 7 over seven replicates). The parity structure was similar among treatment groups.

Housing

The experimental building had a galvanised roof and thermostatically controlled blinds that maintained an optimum internal shed temperature. The farrowing building was open-sided with shutters and heating and water dripper cooling which enabled temperature control. A natural lighting schedule was maintained throughout the experiment. There were two farrowing sheds used in the experiment and each shed contained 60 crates. The sows were moved from gestation group housing into the farrowing shed approximately 7 days prior to predicted farrowing date (Range = 0 - 18 days prior to farrowing).

Minimal fostering was conducted within the first 24 hrs post-birth. If possible the piglets were fostered within treatment. Prior to farrowing, sows were provided with 2.7kg/day of commercial lactation feed (14.8 MJ DE/kg and 16.2% crude protein). After farrowing, sows were provided with 3kg of feed in the morning and up to 3 kg in the afternoon (if the sow had eaten all of the morning feed). By day 4 of lactation, sows were provided with *ad libitum* feed. Piglets were weaned at approximately 26 days of age in all treatments

On loading into the farrowing crate, sows were allocated to one of six treatments (Table 1), with 10 sows receiving each treatment per time replicate. Each enrichment treatment commenced approximately 2 days prior to farrowing. Video cameras were permanently installed above 18 farrowing crates in one shed to enable behaviour observations. All treatments were blocked within each shed so that each treatment was equally represented within each block.

Table 1
Treatments imposed during Experiment 2

Treatment	Description
Control	Standard housing, no enrichment
Cotton rope	A cotton rope (30cm long x 3cm thick) was tied to the top rail of the farrowing crate, so that the rope hung vertically next to the feed trough prior to farrowing and throughout lactation.
Straw pre-farrow	1 kg of straw was placed in the feed trough daily prior to farrowing
Straw whole lactation	1 kg of straw was placed in the feed trough daily prior to farrowing, followed by 0.25kg of straw daily during lactation
Lucerne hay pre-farrow	1 kg of lucerne was placed in the feed trough daily prior to farrowing only
Lucerne hay whole lactation	1 kg of lucerne was placed in the feed trough daily prior to farrowing, followed by 0.25kg of lucerne daily during lactation

The straw and lucerne were provided at an approximate rate of 1 kg /sow provided 2 days prior to expected farrowing date and then replenished each day (approx.0.25kg/sow/day) for straw and lucerne whole lactation treatments. There was no adjustment made for the diet of the sows; the enrichment was additive to the commercial lactation diet.

Sow liveweight, backfat and reproductive performance. Piglet growth rate

All of the sows were individually weighed and P2 back fat measured by ultrasound prior to entry to the farrowing shed and at weaning. Reproductive data (number of piglets born alive, still-born and number weaned) were collected and the liveborn piglet mortality was calculated for each litter taking into consideration fostering adjustments i.e. (100 x total live born deaths/total born alive plus fostering adjustment). The daily feed intake of individual sows was recorded. The litter weight (post-fostering) and pre-weaning weight was measured.

Please note: For the purpose of brevity, all parity 0 sows will continue to be referred to as gilts after the birth of their first litter, even though they are technically parity 1 sows at this stage.

Sow behaviour measurements

The behaviour of the sows in both experiments was recorded using overhead video cameras. All farrowing crates in Experiment 1 (12 sows per replicate), and a subset of the farrowing crates in Experiment 2 (18 sows per replicate) had a permanently installed single overhead camera (3MP fixed lens IP dome camera) connected to the 16 channel NVR, with infrared capabilities to allow visual recording at night. Sow behaviour was recorded continuously, and the following footage was kept for analysis:

- During the startle tests, performed on Days -3, +4 and +12 post-farrowing (Experiment 1 only)
- During the cognitive bias tests, performed on Day +1 and +15 post farrowing (Experiment 1 only)
- During feeding (anticipatory behaviour) on -2, +3 and +12 days post-farrowing (Experiment 1), and + 11 days post-farrowing (Experiment 2).
- After the delivery of enrichment (enrichment use) on -2, +5 and +13 days post-farrowing (Experiment 1) and +7 days post-farrowing (Experiment 2).
- During farrowing (farrowing duration and piglet intervals)
- 24 hrs prior to farrowing (nesting behaviour)

The video footage was analysed by three people using the Noldus Observer XT software (Version 11) and Windows Media Player.

Affective State Tests

Cognitive bias (Experiment 1 only)

An *in-situ* spatial go/no-go task was used to test sows for cognitive bias during early (Day +1) and late (Day +15) lactation. Sows were trained to differentiate the outcome of touching their snouts onto a visual cue presented to them in two different locations. A diagram of the testing apparatus is presented in Figure 1.

When the sow's snout touched a visual target (silver rectangle) in one corner above the feeder (340 mm wide) at the front of the crate she was rewarded with a sugar cube, which was delivered with the assistance of a secondary reinforcer (a clicker). In contrast, when the sow touched the target in the alternate corner she was 'punished' (not rewarded and received 10 s time out).

The time to respond to the rewarded target was almost instantaneous and the maximal time to respond was set at 4s before a non-response was recorded. Sows received two training sessions (average 260s) and after one training session achieved 85% accuracy in the task ($P<0.05$). One ambiguous location was chosen 226 mm and 114 mm from the positive and negative locations respectively. The latency to respond to the cue each time it was presented was recorded for analysis.

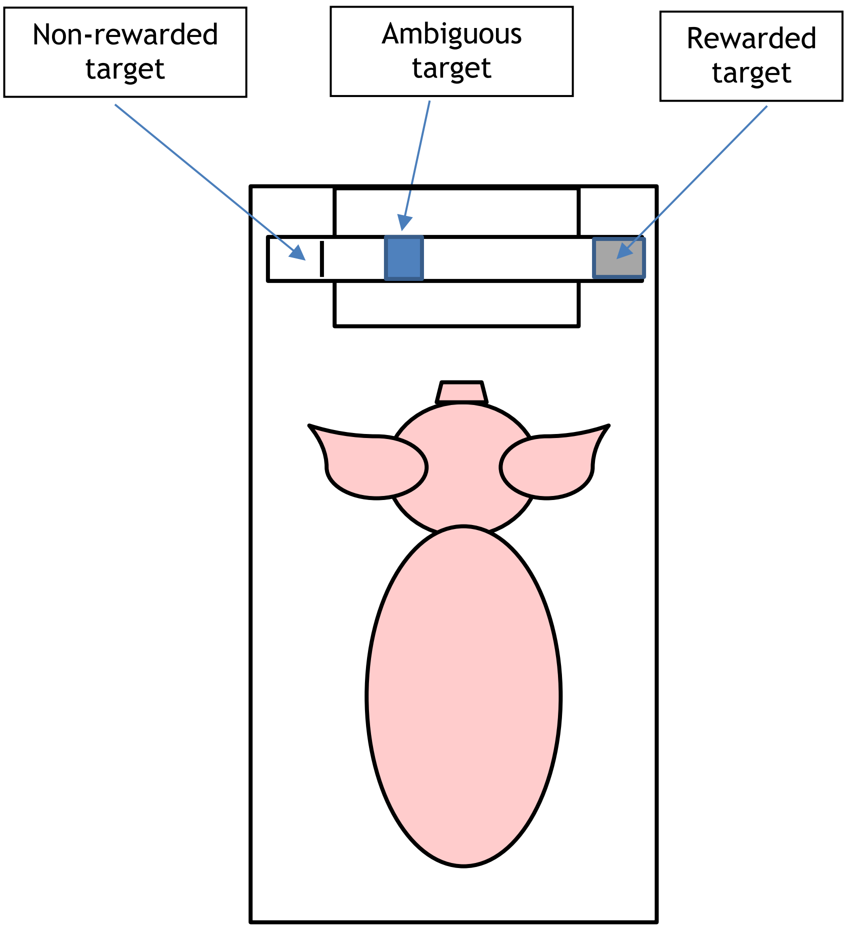

Figure 1
Visual depiction of the testing apparatus and cue locations in the cognitive bias test, with the rewarded target on the right-hand side of the feed trough during training. Only one ambiguous target was presented at a time during testing.

Startle test (Experiment 1 only)

Sow startle response

The startle response of the sows to a loud (average 73 dB), unexpected sound stimulus was recorded on three test days: late gestation (-3 days), early lactation (+4 days) and late lactation (+12 days). On each test day the sound stimulus was played three times (labelled Startle 1-3) at 3 min intervals. Video footage was recorded from 1 min prior to the first startle (Startle 1) stimulus and finished 3 mins after the third startle stimulus (Startle 3), resulting in a total of 10 mins of footage for analysis on each of the three testing days. During video analysis, the starting posture and the magnitude of the startle response displayed by each sow was scored using the 6-point scale presented in Table 2

Table 2
Scoring system for the sow startle response

Score	Response to startle stimulus
0	No response
1	Ears move
2	Head moves, no freeze
3	Head moves + short freeze (≤5 secs)
4	Head moves + long freeze (>5 secs)
5	Flinch and freeze (body changes position)

In addition to the startle score, a time budget for each sow was recorded by continuous observations during the 10 min test period using the ethogram described in Table 3. This resulted in two behavioural categories: Posture and Behaviour. The behaviours within each category are mutually exclusive, and the results are presented as percentages

Table 3
Ethogram of sow behaviours during the 10 min startle response test period

Behavioural category	Description of behaviour
Posture	
Standing	Body not touching ground. Includes kneeling as sow begins to lie down.
Sitting	Rump on ground, weight on forelegs.
Lying sternal	Lying on ventral surface, both shoulders point up
Lying lateral	Lying on side, one shoulder higher than the other, sternum off ground
Behaviours	
At feeder	Sow has head in feeder or is touching feeder with snout or mouth. Can be performed in any posture. Includes frustration behaviours such as rubbing the mouth along the feeder or pawing at the feeder (so long as these behaviours are <30s. If >30s then they are classed as stereotypical). Also licking/nibbling the feeder.
Drinking	Sow places mouth around a drinker and remains there for >5s. Water can sometimes be seen dripping down.
Eating	Chewing food in the feeder, indicated by repetitive movements of the jaw or ears.
Active interaction with piglets	Sow contacts piglet with snout or moves the head toward a nearby piglet to make contact. If the piglet is out of reach it also includes looking at the piglet with snout outstretched and ears forward. Also includes negative interactions where the sow is trying to move the piglets away from her with her head. Does not include sow kicking at piglets with leg of shifting body position away from piglets.
Passive interaction with piglets	Piglets contact sow on any part of her body with their snout while moving (does not include resting with the snout touching the sow). Can include nosing the udder when <90% of piglets are doing this behaviour.
Sniffing	Sow contacts floor or bars of crate with snout and makes small movements (as if sniffing around)
Suckling	At least 90% of the piglets are nosing at the udder, sucking a teat or attempting to reach the udder.
Inactive	The sow is not performing any of the above behaviours. Includes remaining motionless as well as looking around.
Interacting with hay	Nosing at hay on the floor or chewing hay

Piglet startle response

During the video analysis of Experiment 1 it was noticed that the piglets were also responding to the startle stimulus. The 6-point startle scoring system was adapted for use with free-moving piglets (Table 4), and the proportion of each litter that received each score was recorded.

Table 4

Scoring system for the piglet startle response

Score	Response to startle stimulus
0	No startle
1	Small movement with no pause, or small pause with no movements
2	Movement and pause < 5 secs
3	Movement and pause > 5 secs, or jump
4	Run or flee

Behavioural observations

Anticipatory behaviour

On Days -2, +3 and +12 post-farrowing the anticipatory behaviour of the sows was tested by walking the feed cart past the sows without feeding them. Once the feed cart had passed all of the pens the stockperson waited for 3 mins before commencing the normal feed delivery. The behaviour of the sows during this anticipatory period was recorded, using a slightly different protocol for each experiment.

Experiment 1

The behaviour of the sows was recorded continuously using the ethogram presented in

Table 5, starting 2 mins prior to the stockpeople entering the shed and finishing when the focal sow received feed. This meant that each sow was observed for a different duration, as sows fed first would have a shorter observation period than sows fed last. The 2-min period prior to the stockpeople entering the shed was called the Pre-Test period and was used as a baseline measure of sow behaviour, before the auditory cue was sounded. The period between the stockpeople entering the shed and the sow receiving feed was called the Test period and was used to measure the anticipatory behaviour of the sows to feed delivery. These observations were made on Replicates 1-5, on Days -2, +3 and +12 post-farrowing.

Experiment 2

The behaviour of the sows was recorded continuously for 10 mins prior to feed delivery, using the ethogram in

Table 5. Due to time restrictions on the video analysis, the anticipatory behaviour was only analysed for one of the test days (Day +11). Difficulties with the file types used during the video recordings also meant that the footage from Replicates 2 and 3 were not analysed.

