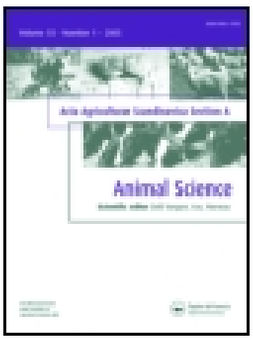

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Providing additional objects to straw reduces piglets' redirected behaviour post-weaning but influences weight gain pre-weaning negatively

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ABSTRACT

We investigated the post-weaning effect of providing additional objects (i.e. rope, ball, tyre) to commercial piglets given straw pre- and post-weaning on behaviour and average daily gain (ADG). Piglets from litters with objects (O, $n = 20$ in 5 litters) and controls (C, $n = 20$ in 5 litters) were observed from 24 h post-weaning and during six days. Piglets were weighed at birth, weaning and 11 days post-weaning. O-piglets performed less littermate manipulation ($P < 0.05$), exploring pen fixtures ($P < 0.1$) and lying ($P < 0.1$) but spent more time in the creep post-weaning than C-piglets ($P < 0.1$). Social or locomotor play was expressed similarly in both treatments. Day strongly influenced the behaviour of pigs post-weaning. O-piglets had significantly lower pre-weaning ADG than C-piglets ($P < 0.05$), but there was no significant difference in post-weaning ADG between the treatments. Providing objects to piglets around weaning may reduce some negative behaviours, but may affect weight gain negatively.

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Pigs; enrichment; exploration; growth; play; social manipulation

Introduction

Indoor housing systems in which piglets are reared, generally lack the diversity of stimuli that can be offered in more natural environments (Johnson et al., 2001). This may hinder animals from performing highly motivated behaviours, such as exploration and foraging (Lawrence & Terlouw, 1993), and can lead to welfare problems like boredom and abnormal behaviours (Oostindjer et al., 2014). The most common abnormalities are belly nosing, tail biting and other manipulative behaviours directed toward the littermates, the sow and the pen fixtures (Bench & Gonyou, 2006). A barren environment has also been observed to increase sitting, standing or lying compared to an enriched environment (Beattie et al., 2000).

For piglets, weaning is a major stressor as it usually involves several challenges such as early and abrupt loss of the sow and their main feeding source (i.e. milk) plus a new social and physical environment (Oostindjer et al., 2014). These changes cause distress in piglets as indicated by a depressed immune system, elevated plasma cortisol concentrations, increased aggression, distress calling, littermate manipulation (including belly nosing and tail biting), set-backs in growth, low food intake and reduced play behaviour (Worobec et al., 1999; Donaldson et al., 2002).

Play is considered a sensitive indicator of positive welfare in captive animals (Newberry et al., 1988; Boissy et al., 2007). The argument is based on the findings that juveniles are highly motivated to play when their primary needs have been met (Jensen & Kyhn, 2000), whereas individuals who suffer from environmental and physical stress are not (Siviy & Panksepp, 1985). An important aspect of the welfare of captive animals is that individuals motivated to play, may not be able to do so due to a lack of sufficient space, play partners or appropriate objects to play with (Jensen & Kyhn, 2000). Thus, the distress caused in piglets at weaning may be alleviated by providing them with familiar objects and triggering more play behaviour. Straw would be the best enrichment but due to manure handling systems that cannot handle long straw or too much straw, farms are trying to give only small amounts of straw.

To the authors' knowledge not much is known about the effect of objects at weaning on positive behaviours like play behaviour and exploratory behaviour. Most studies have focused on enriching the pre-weaning environment in order to reduce stress at weaning

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(Donaldson et al., 2002; Lewis et al., 2006; Chaloupková et al., 2007; Oostindjer et al., 2011; Martin et al., 2015). This is the first study in pigs aiming to reduce stress at weaning by providing piglets with objects (i.e. rope, tyre and ball) without changing anything else in their environment in order to increase positive behaviours. We predicted that in litters with objects, piglets would engage less in manipulation directed at littermates and pen fixtures and perform more play post-weaning. We also predicted that litters with objects would grow better. This is based on evidence suggesting play and exploration affect body weight (e.g. pigs: Zupan et al., 2016; goats: Theoret-Gosselin et al., 2015) and promote positive emotions (Held & Špinka, 2011). We further expected piglets to interact more with a rope than with a tyre or a ball, as this material is the most chewable, deformable, destructible, odorous and ingestible and pigs have been found to prefer such objects (e.g. Van de Weerd et al., 2003).