Table 5
Ethogram of the behaviours recorded during the anticipatory test

Behaviour	Definition
Lateral laying	Laying laterally with shoulder resting on ground
Sternal laying	Laying with sternum on ground
Sitting	Rump on ground, sternum elevated, head between two top bars
Standing	On all four hoofs, head between two overhead bars/in the centre of the crate
Head left corner	Snout is in the far left corner of the crate, above the feed trough
Head right corner	Snout is in the far right corner of the crate, above the feed trough
Head between bars	Snout between side rails. Includes when lying down or suckling
Head in feeder	Snout in feeder, past line of front of crate
Head above bars	Head above level of top rail
Drinking	Snout on nipple drinker
Shake	Shake side to side, not in contact with bars
Scratch side	Rub side up and down against side bars of crate
Stepping	Moving foot and shifting weight side to side; similar to walking, but stationary
Bar biting	Mouth open and around bar anywhere on crate, or pushing snout against bars
Pawing	Scratching at ground, feeder or bars with one front leg
Climbing	One front hoof resting on bar/feeder
Urinate	
Defecate	
Suckling	Lying lateral with all piglets at teats (also scored when up to 2 piglets not at teats)
Feeder interaction	Rubbing snout on feeder, biting feeder
Rooting	Rubbing snout over floor

Enrichment use

Sow behaviour following the delivery of the enrichment items (straw or lucerne) was recorded for 20 mins following delivery on Days -2, +5 and +13 days post-farrowing (Experiment 1) and +7 days post-farrowing (Experiment 2). For sows that were in the Control treatment or Rope treatment (Experiment 2 only), the behavioural observations started when the nearest neighbour in the lucerne or straw treatments received their enrichment. Sow behaviour during this 20-min period was analysed using the ethogram presented in

Table 6, using 15 second instantaneous samples (a total of 80 observations per sow). The latency to interact with the enrichment and the duration of enrichment use was also recorded. The duration of enrichment use was considered to have ceased when the sow had not touched the enrichment for a period of at least 5 mins.

Table 6
Ethogram of the behaviours used for assessing enrichment use following enrichment delivery

Behaviour	Definition
Stand	Standing still on all four feet
Kneel	Kneeling on forelegs, standing with hind legs. Generally occurred as sow was lying down.
Sit	Sitting on rump, forelegs straight.
Lie	Lying laterally or sternally
Step	Walking more than two steps forward or backward
Chewing enrichment	The mouth is visibly opening and closing while chewing, and/or has lucerne sticking out of the mouth, or snout and ears are moving rhythmically with snout above lucerne (when mouth is not visible)
Sniff enrichment	Sow is moving snout over lucerne. She may be eating/chewing it but mouth is not visible. No upward thrusting movements like rooting.
Rooting enrichment	Sow is making upward thrusting movements with her snout while her snout is in the lucerne, lifting the lucerne up off the ground.
Pawing at enrichment	Sow is moving one foreleg forward and backward to move the lucerne. This may occur while standing or lying.
Drinking	Sow had mouth or snout in the position of the drinker and remained motionless except for small regular movements of the jaw or ears that indicated swallowing.
Feeding	Sow had head in feed trough in the presence of food.
Inactive	Sow was not performing any of the other behaviours on this ethogram. Included urination/defecation, and watching stockpeople in the shed.
Pawing	Sow is moving one foreleg back and forth, dragging the foot across a surface, with no lucerne present. This may be the floor or the feed trough.
Rooting/nosing	The sow is pushing her snout around on the floor or another surface. There may be forward thrusting movements as for rooting. There is no lucerne present.
Oral manipulation	The sow is manipulating an object with her mouth that is not feed, the drinker or Lucerne. This includes bar biting and having her head in the empty feed trough.
Sniff floor	Sow points snout directly down toward the floor. It may be still or moving. There is no lucerne on the part of the floor that she is sniffing.
Active with piglets	Sow contacts a piglet with her snout, or extends her snout toward a piglet that is out of reach. May include both positive and negative interactions.
Suckling	Sow is lying on her side and >90% of her litter are suckling. If less than 90% are suckling then it is classified as a passive interaction with the piglets (see below)
No piglet interaction	None of the piglets are touching the sow with their snout
Passive with piglets	At least one piglet is touching the sow anywhere on her body with their snout. The piglet must be awake - piglets sleeping in contact with the sow were not included.

Nesting behaviour

The nesting behaviour of the sows was analysed for 18 hrs prior to the birth of the first piglet, using 15 min instantaneous samples (72 observations per sow). Sow behaviour was recorded using the ethogram presented in Table 7. The behaviours indicative of pain were provided by Ison et al. (2016).

Table 7
Ethogram of the behaviours used to record nesting behaviour in sows

Behaviours	Definition
Lateral lying	Lying on side, or partially on stomach but at less than a 45 degree angle. Both front legs visible
Sternal lying	Lying on sternum or partially on side, only one front leg visible
Sit	Weight on rump and fore feet
Kneel	Weight on hind feet and knees
Stand	Standing on all four feet without any feet moving
Stepping	Taking one or more steps
Inactive	No behaviour of interest is being performed (idle, watching stockperson, etc)
Eat	Head in feeder with feed present. Look for rhythmic chewing motions (cheeks or ears) and standing still at the feeder. Fed in early morning.
Drink	Mouth in contact with drinker. There are two drinkers (high and low) - sow may drink from any posture. Often drink for a long period (10 secs+) Look for standing still with the mouth angled up and in contact with the drinker, with rhythmic swallowing movements of cheeks and ears. You may see some water trickling down near the mouth.
Eliminate	Urination or defecation. Sow may show a small squatting/rounded rump position while urinating.
Sniffing floor	Moving snout over floor where no lucerne is present, just before lying down. Little movement of head.
Feeder interaction	Bites or rubs head against feeder, pushes or roots against feeder, head in empty feeder. No standing and chewing.
Drinker interaction	Chewing on drinker, or pushing snout against drinker to let water out. Obviously not swallowing water (no rhythmic swallowing movements)
Bar interaction	Bites, paws or rubs head against bars, pushes against bars with snout
Nesting behaviour	No lucerne/straw under snout. Sniffing floor, rooting floor, pawing any object - **all without touching the enrichment object**

Vacuum nesting behaviour	A composite variable, created by summing all nesting-related behaviours that don't use enrichment (feeder/drinker/bar interactions, and nesting behaviour)
Enrichment interaction	**Must be touching the enrichment object.** Enrichment can be straw/hay/lucerne in feed trough or on floor, or rope hanging next to feed trough. Sniffing, chewing, pawing at, carrying in mouth, rooting
Other behaviour/ Sham chewing	Sham chewing (rhythmic movement of head or ears with no feed or enrichment visible in the mouth, and no prior feeding or enrichment interaction), interacting with stockperson etc
Strain	Body clenches, with hind quarters drawing toward belly and/or back tensing
Pain indicators	Tail flick, leg lift (one or both hind legs lift toward belly), shaking, front leg row (rowing motions)

Farrowing behaviour

The farrowing behaviour of each sow was observed continuously from the birth of the first piglet until the placenta was passed, or if the placenta could not be observed then observations ceased at the time the last piglet was born. These observations allowed the farrowing duration to be calculated (first piglet to placenta, and first piglet to last piglet), as well as the average piglet interval. The number of stillborn piglets was also recorded, with a stillborn piglet classified as a piglet that did not move at all after being born.

Sow physiology

Catheterisation

In Experiment 1, across replicates four, five and six, 20 selected sows (n=11 enrichment, n=9 control) had an indwelling ear vein catheter (vinyl, Microtube Extrusions Pty Ltd, NSW; internal diameter 1.0mm and external diameter 1.5mm) inserted one day before the first test, with local numbing gel (Xylocaine Jelly 2% Gel, Astrazeneca Pty Ltd, NSW) applied before the procedure. Sows were snared in their farrowing crate during insertion. The catheter was protected and held in place by adhesive bandage, with the external tubing and catheter port used for extracting blood held in a pouch on the back of the head. Catheters were flushed daily with heparinised saline.

Blood sampling

Blood sampling was conducted around the anticipatory test. During the anticipatory test, blood samples were taken at -60 minutes, -30 minutes, -10 minutes, +3 minutes, +15 minutes, +30 minutes, +45 minutes and +60 minutes relative to the test being conducted.

Assays

Heparinised vacutainers (BD, Mississauga, ON) were used to collect blood samples of 5ml volume. The samples were stored at 4-8^{O}C before being spun at 3000rpm for 15 minutes. The plasma was pipetted into aliquots and stored at -20^{o}C. Cortisol concentrations were measured using radioimmunoassay (MP Biomedicals), from 100µl of plasma.

Statistical analysis

Anticipation, enrichment use and nesting
Generalised linear models with a quasibinomial distribution were used to analyse results presented as a proportion (e.g. % nesting behaviour). Poisson distributions were used for count data (e.g. number of behavioural transitions). Linear models were used for the few continuous measures (e.g. total use).

When there were repeated measures, individual sow's ID was fitted as a random factor and a generalised linear mixed model was used. Examples of this include enrichment use over time and anticipatory behaviour over time.

For all models, interactions of treatment, parity and rep were included, and time when it was repeated, to investigate all relationships. Step wise reductions of the models were performed to reach the final models.

When analysing simple binary outcomes (enrichment use vs. no use), chi square tests were used. Spearman's correlations were performed to investigate correspondence between count-count and count-continuous variables.

For Experiment 2 sows were grouped as either gilts or sows, and treatments were grouped where relevant. For measures around farrowing, pre-farrowing and whole lactation treatments were combined; for measures after farrowing, pre-farrowing and control treatments were combined.

Startle scores
Data were missing for sows in Experiment 1, Day 1 Rep 5 (the startle scores and time budgets were not analysed for Day 1), but there were no other missing data. The video footage was not analysed for Experiment 2 due to technical difficulties. Continuous data (Time budgets %) were checked using the Shapiro-Wilk test of normality. All of the time budget data except one variable (Passive with piglets Day 3) were found to be non-normal ($P < 0.003$) due to the large number of zeroes in the data set.

Generalised estimating equations (GEE) with a multinomial distribution and a cumulative logit link function were used to determine the effects of Treatment, Replicate, Posture and Startle Number on the Startle Score.

Time budgets were examined for treatment and time effects using GEE, and their relationships to the Startle Scores were examined using Spearman rank correlations.

Mann-Whitney U-Tests were used to test for treatment effects on the startle scores of the piglets on one day only (late lactation).

Cortisol analysis
Cortisol data were analysed using a repeated measures analysis of variance. Data that were not normally distributed were $\log_{10}$ transformed prior to analysis and all data are presented as back transformed means.

Production analyses

Experiment 1

Statistical analyses were performed using Univariate General Linear Models, using each sow/litter as the experimental unit with parity, treatment and their interaction as fixed effects, and batch replicate as a random term, were run for the following variables: farrow duration (log10), piglet interval (log10), total piglets born, piglets born alive, and piglets weaned. A covariate of total number of piglets born was added to the model for farrowing duration and piglet interval only. The same model was used for number of piglets born dead and post-natal piglet deaths but a generalised linear model with Poisson distribution was applied, and a binomial distribution was applied to the number of sows that were mated next batch.

Experiment 2

Statistical analyses were performed using Univariate General Linear Model, using each sow/litter as the experimental unit with parity, treatment and their interaction as fixed effects and batch replicate as a random term. Chi-squared analysis was used to determine number of sows removed due to death, illness and agalactia and if there were differences between farrowing rate of sows post-weaning.

3. Outcomes

Measures of affective state

Anticipatory behaviour

Experiment 1

Anticipatory behaviour is characterised by increased activity levels, and an increased rate of change from one activity to the next (behavioural transitions). The number of behavioural transitions was measured using the total number of behaviour bouts recorded for each sow. Acting as a proof of concept, sows transitioned between behaviours more (test time × day interaction $p = 0.052$; Figure 2; Table 8) and spent proportionally less time lying (test time × day interaction $p < 0.001$) during the anticipatory test compared to the pre-test period, indicating that the procedure had successfully elicited anticipatory behaviour.

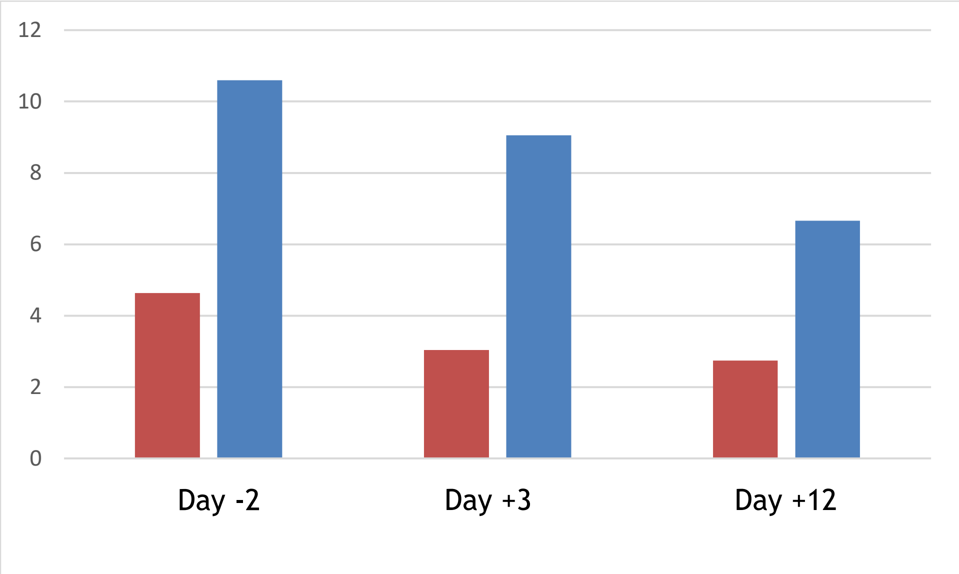

Figure 2

Average number of behavioural transitions before (red) and during the anticipation (blue) test. Sows performed more behaviours/min during test than before the test, but the number of transitions during the test on Day +12 was lower than the other two days.

Table 8

Behaviours before and during the anticipatory test[1,2]

Test	Day	**Transitions**	**Proportion lying**
		Mean behaviours/min	Mean %
Pre-test	-2	4.6[a] (4.6± 0.52)	53%[a] (-2.08 ± 0.10)
	+3	3.0[a] (3.04 ± 0.52)	79%[b] (-2.08 ± 0.10)
	+12	2.7[a] (2.73 ± 0.52)	81%[c] (-0.69 ± 0.37)
Anticipation test	-2	10.6[c] (10.5 ± 0.52)	10%[d] (-2.8 ± 0.17)
	+3	9.0[c] (9.0± 0.52)	28%[e] (-1.2 ± 0.17)
	+12	6.7[b] (6.7± 0.52)	35%[f] (-0.68 ± 0.17)

The number of behavioural transitions per minute changed over days ($p < 0.001$;

[1] For all results raw means are presented first, with transformed means and SEM presented in parentheses where there is a statistical difference. Different superscripts represent where there are statistical differences in post-hoc tests

[2] P values for behavioural transitions and proportion of lying time for anticipatory tests are in the written results.

Table 9), with it declining from day -2 to day +12.

There was no influence of treatment on anticipatory behaviour. The proportion of time spent lying was significantly influenced by treatment × day ($p < 0.001$;

Table 9), but there is no clear relationship. Both treatments spent a similar amount of time lying on Days -2 and +12. Sows in the Lucerne treatment spent more time lying than the Control sows on Day +3. The amount of time spent lying increased as the experiment progressed for both treatments.

Table 9

Effect of treatment on anticipatory behaviours

Treatment	Day	**Transitions** Mean behaviours/min	**Proportion lying** Mean %
Lucerne	-2	11.5[a] (10.6 ± 0.57)	10%[a,b] (-4.84 ± 0.49)
	+3	9.5 [b] (3.04 ± 0.52)	36%[b,d] (-1.5 ± 0.46)
	+12	7.1 [c] (2.73 ± 0.52)	33%[c,d] (-1.04 ± 0.43)
Control	-2	9.7[a]	10%[a] (-5.27 ± 0.46)
	+3	8.6[b]	19%[b,c] (-2.82 ± 0.42)
	+12	6.2[c]	38%[d,e] (-1.47 ± 0.42)

Experiment 2

The treatments were pooled for this analysis. There was a significant effect of treatment × parity on the number of behavioural transitions that occurred during anticipation ($P < 0.001$, Figure 3). Multiparous sows showed significantly more behavioural transitions than the gilts in the lucerne/straw treatment, but there was no difference between parities in the control/rope treatment. Multiparous sows in the lucerne/straw treatment also showed a higher number of behavioural transitions than all sows in the control/rope treatment ($P < 0.05$). There was no significant effect of parity ($p = 0.57$) or treatment ($p = 0.40$) on the proportion of time spent lying (Figure 4).

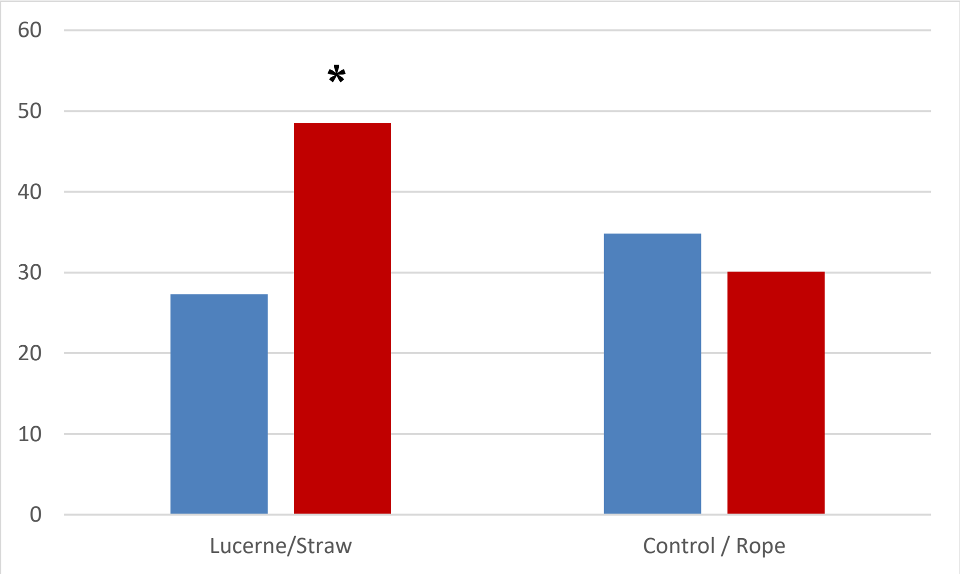

Figure 3

Number of behavioural transitions during a 10 min period prior to feeding (Day +11) for the pooled treatments; gilts in blue, sows in red. * P < 0.05

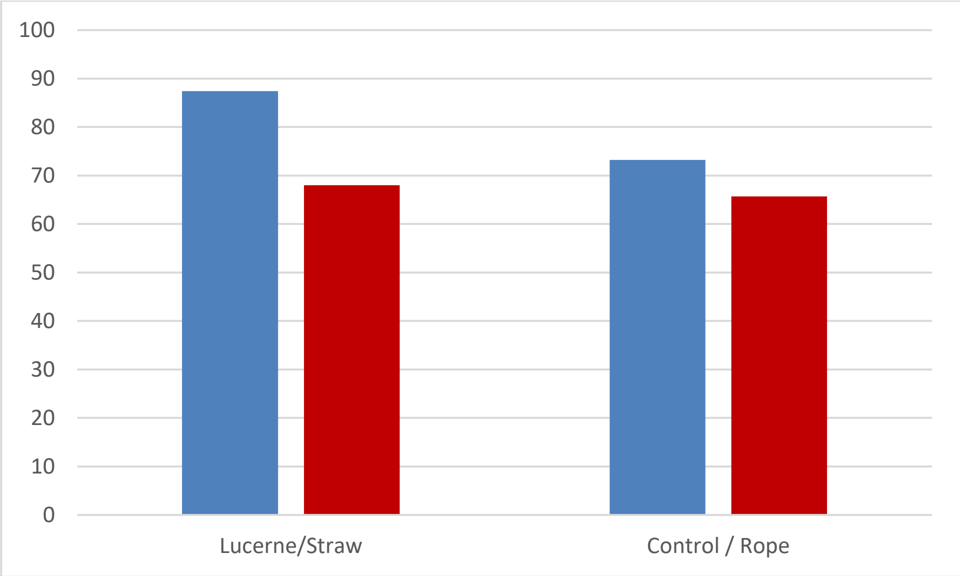

Figure 4
The percentage of time spent lying during the 10 mins prior to feed delivery (Day +11). Gilts in blue, sows in red. No significant differences.

Interpretation
For Experiment 1, there was evidence of less anticipation in the sows over time, suggesting that the interest in the feed decreased over the lactation period. It is not clear what caused this decrease, but it may be related to the increased feed allowance that was provided through lactation (3 kgs / day during gestation cf 5-10 kgs / day during lactation). While this would certainly decrease the value of feed delivery, it does not explain why the sows showed a decrease in feed anticipation between early (Day +3) and late (Day +12) lactation rather than an increase, when the nutritional demand of feeding the growing litter was increasing (Quesnel *et al.* 2007). It is possible that the affective state of the sows was becoming more negative as the experiment progressed, but this cannot be separated from the effect of increased feed allowance using the current data.

For Experiment 2 there was evidence that on Day +11 of lactation, multiparous sows showed more anticipatory behaviour toward feeding when they had been provided with straw or lucerne. The multiparous sows in the control/rope treatment did not show a similar increase, despite receiving less nutrition in the form of straw or lucerne, suggesting that the amount of anticipatory behaviour shown by multiparous sows in the straw/lucerne treatment may reflect a more positive affective state, rather than hunger.

The multiparous sows in the straw/lucerne treatment also showed more anticipatory behaviour than gilts receiving the same enrichments. One explanation may be that the multiparous sows tend to have larger litters and thus may have a higher metabolic demand and anticipation of feed; however, the lack of a similar parity effect in the control/rope treatment does not support this explanation. This parity effect may be related to the previous farrowing experience of the multiparous sows, in which they would have farrowed without enrichment items. Relative to previous farrowings, being provided with fibrous, edible enrichment may be more rewarding as the sows can compare the two experiences, resulting in a more positive affective state. In comparison, gilts do not have past experience to put their situation in context. Furthermore, this is a novel environment and experience for gilts. We propose that this stress would impact behavioural expression and/or more positive emotions for gilts, and so anticipation is muted. For sows, their past experience means that they have less stress and a greater expression of behaviours.

As the anticipatory behaviour of sows in Experiment 2 was only assessed on Day +11, the change in anticipatory behaviour over time could not be assessed. When looking at behaviours at both locations, sows in Experiment 2 spent more time inactive and performed less behavioural transitions per minute during observations

In terms of evaluating the anticipatory test itself, the results from Experiment 1 show that the method for testing anticipation was valid and would be simple to administer in a semi-controlled environment. This supports findings from Mahnhardt et al. (2014), who also showed that the acoustic announcement of feed delivery increased the activity levels of pigs using a simple ethogram. The results from Experiment 2 show that the provision of straw or lucerne can induce changes in affective state in multiparous sows during lactation. The anticipatory test in Experiment 1 worked effectively as the number of sows in the room was small, so we could ensure the anticipatory cue was being delivered to the sows at a consistent and similar time. Conducting a controlled anticipatory test in a commercial setting was more difficult because of the size and design of the building. Anticipatory testing on a larger scale would require automation and training that is not practical in a commercial setting.

Startle response

Experiment 1

There were no significant effects of treatment or startle number on the magnitude of the startle score (

Table 10). There were significant effects of posture on the magnitude of the startle response during late lactation ($p = 0.005$), and significant interactions between posture x treatment at pre-farrowing ($p < 0.001$) and between posture x replicate during late lactation ($p = 0.023$). The significant posture x treatment interaction during pre-farrowing explains the significant treatment effect presented in

Table 10.

Due to the very large number of zeroes in the startle score for the pre-farrowing startle test, these results must be treated with caution. When the startle score has been analysed using other tests (such as binary analyses and Mann-Whitney U tests), there were no significant effects of treatment.

Table 10
The median startle score for sows in each treatment on each test day in Experiment 1. Note there are three startle stimuli (Startle No. 1-3) during each test.

Day	Startle No.	Lucerne	Control	P-value
Late Gestation	1	0	0	0.00*
(Day -3)	2	0	0	
	3	0	0	
Early lactation	1	1	0.5	0.14
(Day +4)	2	2.5	1	
	3	3	1	
Late lactation	1	2	3.5	0.16
(Day +12)	2	2	3	
	3	1.5	1.5	

*Significant due to an interaction effect between posture and enrichment

The correlations between the time budgets of the sows during the 10-min startle test and the magnitude of the startle response are presented in
Table 11. Sows that were engaged in active behaviours during the startle test displayed a higher magnitude startle and sows that were engaged in passive behaviours displayed a lower magnitude startle.

Table 11
Spearman's rank correlation between startle scores and time budgets (%)

Test day	Behaviour	Startle #	r	p-value
Day -3	Standing	1	0.34	0.041
	Inactive	1	-0.33	0.053
	At feeder	1	0.53	0.001
Day +4	Sitting	2	0.29	0.046
	Passive with piglets	2	-0.33	0.023
	Suckling	2	-0.30	0.037
	Inactive	1	0.34	0.019
	Inactive	2	0.42	0.003
Day +12	Drinking	1	0.33	0.024
	Interacting with hay	2	0.30	0.037
	Sniffing	2	0.28	0.058

Due to the large number of zeroes in the time budget data, only the time spent Inactive was analysed, as this was a common behaviour to most sows. The amount of time spent inactive during the startle test decreased from pre-farrowing to late lactation ($p < 0.001$), but there was no significant effect of enrichment treatment on this behaviour.

The startle response of the piglets was also recorded for two replicates, and a significant effect of treatment was found for the startle test during late lactation Day +12 (Table 12). Piglets in the lucerne treatment showed a higher magnitude startle than piglets in the Control treatment for the first startle of the test (Startle 1,p = 0.04) and the second startle (Startle 2,p = 0.02). Piglet startle scores during late lactation (Day +12) were positively correlated with the startle score displayed by the sow for Startle 1 (r = 0.28, p < 0.001) and Startle 2 (r = 0.19, p = 0.01).

Table 12
The median startle score for piglets in each treatment on each test day in Experiment 1. Note there are three startle stimuli (Startles 1-3) during each test.

Day	Startle No.	Lucerne	Control	P-value
Early lactation	1	0	0	0.26
(Day +4)	2	0	0	1.00
	3	0	0	0.12
Late lactation	1	2*	2*	**0.04**
(Day +12)	2	2	1	**0.02**
	3	0	0.5	0.66

*The median for both treatments is 2, but the means indicate that the Lucerne treatment showed a greater startle magnitude (Lucerne = 1.95 vs Control = 1.56)

Interpretation
The magnitude of the startle response displayed by the sows was not affected by treatment, suggesting that either the provision of lucerne did not alter the affective state of the sows at the time of the startle test, or that the startle test was not adequate for measuring sow affective state. The successful use of the startle test to detect treatment effects in the piglets indicates that is a suitable test of affective state in pigs. Combined with the lack of treatment effects found for the other behavioural tests (anticipatory and cognitive bias) in Experiment 1, this result suggests that the affective state of the sows at the time of the startle test was unaltered by the provision of lucerne.