Material and methods

Animals and housing

The study was performed in April 2012 in a pig stable with 10 farrowing pens at the Swedish National Livestock Research Centre, Uppsala, Sweden. The Swedish Ethical Committee of Experimental Animals in Uppsala (Dnr. C 34/12) approved the study.

The 10 first parity purebred Yorkshire sows and their offspring (half purebred Yorkshire, YxY, and half Yorkshire-Landrace, YxL) were used. Prior to parturition, the sows were kept in a deep straw loose housing system, and two weeks before parturition they were moved to the individual farrowing pens. The piglets were all born within 6 days of each other. The sows whose piglets received objects before weaning had the following number of piglets in their litters three weeks after farrowing; 11, 11, 10, 10 (including 2 adopted), 10 (including 4 adopted). The control sows whose piglets did not receive objects had the following number of piglets in their litters three weeks after farrowing; 11, 9, 7, 10 (including 2 adopted), 10 (including 4 adopted). Adoption of piglets only occurred within the same farrowing room of the 10 sows.

Pre-weaning phase

The experiment started with the birth of the piglets, i.e. day 0. The sows and their piglets were housed in the individual farrowing pens with a total area of 6.5 m^2 (3.25 m × 2 m). The pens consisted of a lying area (2.8 m^2), a dunging area (2.4 m^2) and a covered creep area (1.3 m^2) with a heat lamp for the piglets (Figure 1). The creep area was separated from the lying area of the pen by a dividing wall with openings that piglets could pass through. The lid over the creep area was partly opened one week before weaning, as a single feeder was placed in the creep area at this time. The pens had an underfloor heating coil that was on during the observation period. Each pen was provided with 1 kg of chopped straw on the lying area once per day in the morning from an automatic straw machine (JH ministrø, Jørgen Hyldgård Staldservice A/S, Denmark). Sows were fed automatically at 9.00, 12.00 and 15.00 h with a commercial complete feed in a feeding trough. Piglets were fed with the commercial piglet feed (Gottfrid, Lantmännen, Sweden) in a single feeder from one week of age and changed at three weeks of age to another feed (Medly 352, Lantmännen, Sweden). Piglet feed was available *ad libitum* and refilled every day at 10.00. The feeder was round and made of plastic, which allowed several piglets to feed at the same time. Water was available *ad libitum* from two drinking nipples located in the dunging area for both the sows and the piglets. Before the piglets were four days old, they were individually marked with an ear tattoo, got their teeth rasped, iron injections were given and male piglets were castrated during analgesia. No vaccinations were given.

Post-weaning phase

Weaning was performed at the mean age of 33 days (ranging from 30 to 35 days in object litters and 31–36 days in control litters) by removing the sow from the farrowing pen and placing her in a dry sow stable. The barn staff removed all sows on the same day and not according to the exact piglet´s age. The piglets were kept in the same pens after weaning as during nursing, but the pen structure changed according to our study protocol described below (see Figure 1 and Section 'Pre-weaning object placement'). The pens were provided daily with 1 kg of chopped straw in the lying area, from the same automatic straw machine as pre-weaning. The straw was provided once in the morning, at the latest 1.5 h before the start of behavioural observations.

The piglets continued to be fed the commercial piglet feed (Medly 352, Lantmännen, Sweden) from a single feeder, as in the two weeks before weaning. Piglets feed was available *ad libitum* and refilled every day at 10:00 h. The feeder was round and made of plastic, which allowed several piglets to feed at the same time. Water was available *ad libitum* from two drinking nipples located in the dunging area. The pens were cleaned each day in the morning between 08:00 and 09:00 h. The temperature and ventilation in the room were thermostatically controlled with the temperature set at 20°C, but during the last week of observation temperature fluctuated from 18°C to 24°C due to problems with the ventilation system. The lights in the