In comparison, piglets in the lucerne treatment displayed a higher startle response than piglets in the control treatment. This result is supported by the work of Statham et al. (2015a), who reported an increase in the startle response of pigs housed in enriched housing conditions when compared to pigs in barren housing conditions. The increased startle magnitude in these instances is puzzling, as it was hypothesised that enrichment would lead to a reduction in the startle response by improving the affective state of the pigs. The validity of the startle response as a measure of affective state is well documented (Lang *et al.* 1990; Grillon and Baas 2003), and pharmacological manipulation of affective state in pigs have confirmed the expected changes in startle response (Statham *et al.* 2011). An explanation for the unexpected response of the piglets and lack of response from the sows may lie in the arousal and activity levels of these animals. Providing enrichment can lead to a higher state of emotional arousal in pigs (Beattie *et al.* 2000), and in the current study sows that were more active during the startle test showed a greater startle magnitude. This result is supported by the work of (Statham *et al.* 2015b), who found that pigs displayed a greater startle magnitude when they were standing compared to when they were sitting or lying. This result emphasises the importance of ensuring the sows are up and alert prior to playing the acoustic startle.

In terms of evaluating the startle test, the acoustic startle stimulus successfully elicited a startle response in confined sows housed under semi-commercial conditions, and was able to detect treatment differences in the piglets. A recent study on commercial farms was successfully able to relate the startle magnitude to aspects of pig welfare, with pigs showing a lower startle response when housed on straw bedding (positive affect), and a higher startle response when they were dirty and fearful of humans (negative affect) (Statham *et al.* 2018). While the treatments used in the current experiment did not alter the startle response of sows, this study does demonstrate that the startle test can be easily administered to confined sows under semi-commercial conditions, and the startle test should be further investigated as an on-farm measure of affective state.

Cognitive bias

Experiment 1

Learning results

During training, sows were rewarded (sugar cube) for touching their snout on the positive visual target (a silver rectangle) presented on a plastic pipe held over their feeder. Of the 24 sows tested over two farrowing batches, 20 were highly motivated to eat sugar cubes and learnt the task. After one single training session, sows were averaging 85% accuracy on the task. After the second session of training, individual training data showed statistically significantly different responses for each sow to the two trained locations (fishers exact tests; all $p < 0.05$). This means that sows learnt the task in ~4 min 20 s (average training time for one session), and after two training sessions (total of <10 min) sows progressed to testing.

Testing results

Of these 20 sows, 16 completed the two rounds of testing. Three did not perform the test day one of lactation, but performed the task in late lactation, and one performed all of the tests but was not in pig. Sows touched the positive cue 98% of the time and the average response time was 0.4s (SEM±0.04s; Figure 5); negative cue: 11% touched, average 3.8±0.04s; ambiguous cue: 55% touched, average 2.6±0.13s. This differentiation between cues is the critical component for a cognitive bias task, showing that the animal has learnt the difference between the two reference cues and judged the ambiguous cue differently.

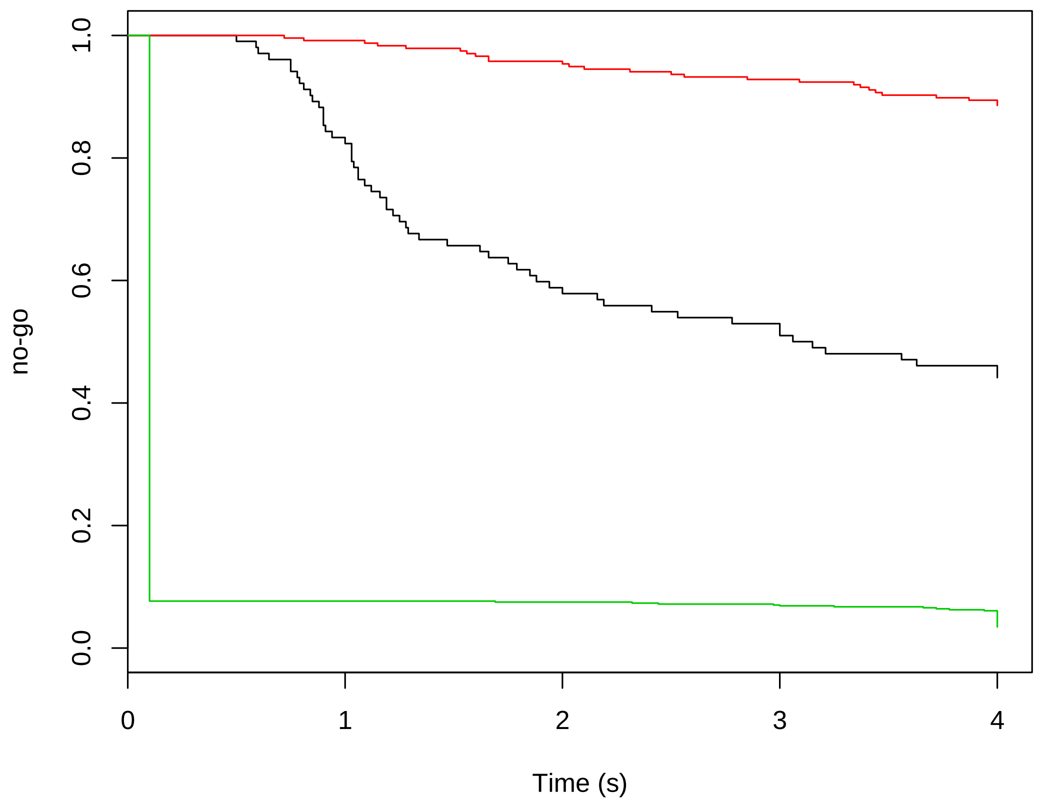

Figure 5
Kaplan-Meier curves for the three cues: green line, positive cue; black line, ambiguous cue; red line, negative cue. Every time a sow touches the cue, the probability on the Y axis drops, and the time the cue was touched is represented on the X axis.

There was a significant cue × time interaction (p<0.001) with sows being more likely to touch the positive cue in late lactation (early: 94% touched, average 0.6±0.07s SEM; late: 99%, 1.8±0.03s). This could reflect either more time to learn the task and/or increased appetite after farrowing. There was no influence of treatment (p = 0.41) on the results

Interpretation
This cognitive bias method failed to detect any treatment differences in affective state. As the other two behavioural tests used in Experiment 1 (anticipatory and startle test) had similar findings, it may be that the treatment was not sufficiently different enough to the control situation to generate a change in affective state. A previous study successfully generated more optimistic cognitive biases in pigs following enrichment use (Douglas *et al.* 2012), but this study was conducted with loose-housed gilts and enrichment was provided over five weeks during rearing, which is likely to explain the different result to the current study

As for the cognitive bias test alone, this methodology is a novel one that could be used for animals with restricted/slow movement; in confinement; when social separation is undesirable; or when ex situ testing is inappropriate (e.g. zoo settings). This method also allowed the animal to be exposed to treatments during testing and is quick to train, making it practical in a diverse set of research circumstances. For example, previous tests of cognitive bias require animals to move out of their home pens (defeating the purpose of testing cognitive biases for sows in farrowing crates), and take week(s) to learn (Asher *et al.* 2016).

Plasma cortisol

Experiment 1

The concentration of plasma cortisol response to feed delivery was significantly greater for the sows that received lucerne compared to sows that did not receive lucerne ($p<0.05$). This effect was only seen after the introduction of the feed cart (Figure 6). Therefore, the provision of lucerne altered the cortisol response of the animals to the feeding event.

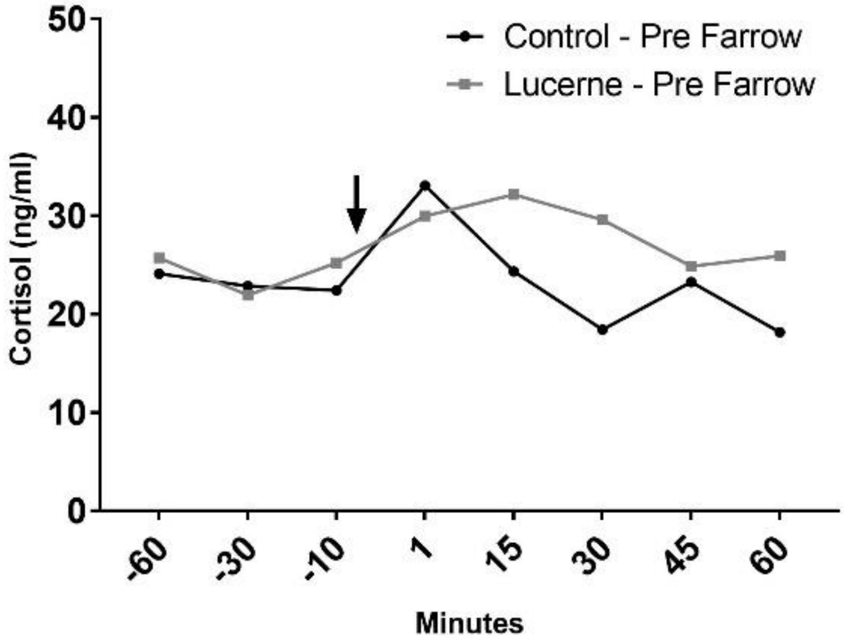

Figure 6

The mean plasma concentration of cortisol (ng/ml) for sows for 60 min prior to and 60 min after the introduction of a feed cart. Arrow indicates the introduction of the feed cart. The sample size is Lucerne (n = 11) and Control (n = 9).

Interpretation

The cortisol response of pigs to enrichment reported in the literature is variable. For example, compared to barren environments, providing enrichment to pigs can cause an increase in cortisol (de Jong *et al.* 2000), a decrease in cortisol (van der Staay *et al.* 2017), or no difference in cortisol (Cornale *et al.* 2015b; Backus and McGlone 2018).

Beattie et al. (2000) found that pigs housed in an enriched environment had a higher cortisol and behavioural response to a novel object test, and to slaughter, than pigs housed in a barren environment, indicating a higher level of arousal in the enriched pigs. These results support the cortisol relationship reported above, as enrichment increased the physiological response to feeding. However, there was no concurrent change in the anticipatory response to feeding in Experiment 1.

In conclusion, it is difficult to attribute this cortisol response to a state of positive or negative welfare. The relationship between cortisol and environmental enrichment in the literature is variable, but indicates that enrichment may increase arousal. However, in the absence of a concurrent treatment effect on anticipatory behaviour, it is difficult to put this cortisol response in context.

Measures of natural behaviour

Nesting behaviour

Experiment 1

Of the 35 focal sows that received the lucerne treatment, 30 interacted with it during the observed nesting period (85%). For sows that interacted with the lucerne, the median number of interactions was 4 (out of 73 observations), the maximum recorded was 12 and the mean was 4.3, representing 6% of the sow's total time budget.

When the vacuum nesting behaviour of the sows was compared, there was a tendency for sows in the Control group to spend more time performing vacuum nesting behaviours than the enriched sows ($p = 0.08$;Table 13). When enrichment use was combined with vacuum nesting behaviours, there was a significant effect of treatment on the total time spent nesting ($p = 0.009$) with sows with lucerne spending significantly more time performing nesting behaviours than Control sows.

Only one other treatment effect was observed, with control sows spending significantly more time sham chewing than sows in the lucerne treatment ($p = 0.01$, Table 13).

There were significant effects of parity on several behaviours that are suggestive of frustration in multiparous sows: activity (not nesting), bar biting and sham chewing. Parity 1 sows were significantly more active prior to farrowing than Parity 2 sows ($p = 0.021$) and showed significantly more sham chewing ($p < 0.001$) and bar biting ($p = 0.002$) than Parity 0 sows. Parity 2 sows also showed more bar biting than Parity 0 sows ($p = 0.002$).

The incidence of pain related behaviours was low (average 1.4%) and was not affected by treatment or parity. Farrowing duration and the number of stillborn piglets were not significantly ($p > 0.05$) correlated with the performance of nesting behaviours or the amount of activity shown during the nesting period.

Table 13
Treatment differences in proportions of nesting behaviours (% mean) displayed for 18 hrs prior to farrowing (Transformed mean ± SEM)

	Lucerne Mean %	**Control** Mean %	p-value
Vacuum nesting behaviours	9.0	11.1	0.08
Vacuum nesting behaviours + lucerne use	14.8 (-1.75 ± 0.08)	11.1 (-2.08 ± 0.10)	**0.0009**
Lateral lying	52.0	53.0	0.67
Inactive	80.7	83.1	0.11
Pain behaviours	0.02	0.02	0.69
Bar biting	2.19	2.61	0.28
Sham chewing	1.0 (-0.95 ± 0.38)	1.9 (-0.69 ± 0.37)	**0.01**

Table 14
Parity differences in proportions of nesting behaviours (% mean) displayed for 18 hrs prior to farrowing (Transformed mean ± SEM)

	Parity 0	Parity 1	Parity 2	P-value
Nesting behaviours	9.0	11.2	8.0	0.39
Nesting behaviours + lucerne use	13.6	13.2	10.1	0.30
Lateral lying	53.4	50.3	54.6	0.52
Inactive	82.5^{ab} (1.55 ± 0.1)	79.7^{a} (1.37 ± 0.1)	86.5^{b} (1.86 ± 0.2)	**0.02**
Pain behaviours	0.02	0.02	0.02	0.69
Bar biting	1.3^{a} (-0.06 ± 0.2)	3.4^{b} (0.84 ± 0.1)	3.9^{b} (1.01 ± 0.2)	**0.002**
Sham chewing	0.4^{a} (-0.14 ± 0.3)	3.1^{b} (0.77 ± 0.1)	0.2^{a} (-2.09 ± 1.0)	**P<0.001**

Experiment 2
Of the 28 focal sows that received lucerne, 10 were recorded using it (36%) and 18 focal sows from the straw treatment were recorded using straw (62%). Six out of 18 sows were recorded using the rope (33%), but only one of these sows used the rope more than once. While use as a proportion of time budget was low, sows with straw were observed using it more often than the lucerne treatment (p = 0.018). Rope use was so low it was not included in this analysis.

There was no significant effect of treatment on nesting behaviours or activity levels during the nesting period (Table 15). There were significant treatment effects on the amount of pain behaviours (p = 0.03) and sham chewing (p < 0.001) observed, with the Control treatment showing the least pain and sham chewing, and the Rope treatment showing the most pain and sham chewing. As noted in the table however, the incidents were very low and so further interpretation of the results is limited.

There was a significant parity effect on sham chewing behaviour ($p < 0.001$), with gilts showing less sham chewing than older sows (Table 16). There were no other effects of parity on sow behaviour during the nesting period. There was no significant correlation between nesting behaviours and farrowing duration or stillbirths however a larger sample size than n = 126 would be required to examine this in more detail.

Table 15

Treatment differences in proportions of nesting behaviours (% mean) displayed for 18 hrs prior to farrowing (Transformed mean ± SEM).

	Lucerne	Straw	Rope	Control	p-value[3]
Enrichment interaction	1.7 (-4.08 ± 0.3)	3.7 (-3.26 ± 0.2)	0.01[4]	-	**0.018**
Nesting behaviours	11.6	12.7	13.5	13.6	0.81
Nesting behaviours + enrichment use	13.2	16.4	14.9	13.7	0.60
Lateral lying	39.6	38.3	35.9	40.6	0.88
Inactive	0.83	0.79	0.78	0.77	0.20
Pain behaviours	0.9 (-4.74 ± 0.3)	1.2 (-4.39 ± 0.2)	1.4 (-4.28 ±0.3)	0.2 (-6.23 ± 0.8)	**0.03**
Bar biting	4.3	5.0	4.0	5.7	0.09
Sham chewing	2.0^a (-0.67 ± 0.3)	1.4^a (-1.06 ± 0.4)	2.2^a (-0.3 ± 0.4)	0.0^b (-17.6 ± 819.0)	**P<0.001**

[3] **Pain behaviours and sham chewing were statistically significant; low numbers of events give extremely large SEMs and prevent post-hoc analyses from running and making meaningful conclusions; applies to**

Table 16 as well

[4] Rope was excluded from the enrichment use analysis due to a very low incidence of use

Table 16
Parity differences in proportions of nesting behaviours (% mean) displayed for 18 hrs prior to farrowing (Transformed mean ± SEM)

	Gilts	Multiparous	p-value
Enrichment interaction	1.3	2.3	0.22
Nesting behaviours	12.4	12.5	0.93
Nesting behaviours + enrichment use	13.7	14.8	0.60
Lateral lying	38	39	0.21
Inactive	82.0	78.2	0.11
Pain behaviours	0.7	1.0	0.51
Bar biting	3.6	5.0	0.11
Sham chewing	0.2 (-5.83 ± 204.8)	1.8 (-4.01 ± 204.8)	**P<0.001**

Interpretation
The results of Experiment 1 indicate that when provided with lucerne, sows performed more nest building behaviour than those in a barren environment. Despite their restricted movement, sows used the enrichment provided to them during this nesting period. This agrees with the literature, which suggests that once the sow is hormonally motivated to begin performing nesting behaviour, the availability of appropriate nesting material is influential in releasing the entire repertoire of natural nesting behaviour (Arey *et al.* 1991; Jensen 1993).

Despite evidence of sows using the various enrichments provided in Experiment 2, there was limited use of enrichment during the pre-farrowing nest building stage. This observation combined the large amounts of missing data due to missing video files may explain this lack of a treatment effect for Experiment 2.

The frequency of pain behaviours observed during the nesting period in Experiment 2 were significantly lower for the Control group compared to all other enrichment treatments. This is an unexpected result, as previous research has found that environmental enrichment can reduce the incidence of pain-related behaviours in rats (Tall 2009; Gabriel *et al.* 2010), although a similar effect could not be replicated for piglets undergoing castration and tail docking procedures (Backus and McGlone 2018). It is possible that the enrichment treatments were stimulating an increased concentration of endogenous oxytocin in the enriched sows by encouraging nesting behaviours (Yun *et al.* 2013), leading to stronger uterine contractions and increased pain. However, plasma oxytocin concentration is negatively associated with farrowing duration (Oliviero *et al.* 2008) and the time taken to expel the placenta (Björkman *et al.* 2017), and there were no treatment differences found for either of these variables. This suggests that plasma oxytocin concentration is unlikely to explain the lower incidence of pain behaviours in the Control sows, although this hormone was not measured as part of this study. An explanation for the very low rate of pain behaviour in the Control sows is not forthcoming, although this result does match the very low rate of sham chewing seen in the Control sows (discussed below).

The performance of oral stereotypies such as bar biting and sham chewing were investigated, as they have been previously reported in sows housed in barren environment (Stolba and Wood-Gush 1984; Appleby and Lawrence 1987). Sham chewing was performed at a higher rate in the Control treatment than the Lucerne treatment for Experiment 1, but at a lower rate in the Control treatment than the enriched treatments for Experiment 2. The definition and observation methods for this behaviour was the same for both experiments. Bar-biting was not affected by treatment in either experiment. The origin and mechanisms of stereotypic behaviour in animals remains unclear, however, it has been linked to frustration due to inability to perform natural behaviour such as nesting or foraging (Jensen 1988). Sham-chewing in pigs appears to be related to unsatisfied feeding or foraging motivations (D'Eath *et al.* 2009), as its performance in pigs increases during feed restriction and decreases when nutritious fibrous enrichments are provided (O'Connell 2007; Hansen *et al.* 2017b). It is possible that the Lucerne treatment in Experiment 1 helped to alleviate hunger in these sows, and the higher rate of sham chewing seen in the Control sows reflected a general increase in this stereotypy due to hunger, rather than specifically related to frustrated nesting behaviour. This explanation does not agree with the results of Experiment 2, where the Control sows showed less sham chewing than the enriched sows. There is no obvious reason for this disparity, but the lack of a complete data set combined with the very low incidence of sham chewing behaviour across all treatments for Experiment 2 means that caution should be used when drawing conclusions about the treatment effects on this behaviour, and for pain behaviours, for Experiment 2 (e.g SEM for this effect in Table 14).

A significant effect of parity occurred for nesting behaviour in both experiments. Gilts showed less evidence of frustration than the multiparous sows, indicated by less sham chewing, less bar biting, and more time spent inactive during the nesting period for Experiment 1, and less sham chewing for Experiment 2. This result is supported by Rosvold et al. (2018), who also reported less stereotypies in periparturient gilts, and more time spent inactive for gilts compared to multiparous sows during the nesting period (Hansen *et al.* 2017a; Rosvold *et al.* 2018). One explanation for this effect may be the increased concentration of prepartum prolactin seen in multiparous sows compared to gilts (Yun *et al.* 2014). A lower hormonal concentration in gilts may result in a lower motivation for nest building behaviour.

The performance of nesting behaviour does not appear to influence farrowing outcomes.

Enrichment use

Experiment 1

Sows that received the Lucerne treatment showed significant effects of test day on the duration of Lucerne use ($p = 0.050$; Table 17), and the number of times they interacted with the Lucerne ($p = 0.02$). These sows interacted with the Lucerne in fewer bouts but for longer durations during the late lactation period.

Enrichment use varied with the time of the observations. All sows were less active during the late lactation period ($p < 0.001$ Table 17). Sows showed the highest amount of oral manipulation during the pre-farrowing period ($p < 0.001$).

A significant test day x treatment interaction ($p = 0.0002$; Table 18) occurred for the total amount of active (non-enrichment) behaviours that the sows displayed following Lucerne delivery. Sows provided with Lucerne differed in their activity between early and late lactation but were comparable to all other groups. There was a significant test day x treatment interaction ($p = 0.003$; Table 19) on feeding behaviour as well. Sows with access to Lucerne displayed more feeding behaviour than at other times and both treatments showed more feeding during late lactation than pre-farrowing. Other than this, there were no effects of treatment (Table 20).

Table 17
Test time differences in behavioural time budgets following the provision of Lucerne (Transformed mean ± SEM)

	Pre-farrowing	Early lactation	Late lactation	p-value
Frequency of Lucerne use (count)	9.8[a] (2.2 ± 0.16)	12.8[b] (2.4 ± 0.16)	9.2[a] (2.1 ± 0.16)	**0.02**
Duration of Lucerne use (s)	617[a] (617 ± 103.0)	605 [a] (605 ± 103.0)	859[b] (859 ± 103.0)	**0.05**
Oral manipulation (count)	4.5[a] (0.5 ± 0.4)	1.2[b] (-0.4 ± 0.4)	1.8[b] (-0.8 ± 0.4)	**<0.001**
Inactive (%)	56.9 (4 ± 0.04)[a]	55.0 (4 ± 0.04)[a]	43.6 (3.7 ± 0.05)[b]	**<0.001**

Table 18
Active behaviours for day × treatment interaction (Transformed mean ± SEM)

	Control	Lucerne
Pre-farrowing	7.7 (1.9 ± 0.21)[a,b]	5.6 (1.5 ± 0.22) [a,b]
Early lactation	8.3 (2 ± 0.21) [a,b]	3.9 (1.2 ± 0.23)[a]
Late lactation	6.3 (1.7 ± 0.21) [a,b]	8.2 (1.9 ± 0.21)[b]

Table 19
Feeding behaviours (counts) for day × treatment interaction (Transformed mean ± SEM)

	Control	Lucerne
Pre-farrowing	1.3 (-0.7 ± 0.)[a,b]	0.25 (-2.7 ± 0.86) [a]
Early lactation	0.16 (-2.8 ± 0.92) [a,b]	0.91 (-1.4 ± 0.71)[a]
Late lactation	9.25 (1.2 ± 0.60)[c]	3.4 (-0.1 ± 0.66) [b,c]

Table 20
Treatment differences in behavioural time budgets following the provision of Lucerne (Transformed mean ± SEM)

	Lucerne	Control	p-value
Oral manipulation (count)	2.3	2.6	0.45
Inactive	39.9 (3.7 0.05)	63.8 (4.1 0.05)	<0.001

Experiment 2
The frequency and duration of enrichment use following enrichment delivery on Day +7 post-farrowing is presented in Table 21. Please note that the mean duration of rope use was not representative of all sows; this mean was given by two sows using the rope for 345s and 645s each. The difference in the number of sows using the enrichment was statistically significant (p = 0.04), as was duration of use (p = 0.03).

Table 21
Treatment differences in the frequency and duration of enrichment use on Day+7 post-farrowing

Enrichment	Mean frequency	Mean percentage	Mean duration (s)
Lucerne	19	24%	378
Straw	26	32%	448
Rope	0.7	<1%	99
p - value	**0.04**	NA	**0.03**

Due to the low occurrence of enrichment use in the rope group, the treatments were grouped into Control/Rope (Control and Rope) and Lucerne/Straw (Lucerne and Straw). The effect of parity was also not tested as data from only 3 gilts receiving enrichment was collected.

Sows in the Control/Rope treatment were more likely to feed following enrichment delivery than sows provided with enrichment ($p = 0.005$ Table 22). Sows in the Lucerne/Straw treatment showed significantly ($p < 0.001$) less inactive behaviour than the Control/Rope treatments following enrichment delivery (Lucerne/Straw 51% vs Control/Rope 65% inactive).

Table 22
Treatment differences in behavioural time budgets following the provision of enrichment (Transformed mean ± SEM)

	Control/Rope	Lucerne/Straw	P-value
Feeding (number of animals)	15 (37%)	0 (0%)	**0.005**
Inactive (% time)	55 (4.0 ± 0.02)	43.6 (3.7 ± 0.04)	**<0.001**

Interpretation
Sows receiving lucerne in Experiment 1 (Days -2, +5, +13 post-farrowing) and lucerne or straw in Experiment 2 (Day +7 post-farrowing) used the enrichment when it was freshly provided. These results indicate the lucerne/straw enrichments have value for the sows beyond the nesting period alone, because sows continued to use the enrichments during lactation. In these two experiments, enrichment use continued during *ad libitum* feeding, suggesting that the interest in the enrichment was not solely nesting or nutritionally dependent.

Previous studies have shown that the addition of fibre is beneficial for sows both reducing constipation in pigs (Oliviero *et al.* 2010) and providing a greater and prolonged intake of energy (Theil 2015). There is limited information in the literature around use of enrichments in farrowing and lactating sows. These current experiments suggest that the value may extend beyond nutritional.

The rope enrichment was only used more than once by two sows during the observation period. It is difficult to compare rope to the other two treatments however, as it is both continuously available after farrowing and provides no nutritional value, so represents a different type of enrichment. One third of sows in the Rope treatment were observed using the rope, but usage rates were very low (single events observed), and Rope appears to offer limited value as an enrichment item for confined sows. This is supported by (Cornale *et al.* 2015a) who found that providing point source enrichment object, such as a wooden block did not have any beneficial effect on pigs.

Biological functioning

Reproduction and subsequent reproductive outcomes

Experiment 1

The number of piglets born dead in the farrowing immediately following enrichment treatment was reduced by 0.3 piglets in the lucerne treatment (p = 0.027; Table 23). There were no other significant treatment differences for any of the reproductive measures recorded during this experiment.

A significant parity × treatment interaction occurred for the weaning to oestrus interval (p = 0.034). Sows displaying oestrus within two weeks of weaning were bred, whilst the remainder were not bred that batch. A significant parity × treatment interaction occurred for the percentage of sows mated within the batching requirements (p = 0.030). More gilts from the Lucerne treatment were mated immediately following weaning (81%) than Controls (60%), but this relationship was reversed in multiparous sows (Lucerne 67% vs Control 90%). No other treatment effects were seen on subsequent reproduction data (Table 24).

Table 23
Sow production variables for Experiment 1

	Control (n=31)		Lucerne (n = 33)		
Farrowing measure	Mean	SEM	Mean	SEM	p-value
Log mean piglet interval	1.18 (15.1)	0.05	1.24 (17.4)	0.05	0.364
Log total farrowing duration (min)	2.22 (166.0)	0.05	2.31 (204.2)	0.04	0.174
Total piglets born	10.9	0.5	11	0.5	0.834
Piglets born alive	10.4	0.5	10.9	0.5	0.45
Piglets born dead	0.4	0.1	0.1	0.1	**0.027**
Piglet deaths	0.8	0.2	0.6	0.1	0.328
Piglets weaned	10.5	0.3	10.6	0.3	0.865

Table 24
Sow subsequent production variables for Experiment 1

	Control		Lucerne		
Subsequent reproduction measure	Mean	SEM	Mean	SEM	p-value
Weaning to oestrus interval (days)	13.2	1.8	11.7	1.9	0.58
Mated next batch (%)	79	(54-84)	74	(58-86)	0.363
Pregnancy rate (%)	79	(61-90)	67	(50-80)	0.111
Farrowing rate (%)	69	(51-82)	62	(45-76)	0.562
Total piglets born	12.5	0.6	12.3	0.6	0.812
Piglets born alive	11.8	0.6	11.5	0.6	0.729
Piglets born dead	0.6	0.2	0.7	0.2	0.631

Experiment 2
There was a tendency (p=0.061) for less stillborn piglets in all of the enriched treatments (Table 25), which supports the findings from experiment 1. The provision of enrichment did not significantly affect (p>0.05) sow body weight of P2 backfat levels throughout lactation or piglet growth rate (Table 26).

There was no significant (p>0.05) interaction between replicate or sow parity and treatment in any of the factors measured during the study or in the subsequent reproduction (Table 27, Table 28).

There was no significant difference (p>0.05) in number of sow deaths and removals due to poor body condition, agalactia and lameness during the experiment (Table 25). There was no significant difference (p>0.05) in the days to farrowing once the sows has been put into the farrowing pen, indicating that the provision of enrichment materials prior to farrowing did not promote farrowing.

There was no significant difference (p>0.05) in the total number of born piglets or mummified piglets.

Table 25
Sow production variables for Experiment 2

	Control	Cotton rope	Straw pre-farrow	Straw whole lactation	Lucerne pre-farrow	Lucerne whole lactation	SEM	p-value
Number of sows	123	120	120	119	122	120	-	-
Sow deaths and removals	7	2	1	5	2	1	-	0.175
Days to farrow from entry to shed	7.7	7.8	8.1	8.2	7.9	8.4	0.15	0.274
Av. no. total born	13.3	12.9	13.2		13.7		0.12	0.485
Av. no. piglets born alive[1]*	11.8[b]	12.1[ab]	12.1[a]		11.8[b]		0.11	0.058
Av. no. still born piglets[1]*	1.0[ab]	0.8[ab]	0.7[a]		0.9[b]		0.04	0.053
Av. no. mummies[1]*	0.4	0.2	0.3		0.3		0.02	0.572
Av. no. piglets weaned	9.8	9.5	9.9	9.2	9.6	9.8	0.08	0.757
Live born mortality (%)*	13.3	15.5	13.9	16.9	13.1	14.9	0.56	0.457

[1]Straw/lucerne pre/farrow and straw/lucerne whole lactation treatments were pooled since treatments were the same up to the post-farrowing
*Number of piglets total born used as covariate in analysis. Liveborn mortality figures are calculated for each litter (taking into account fostering adjustment)
**Piglet birth weight used as covariate in analysis.
[ab] Within rows values with different superscripts are significantly different ($P<0.05$).

Table 26
Piglet performance variables from Experiment 2

	Control	Cotton rope	Straw pre-farrow	Straw whole lactation	Lucerne pre-farrow	Lucerne whole lactation	SEM	p-value
Piglet growth								
Av. piglet birth weight (kg)[1]	1.5	1.5	1.5	1.4	1.5	1.5	0.009	0.720
Av. piglet weaning weight (kg)**	6.3	6.2	6.1	6.3	6.1	6.1	0.04	0.343
Sow performance								
Sow weight at entry (kg)	268.0	268.8	267.8	266.6	270.1	261.5	1.74	0.505
Sow P2 entry (mm)	24.9	25.0	24.3	23.9	25.4	24.8	0.22	0.120
Sow weight at weaning (kg)	247.5	248.6	247.8	251.7	251.5	244.6	1.73	0.513
Sow P2 weaning (mm)	22.6	22.6	22.7	23.0	23.2	23.2	0.19	0.280
Sow ADFI (kg)	7.5	7.4	7.4	7.6	7.5	7.5	0.03	0.111

[1]Straw/lucerne pre/farrow and straw/lucerne whole lactation treatments were pooled since treatments were the same up to the post-farrowing*Number of piglets total born used as covariate in analysis. Liveborn mortality figures are calculated for each litter (taking into account fostering adjustment)
**Piglet birth weight used as covariate in analysis.

Table 27
Sow subsequent production variables for Experiment 2

	Control	Cotton rope	Straw pre-farrow	Straw whole lactation	Lucerne pre-farrow	Lucerne whole lactation	SEM	p- value
No. sows mated post-weaning (%)	91	88	91	91	92	91	-	0.90
Farrowing rate (%)	84.0	91.1	93.4	81.4	88.9	88.8	-	0.081
Wean to oestrus interval (d)	6.0	5.3	5.8	5.8	5.9	6.1	0.22	0.943
Av. no. piglets born alive*	12.4	12.4	12.8	13.4	12.4	12.0	0.12	0.350
Av. no. still born piglets*	0.8	0.8	1.0	0.8	0.9	1.0	0.05	0.544
Av.no. mummies*	0.4	0.5	0.4	0.2	0.3	0.3	0.02	0.711

[1]Straw/lucerne pre/farrow and straw/lucerne whole lactation treatments were pooled since treatments were the same up to the post-farrowing
*Number of piglets born used as covariate in analysis. Liveborn mortality figures are calculated for each litter (taking into account fostering adjustment)
**Piglet birth weight used as covariate in analysis.

Table 28
Sow farrowing behaviour

	Control	Cotton rope	Straw[1]	Lucerne	p- value
Av. expulsion (min)	0.08	0.22	0.06	0.10	0.917
Av. interval between piglets (min)	23.1	20.0	20.4	19.5	0.836
Av. interval between piglets (inc placenta) (min)	36.1	29.1	24.2	26.1	0.069
Farrow duration (no placenta) (min)	244.6	195.4	231.7	223.3	0.168
Farrow duration (inc placenta)	348.9	294.0	295.5	322.1	0.706
Min piglet interval (min)	1.7	2.0	0.9	2.1	0.229
Max piglet interval (min)	98.2	62.8	78.2	71.3	0.153
Time to pass placenta (min)	107.1	153.129	81.0	94.0	0.290

[1]Straw/lucerne pre/farrow and straw/lucerne whole lactation treatments were pooled since treatments were the same up to the post-farrowing
Littersize included as covariate

Interpretation

Providing lucerne in Experiment 1 did not significantly change farrowing duration or piglet interval,) but did significantly reduce the total number of piglets born dead compared to the controls. Data from the subsequent parity of enriched sows showed that once the provision of enrichment was stopped, the total number of piglets born dead returned to similar levels to the control sows. This suggests that it was the immediate presence of enrichment prior to and during farrowing that had a significant impact on the stillbirth rate of piglets in Experiment 1.

In the literature, the number of stillborn piglets is often reduced with a shorter piglet interval and total farrowing time (Oliviero *et al.* 2009), however, the enrichment did not significantly impact on farrowing behaviour in both experiments. There was a slight trend (P = 0.07) for a longer piglet interval (including placenta) in the Control group for Experiment 2, however it is speculated that the provision of enrichment renders protection to piglets through some other pathway. It is possible that the nutritional benefits of the straw and lucerne helped reduce the number of stillborn piglets by increasing piglet size if fed for a longer period of time before farrowing, as low birthweight is a high risk factor for stillbirth in piglets (Vanderhaeghe *et al.* 2013). However, the lack of a treatment effect on birthweights for Experiment 2 does not support this theory, given enrichment was only provided two days before expected farrowing, limiting the time that piglet weight could be impacted nutritionally and it is possible some other mechanism is responsible.

Of interest is a weak but significant correlation between the amount of stereotypic behaviour (sham chewing) displayed by the sows and their rate of stillbirth (r = 0.3, p = 0.02). There is evidence in the literature that the sows that perform more stereotypic behaviour have less piglets that are born live (Borell and von Hurnik 1990). Similar trends (P=0.053) were seen in Experiment 2 in that the sows provided with enrichment tended to have more live born piglets and low piglets born dead. Further research needs to be conducted looking at markers of birthing trauma such as blood lactate, meconium staining etc to further investigate the protective effect of enrichment on the number of stillborn piglets.

In Experiment 2, the provision of both straw and lucerne did not negatively impact on sow liveweight and backfat and did not negatively impact feed consumption during lactation. This is of importance, as any enrichments provided during the farrowing and lactation period must not interfere with feed consumption in the sows.

Summary statement

In summary, providing lucerne to the sows in Experiment 1 resulted in a significant decrease in piglet stillbirths, an increased sow cortisol response to feeding, an increase in the total amount of nesting behaviour performed (vacuum nesting + enrichment use), and a decrease in the amount of sham chewing that occurred during the nesting period. The results of Experiment 2 found that providing lucerne or straw resulted in an increase in anticipatory behaviour shown by multiparous sows, and the Control group showed significantly less sham chewing and pain related behaviours than the enrichment treatments.

4. Application of Research

Potential benefits to cost of production

Providing enrichment to sows in farrowing crates promoted natural behaviours and improved biological functioning in sows. The provision of enrichment to sows also improves the survival of sucker pigs, with fewer stillborn piglets occurring in sows that received enrichment. These results are supported by a separate experiment completed in collaboration with but separately to this project (Pridgeon 2017). This related experiment also examined the provision of lucerne chaff enrichment to sows, and found a similar decrease in stillborn rate, and an improvement in piglet growth rate, for piglets in the lucerne treatment (See Appendix 2). Having a similar effect on the number of stillborn piglets repeated across three different sites with three different genetic lines and management systems provides increasing support for the value of enrichment prior to farrowing for sows in farrowing crates.

The cause of this reduction in the number of stillbirths remains somewhat unclear. In Experiment 1 there was no significant differences in farrowing time recorded, and in Experiment 2 there was a trend (average inter-piglet interval including placenta expulsion), and these results suggest that the reduced stillborn rate may be nutritional, not behavioural. Evidence in the literature suggests that decreased intra-partum death were associated with reduced farrowing duration for sows with access to lucerne or straw (Cronin et al. 1993; Peltoniemi et al. 2016).

In Experiment 1, sows received substantial amounts of lucerne (large biscuits) once per day until farrowing and every second day until weaning. Sows in Experiment 2 received a biscuit of straw or lucerne for two days prior to farrowing and then 0.25kg each day for the remainder of lactation. Sows in the separate experiment by Pridgeon et al (2017) received a large quantity of lucerne chaff (2kg daily of lucerne chaff pre-parturition then 0.25 kg per day for the entire lactation). The nutritional difference in volumes and form of enrichment provided in Experiment 2 vs. 1 and Pridgeon et al (2017) may explain why there was only a strong tendency for reduced stillborns in Experiment 2 compared to a significant difference in Experiments 1 and Pridgeon et al (2017). The rope treatment in Experiment 2 was designed to act as a manipulatable enrichment with no nutritional value to answer this question. The number of stillborn piglets were comparable between straw and rope treatments, but the recorded enrichment use of these two treatments was very different and it is speculated that the sows used the rope at other times outside video observation period Anecdotally, the ropes were often wet and chewed, suggesting that the sows were indeed manipulating them. The sparse sampling method used to assess enrichment use (15 min scans) may not have been sensitive enough to detect rope usage in Experiment 2. The reduction in stillbirth rate across all enrichment treatments suggest that the provision of enrichment, regardless of this type, is beneficial for farrowing sows.

Lucerne in Experiment 1 and both straw and lucerne in Experiment 2 were utilised whenever provided, demonstrating that it was of value to the sows. For sows in Experiment 1, they performed more nesting behaviours than the control animals, allowing them to fulfil their naturally motivated behaviours and display a greater behavioural repertoire than the control sows, which is a sign of improved welfare (Tuyttens 2005). Anecdotally, piglets in Experiment 1 were seen using the lucerne (exploration, playing, eating).

Beyond farrowing, enrichments continued to be used by sows in both studies, further indicating their benefit through increased and more diverse behaviour and feed consumption (Experiment 2). In Experiment 3, the study led by Plush (Pridgeon 2017), there was evidence of benefits for ongoing enrichments too, with sows that received lucerne throughout lactation also weaning healthier, heavier pigs:

Piglets born to lucerne sows had a lower incidence of intra-partum death (0.48 ± 0.127 vs. 0.92 ± 0.133, P = 0.031), higher colostrum intake (308.6 +/- 19.8 vs. vs. 231.4 ± 25.4, P = 0.014) and higher average weights for day 7 (2.39 ± 0.57 vs. 2.08 ± 0.077, P = 0.043), 14 (3.9 ± 0.123 vs. 3.3 ± 0.176, P = 0.05) and 21 (5.6 ± 0.1 vs. 4.7 ± 0.2, P = 0.001) than control piglets. (See Appendix 2)

The effects of enrichment were direct, with no differences seen in subsequent reproductive data although there was a tendency (P = 0.08) for an increased subsequent farrowing rate for sows that had received enrichment in Experiment 2. There were no negative impacts of enrichment on production outcomes. Enrichment did not negatively impact on piglet growth and survival through lactation (live born mortality), and it was not shown to reduce feed intake by increasing gut fill.

Looking at the significant reduction in stillbirths seen in Experiment 1, providing lucerne enrichment to sows would achieve an extra 30 piglets born alive per 100 sows farrowed.

While loose farrowing and lactation systems continue to be investigated, sow confinement continues to be scrutinised by the community. Providing enrichment to sows in farrowing crates may improve their welfare as the sows have positive interactions with the enrichment, it provides production benefits to the sow and her piglets, and may positively impact the societal perspectives of confined sows.

Ease of adoption by producers

Experiment 1 provided the greatest amount of enrichment on top of a slatted floor system and there were incidents of blocked drains as a result. Either the volume of lucerne or the way it is provided would need to be considered for commercial settings to minimise interference with the manure removal system. A rack to hold the enrichment may be a feasible option to provide a consistent supply for behavioural and nutritive benefits without high wastage and blocked drainage. Another potential option may be covering the front half of the farrowing crate with matting to reduce the amount of enrichment passing through the slats. Drainage issues were not reported in Experiment 2, which may be explained by the enrichment being provided in the trough at front which was deep enough the hold enrichment in place, and the smaller quantities and shorter duration of enrichment provision.

The labour required to deliver the enrichment should be considered. Providing the lucerne or straw was a manual task that was done daily. Rope was easy to secure and only needed to be done once, but it was not used very often by the sows, so the behavioural value at least may be limited, and it does not provide nutritive value.

The provision of lucerne in chaff form was beneficial in a separate, concurrent experiment (Pridgeon 2017). During the ten-week trial period, there were no incidences of blocked drains as result of lucerne provision in the farrowing crate due to the size of the lucerne chaff. However, the lucerne had the tendency to fall into the drain as the sows and piglets interacted with it. Sows may have been unable to engage in proper nest building behaviour with chaff. Investigation of their behavioural repertoire and how they used the chaff would be useful if we are to compare the breadth of benefits of this method of enrichment.

Impact of the research

There were three aims of this study:

1. To identify indicators of contentment in sows
2. To test the practicality of these measures in a large scale, production setting
3. To assess how the provision of enrichment affects sow contentment and performance in farrowing crates

This study tested three novel techniques to measure sow welfare: startle response and cognitive bias in confinement, and anticipatory behaviour in a commercial setting. There were no impacts of enrichment treatment for any of these novel measures, therefore there is no evidence to show that affective state at the time of testing changed with the treatment. We conclude that while the enrichments provided benefits to welfare as measured by natural behaviours and biological functioning, there were no signs of treatment influencing affective states. Measures of positive affective state are in their infancy, so it may well be that the measures we chose were not sensitive enough to detect change, or that the treatment was not meaningful enough to generate improvement in affective state. Repeating these tests while sows are actively nest building may reveal changes in affective state, as this is the period when sows are likely to place the most value on the enrichment. While either is possible, farrowing and the associated confinement and changed routine creates psychological stressors in sows, so enrichment alone may not be enough to counteract these stressors. Assessing the feasibility of these measures will give a good understanding of how they may be used to detect positive welfare in the future. Currently these tests are promising in their potential for development in welfare research in the commercial environment.

In the semi-controlled conditions (Experiment 1), the acoustic startle stimulus successfully elicited a startle response in confined sows housed under semi-commercial housing. Conducting a startle test in a commercial setting (Experiment 2) was more difficult because of the size and design of the building. The startle response has the potential to be useful as a measure of affective state in a production context but is in its infancy as a measure of affective state in all production species.

As discussed in the Outcomes section, cognitive bias has not been tested before in restricted environments, let alone in a commercial context. The method developed here is feasible for use in semi-commercial and commercial settings. The sows need training however, and while this method has shortened this compared to previously published work, it will only be feasible as an experimental measure on a small-scale.

Anticipatory behaviour was also assessed in the semi-controlled setting (Experiment 1) and at scale in a production setting (Experiment 2). This test successfully detected a treatment difference in the anticipatory behaviour shown by multiparous sows in Experiment 2. The method for testing anticipation was valid and simple to administer in a semi-controlled environment. There are two limitations however; the way the test is initiated, and way anticipation is measured. The test needs to be initiated indicating the impending arrival of a highly desirable resource. In this case, it was feed. As mentioned in the Outcomes section, this was difficult to control in the large sheds of a commercial environment. Behavioural changes are the best sign of anticipation (scored as counts in a defined period, or transitions/min in this study). This was measured though behavioural analysis of videos. While simple behaviours can be measured automatically with off the shelf products, behavioural changes for anticipation involve head and postural movements, so step counters/pedometers (also known as ICE tags) may not capture the full range of behaviours. The results from the current study show that anticipatory testing, as we have done it, is not practical in a commercial setting, however automation – in terms of both cue delivery and behavioural analysis – will increase the feasibility in the near future.

While the impact of enrichment on sow contentment, as assessed by affective state, was not proven, evidence of improved contentment through natural behaviour and biological functioning was clear. These results provide meaningful findings for sow welfare. Providing high fibre enrichment in any form (lucerne, lucerne chaff or straw) generated biological benefits. It remains unclear if all enrichments are of equal value from a natural behaviour perspective.

5. Conclusion

The provision of enrichment to sows promotes natural behaviours and improved biological functioning in sows. This led to the improved peri-partum survival of sucker pigs, with the number of piglets born alive being higher in the sows that received enrichment. The explanation for this result suggests the cause may be nutritional or may be related to farrowing behaviour.

When enrichment was provided beyond farrowing, sows continued to use it and it provided additional behavioural benefits, with no negative impacts on piglet growth, sow feed intake or on subsequent reproductive performance. Further evaluation of this would be useful so producers can implement the most effective solutions to generate similar welfare and production benefits to those seen across the experiments. This is important because the practicality, cost and behavioural benefits will differ with the form of enrichment.

Measures of positive affective state are in their infancy. While no treatment effects for any affective state measures were identified, this study contributed substantially to the development of these tests by assessing their feasibility in research and production setting. One new method of assessing affective state was developed (cognitive bias in confinement), a novel method for assessing affective state was tested in sows and piglets (startle response), and the feasibility of anticipatory behaviour was assessed. These findings will give a good understanding of how they may be used to detect positive welfare in the future.

The results of this study suggest that the provision of enrichment is beneficial for farrowing sows, with repeated results across three different sites (different environment, management and genetics)

6. Limitations/Risks

Limitations on the statistical analyses
Some video observations were lost for a variety of reasons (e.g. poor visibility, computer malfunction, missing files, inability to determine startle time due to lack of audio), resulting in a loss of data. This meant that the data from Experiment 2 had a reduced sample size for the behavioural analyses.

The very low use of enrichment seen in Experiment 2, especially for the rope treatment, meant that sows were grouped into Lucerne/Straw vs Control/Rope treatments only. This grouping combined with the reduced sample size means that the analyses were not as detailed as intended, and some fine details of sow behaviour may have been lost. For example, some analyses had very large SEMs as a result of the high number of zeroes.

The enrichment items were not always available to the sows
Access to the enrichment material was beneficial for the sows, however it was observed during video analysis that sows could quickly push the lucerne out of reach. This meant that the sows technically had enrichment in their pens, but often could not use it functionally to satisfy their motivations to nest or forage. A sow that is strongly motivated to use an enrichment that is just out of reach may experience frustration, which would be counterproductive to the purpose of providing enrichment. Any provision of enrichment to sows must ensure that the sows are able to functionally use the enrichment. Future re-analysis of the video footage could compare the amount of contact time that the sows had with the enrichment items and determine whether access to enrichment was related to any indicators of frustration, stress or poor farrowing outcomes.

A similar limitation related to enrichment access may relate to when the sows started to farrow in relation to when the enrichments were delivered. Sows that began farrowing in the afternoon or evening may have consumed their enrichments prior to farrowing, and thus went through farrowing without any access to enrichment, similar to the control treatments. This may have influenced their farrowing behaviours and outcomes.

Fibrous enrichment material blocks effluent systems
The provision of fibrous enrichment such as straw and lucerne provided benefits to sow welfare in terms of behaviour and biological function, however this benefit is limited practically by the negative effect of these materials blocking the effluent systems used on farm. If this limitation cannot be overcome, then enrichment practices are unlikely to change on farm.

Possible options for overcoming this barrier may relate to preventing the enrichment from entering the effluent system or using enrichment that is too small to cause blockages. The chaff used in the associated Honours project was sufficiently small to prevent blockages, however the sows had difficulty fully utilising this material. Options for preventing the enrichment from entering the effluent system could include placing the enrichment in racks where it is easily accessed by the sow, placing a cover over the front half of the slatted floor of the crate where the majority of enrichment material will fall, or developing an appropriate enrichment item that is too large to pass through the slatted floor. Currently racks for holding straw or lucerne may be most feasible at this point in time.

Functionality of the cognitive tests
While the proof of concept for the three cognitive tests were able to successfully elicit behavioural change in the sows, they did not detect the treatment differences that were seen using the sow behaviour and biological function. These cognitive tests have been well validated in laboratory species but will need further refinement in terms of the procedures used and the data collected before they will be of practical use on farm.

Opportunities resulting from this research
This research was conducted under both research and commercial conditions, allowing the feasibility of the novel cognitive measures to be tested under different circumstances. The interesting relationship that existed between the provision of enrichment and the reduced stillbirth rate seen in Experiment 1 and the associated Honours experiment led to an expansion of the methodology used in Experiment 2. This meant that Experiment 2 was able to incorporate four additional enrichment treatments. This allowed the effects of these enrichment treatments to be examined immediately without having to run an entire other experiment and was only possible due to the generous contribution of additional funding from the Pork CRC. This opportunity reinforces the importance of providing supportive resources to ongoing projects.

7. Recommendations

As a result of the outcomes in this study, the following recommendations have been made:

1. Providing Lucerne, straw or rope enrichment from when a sow enters farrowing housing until the point of farrowing is recommended as a cost-effective strategy for welfare and production gains.
2. Providing enrichment beyond this point may have benefits to the welfare of the sow and piglets and provide production gains for piglets at weaning too.
3. Strategies to provide straw/lucerne in production settings, and the method by which this could be provided, would be a valuable next step.
4. Further research on refining tests for positive affective states is required before they can be used to evaluate sow contentment in commercial settings.

Appendices

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Appendix 2: Associated Honours thesis

Experiment 3: The benefits of providing lucerne chaff for farrowing crate enrichment on piglet vitality, growth and survival.

by Sofie Byrne Pridgeon

Abstract
Lack of manipulative substrates in farrowing crates reduces sow welfare as intrinsic farrowing behaviours, such as nest building, cannot be performed. Enrichment with lucerne can be used to improve sow welfare and decrease number of stillbirths however, little is known about the impact of enrichment on live born piglets. Our aim was to determine the impact of lucerne on piglets in a commercial environment. The hypothesis was that lucerne provision would increase piglet vitality, survival and growth. Twenty-eight sows and ninety-two gilts were randomly allocated to two treatment groups; control; which received no enrichment, and lucerne; which were given 2kg of lucerne chaff pre-parturition and 250g post-parturition until weaning (~25). Faecal moisture score, farrowing duration and reproductive performance of the sows was recorded. Measurements taken from 1212 piglets included umbilical cord lactate, vitality score, degree of meconium staining and colostrum intake. Piglet weights were recorded on day 7, 14 and 21 day weights and all timing and cause of mortality was noted. Lucerne treated sows had higher faecal scores (2.8 ± 0.3 vs. 2.2 ± 0.21, P = 0.040) but exhibited no difference in farrowing duration (P = 0.420). Piglets born to lucerne sows had a lower incidence of intra-partum death (0.48 ± 0.13 pigs vs. 0.92 ± 0.13 pigs, P = 0.031), higher colostrum intake (308.6 +/- 19.8 gm vs. 231.4 ± 25.4 gm, P = 0.014) and higher average weights for day 7 (2.4 ± 0.6 kg vs. 2.1 ± 0.1 kg, P = 0.043), 14 (3.9 ± 0.1 kg vs. 3.3 ± 0.2 kg, P = 0.05) and 21 (5.6 ± 0.1 kg vs. 4.7 ± 0.2 kg, P = 0.001) than control piglets. These results support the hypothesis that lucerne improves the survival and growth of sucker pigs. Further studies are required to determine whether the beneficial effects of lucerne at farrowing reflect positive nutritional or behavioural influences on the sow.

Appendix 3: Conference proceedings arising from this study

The reproductive value of enrichment to sows at farrowing

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Pre-parturient sows in traditional farrowing environments are confined at a time when they are highly motivated to perform nest building behaviours (Westin et al., 2015). Providing them with enrichment may help alleviate the frustration associated with confinement, and lead to welfare improvements for the sow and her piglets. In this study, we provided sows with lucerne hay, which acted as both a food-based enrichment and nest building material and studied the impact on their reproductive performance. It was hypothesised that the provision of lucerne would reduce parturition time and decrease the number of stillborn piglets.

Sixty nine Large White x Landrace sows (parity 0 to 2) over six farrowing batches were allocated to either the control (n = 33) or lucerne enrichment (n = 36) treatments. Prior to farrowing (6.5±0.3 days), sows receiving enrichment were given ~1 kg of lucerne hay per day into their feeding trough, after receiving their morning ration. Weaning occurred at 16.4 ± 0.3 days. Current farrowing duration and piglet numbers and outcomes were measured from video observations. Subsequent mating performance was taken from farm records. All data were analysed to assess the effects of enrichment. In SPSS (v24 IBM, USA), general linear models with parity, treatment and their interaction as fixed effects, and batch as a random term, were run for the following variables: farrow duration ($\log_{10}$), piglet interval ($\log_{10}$), total piglets born, piglets born alive, and piglets weaned. A covariate of total number of piglets born was added to the model for farrowing duration (from first piglet to last) and piglet interval only. The same model was used for number of piglets born dead and post-natal piglet deaths but a generalised linear model with poisson distribution was applied, and a binomial distribution was applied to the number of sows that were mated the next batch.

The number of piglets born dead was reduced by 0.3 piglets in the lucerne treatment (Table 1). There was no difference in farrowing duration, piglet birth interval, total number of piglets born, or piglets born alive. A significant parity by treatment interaction existed for percentage of sows mated within the batching requirements. Sows displaying oestrus within two weeks of weaning were bred, whilst the remainder were not bred that batch. More gilts from the lucerne treatment were mated immediately following weaning (81%) than controls (60%), but this relationship was reversed in multiparous sows (lucerne 67% versus control 90%; $P<0.05$).

Table 1. The effects of the provision of lucerne prior to and at parturition on sow reproductive performance.

	Control		*Lucerne*		*P value*
	Mean	SEM[1]	Mean	SEM	
$\log_{10}$ farrowing duration (min)[2]	2.22 (166.0)	0.05	2.31 (204.2)	0.04	0.174
$\log_{10}$ piglet interval (min)[2]	1.18 (15.1)	0.05	1.24 (17.4)	0.05	0.364
Total piglets born	10.9	0.5	11.0	0.5	0.834
Piglets born alive	10.4	0.5	10.9	0.5	0.450
Piglets born dead	**0.4**	**0.1**	**0.1**	**0.1**	**0.027**
Piglet deaths	0.8	0.2	0.6	0.1	0.328
Piglets weaned	10.5	0.3	10.6	0.3	0.865

[1]SEM – standard error of the mean. [2]Back-transformed means are presented in brackets

The difference in number of piglets born dead in the absence of any change in farrowing duration is intriguing. One possible explanation is that allowing the sow to perform nest-building activities had positive effects on uterine blood flow and so risk of piglet hypoxia was reduced. This notion needs confirming. Behaviour at parturition from the existing experiment is being analysed to assess if this contributed to difference in the number of stillborn piglets. The finding that gilts may show improvements in re-breeding success is interesting but viewed with caution given the short lactation length and consequent poor subsequent performance. This experiment is being replicated on a larger scale in a commercial piggery, and the nutritional impacts of lucerne are being quantified to evaluate these results further.

References

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The provision of lucerne to sows evoked greater arousal in response to an anticipatory behaviour test.

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Environmental enrichment is thought to be beneficial for pigs. Exposure to enrichment develops resilience to future stressful events by exposing animals to mildly stressful experiences leading to adaptation (Crofton et al, 2015). Rodents housed in enriched environments had greater corticosterone concentrations (Benaroya-Milshtein et al, 2004) and grower pigs housed in enriched environments had greater salivary concentrations of cortisol (deGroot et al, 2000). We investigated the effect of providing lucerne to sows prior to parturition on their anticipatory response to the introduction of a feed cart and of a feeding event. We hypothesised that sows provided with lucerne would show greater concentrations of cortisol and would perform more postural changes than sows that were not provided with lucerne.

Large White x Landrace sows were loaded into conventional farrowing crates approximately 7 days prior to parturition. Sows in the lucerne treatment were provided with 1kg of lucerne hay daily and sows in the control treatment were not provided lucerne hay. Sows were fed manually twice daily from a feed cart at 7am and 3pm. After 3 days in the farrowing crate sows were subjected to an anticipatory behaviour test. On the day of the test blood was collected via an indwelling ear vein catheter every 15 min for 60 min prior to and 60 min after the introduction of the feed cart and feeding event. Behaviours were recorded via video for analysis. At 3 pm (the normal feeding time) the feed cart was moved into the room and was left for 3 min. After 3 min the sows were given their daily feed ration. For behavioural analysis there were n = 10 control sows and n = 11 lucerne sows. For cortisol analysis there were n = 11 lucerne sows and n = 9 control sows. Plasma was assayed for cortisol using radio-immuno assay (MP Biomedicals). Cortisol data were analysed using a repeated measures analysis of variance and behavioural data with a general linear model in SPSS. Data that were not normally distributed were $\log_{10}$ transformed prior to analysis and all data are presented as back transformed means.

The concentration of plasma cortisol was significantly greater for the sows that received lucerne compared to sows that did not receive lucerne ($P<0.05$). This effect was only seen after the introduction of the feed cart. Therefore, the provision of lucerne altered the cortisol response of the animals to the feeding event. Sows that received lucerne displayed a greater number of behavioural transitions than the sows that did not receive lucerne ($P<0.05$). Our data suggest that sows provided with lucerne display greater levels of arousal in anticipation of the arrival of a feed cart and a feeding event, both in terms on hypothalamic-pituitary-adrenal axis and behavioural activity. This is in keeping with previous reports on the effects of enrichment. Therefore, our data indicate that lucerne may be an effective enrichment for sows prior to farrowing.

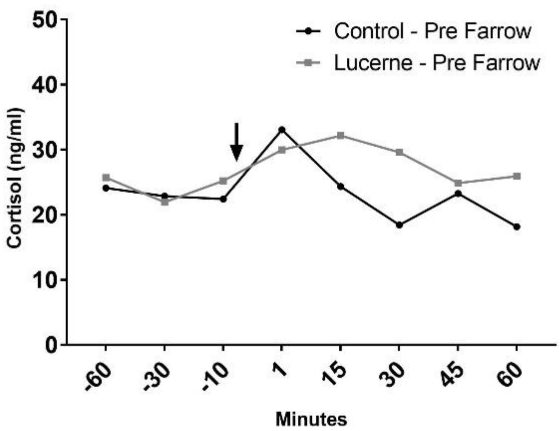

Fig. 1. The mean plasma concentration of cortisol (ng/ml) for sows for 60 min prior to and 60 min after the introduction of a feed cart. Arrow indicates the introduction of the feed cart.

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Play behaviour in piglets is infrequent and not altered by enrichment with lucerne when measured by scan sampling

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Play behaviour in early life may have an important role in the cognitive and social development of piglets. Research also supports play as a potential positive welfare indicator (Brown *et al.* 2015). Environmental enrichment can provide opportunities to express exploratory behaviours that could lead to increased play behaviour. Our aim was to determine the effects of access to lucerne on piglet play. The hypothesis was that the provision of lucerne throughout lactation would increase play behaviour in piglets. Approximately 1 kg of lucerne hay was added to the farrowing crate daily for the first week of lactation, then every second day until weaning. Piglets from nine control litters (n=98) and thirteen enriched litters (n=141), born across several days, were recorded for 24 hours on a set day, two weeks after the farrowing period begun. Behavioural analysis was carried out for two hours of video footage (11:00-13:00) for all litters by instantaneously sampling every 15 seconds. Behaviours expressed were grouped into; play, active, rest or nursing, and were mutually exclusive to one other. Piglets were not individually identified, but each piglet was nominated to one of the behaviour groups at each sample point. Binominal generalised linear mixed models with treatment and piglet age, and their interaction, fitted as factors and sow as a random factor were used to analyse incidents of play, nursing and active behaviours (Bates *et al*. 2014). Analyses were performed in R (R Core Team 2017). Treatment did not statistically influence any of the behaviours (P>0.05). Age influenced nursing (P=0.016) and play (P=0.04), but the relationships were not linear. Behaviour varied widely between litters (Figure 1). The occurrences of play were low and occurred sporadically, but, observationally, they appeared more common after a nursing event. Contrary to the hypothesis and other published literature on environmental enrichment provided during lactation (Martin *et al*. 2015), the provision of lucerne did not increase play behaviour in piglets. The short intervals of scan sampling did identify play behaviour, but it was highly infrequent. Continuous observations or assessing behaviour at other time points during the day when pigs are active would provide a more comprehensive analysis and would give further insight on treatment effects.

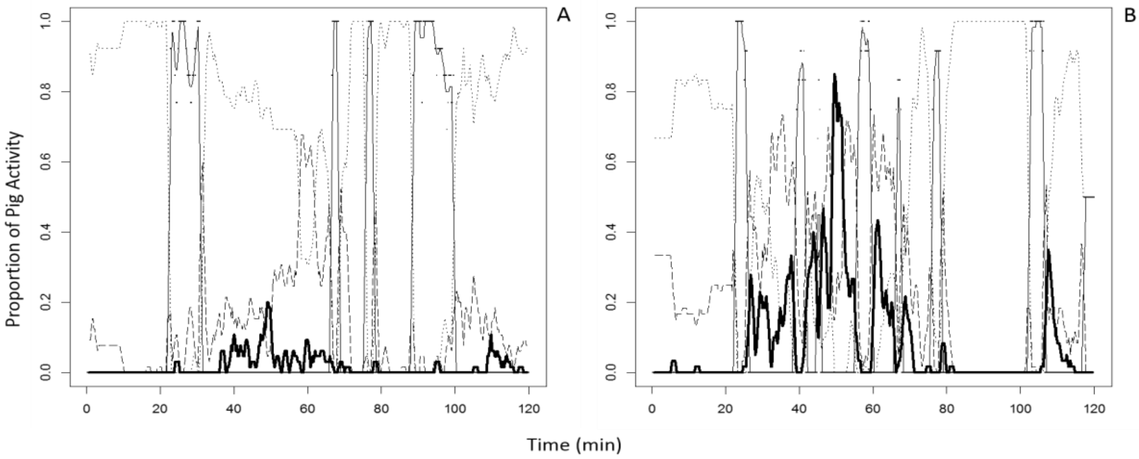

Fig. 1. Behavioural profiles of two litters (control (A) and lucerne (B)), showing the proportion of nursing (thin black), active (broken), play (thick black) and resting (dots) over the two-hour observation period.

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Developing a rapidly learnt judgement bias test in a confined environment

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Judgement bias is the most promising methodology currently available to assess animal affect, but the practicalities of training and testing can limit its use. Our objective was to develop a judgement bias test for sows housed in farrowing crates. The procedure needed to be learnt rapidly and easily applied to confined sows.

There were 24 sows housed in farrowing crates from 4 days pre-farrowing for four weeks (time of weaning). We used an in-situ spatial go/no-go task while the sows were housed in 560 mm-wide crates. When the sow's snout touched a visual target (silver rectangle) in one corner above the feeder (340 mm wide) at the front of the crate she was rewarded with a sugar cube, which was delivered with the assistance of a secondary reinforcer (a clicker). In contrast, when the sow touched the target in the alternate corner she was 'punished' (not rewarded and received 10s time out). The time to respond to the rewarded target was almost instantaneous and the maximal time to respond was set at 4s before a non-response was recorded. Sows received two training sessions (average 260s) and after one training session achieved 85% accuracy in the task ($P<0.05$). One ambiguous location was chosen 226 mm and 114 mm from the positive and negative locations respectively.

Of the 24 sows, 20 learnt the task; 17 were tested for judgment bias at early and late lactation; three completed only one of the two tests, and; four never ate the reward. Survival analysis was used to test responses to the cues over time, with sow fitted as a random effect. There were significant cue $\times$ time interactions ($p<0.001$). Sows touched the positive cue 98% of the time and the average response time was 0.4s (SEM$\pm$0.04s); negative cue: 11% touched, average 3.8$\pm$0.04s; ambiguous cue: 55% touched, average 2.6$\pm$0.13s. Sows were more likely to touch the positive cue in late lactation (early: 94% touched, average 0.6$\pm$0.07s; late: 99%, 1.8$\pm$0.03s), possibly reflecting more time to learn the task and/or increased appetite after farrowing. Response times to the negative and ambiguous cues were consistent during early and late lactation.

Validation following affect manipulation is required. This methodology may have application for animals with restricted/slow movement; in confinement; when social separation is undesirable; when ex situ testing is inappropriate (e.g. zoo settings). This method also allows the animal to be exposed to treatments during testing.
UFAW International Symposium. Measuring animal welfare and applying scientific advances - Why is it still so difficult? Surrey, UK. 27-29th June 2017. P. 92.