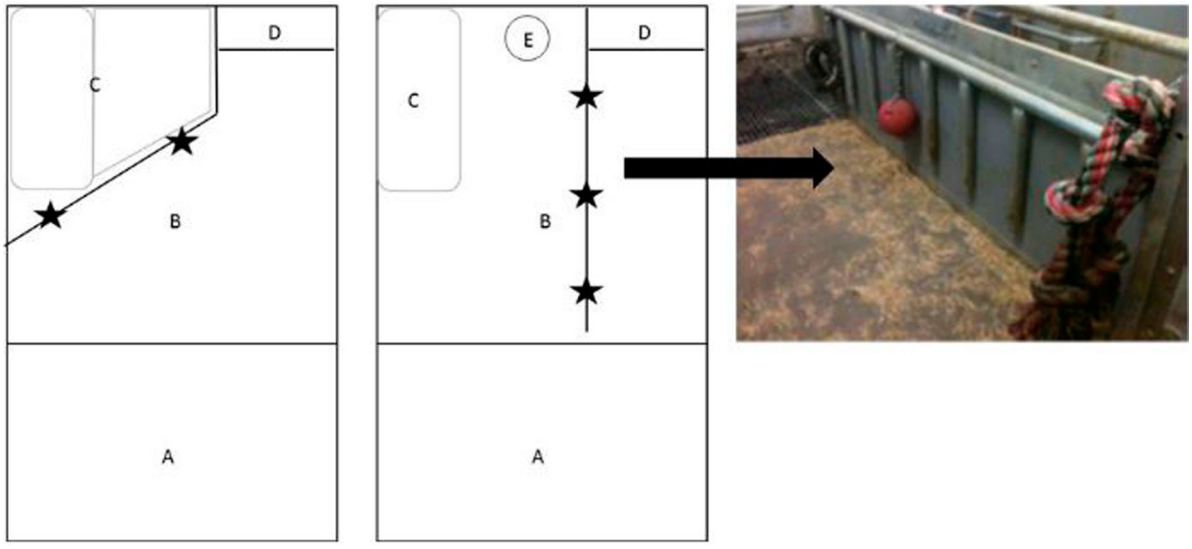


Figure 1. Schematic pictures over the farrowing pens. Pre-weaning (left picture) and post-weaning (right picture). A: dunging area, B: lying area, C: creep area, D: sow feed trough, E: single feeder. ★: places where objects were suspended at the dividing wall. Photo of the three objects and their placement post-weaning.

farrowing room were manually turned on at 08:00 h and were automatically turned off at 19:00 h. A night light was kept on after 19:00 h.

Study design

The 10 litters were randomly assigned to two treatments, an object litter (O) or a control litter (C). Treatments were balanced among litters with respect to breed (YxY or YxL). Five litters were provided with objects (i.e. O litters, three YxY and two YxL) whereas the remaining five litters were not provided with any objects (i.e. C litters, three YxL and two YxY). The O litters were provided with different objects for three set time periods before weaning and then continuously for 6 days, starting the day after weaning. From the beginning of our study, we had 6 sows in each treatment and we wanted to evaluate if one enrichment was more effective than the other pre-weaning. We, therefore, provided one pen with one enrichment at a time and changed the enrichments within three weeks pre-weaning. However, one sow was moved out of the room and another became sick, thus leaving us with only 5 sows per treatment. Switching the enrichments did therefore not work out as planned. Although for the purpose of this scientific paper we do not provide the results of behaviours pre-weaning, we have them summarized in an MSc thesis.

Objects

In order to avoid having an effect on the management on the farm, we added other objects than the straw that could not be consumed. In order to select the three most preferred objects, the following objects were tested in a previous pilot study; two types of rubber balls, three types of ropes, a chain and two types of rubber dog toys (a tyre and a rubber ring). All objects were placed on the floor in two pens with piglets after weaning and the three objects piglets interacted with the most were chosen. The objects selected were:

(1) Rubber tyre: 20 cm in diameter and 5 cm wide. The tyre was cut open so that piglets or the sow could not get stuck.
(2) Rubber ball: 10.5 cm in diameter perforated with a hole, vanilla-scented. A chain was placed through the hole to fasten the ball in the pen.
(3) Knotted rope: 95 cm with five knots and threads hanging out from both ends.

All objects were attached with a chain to a dividing wall in front of the creep area (Figure 1).

Procedures

Pre-weaning object placement

During the three age periods pre-weaning (13–16, 20–23 and 27–30 days post birth, exact days for each sow) the object litters received two of each object within each period but of different types between the periods. This was done to avoid a confounding effect between periods and objects. The types of objects were offered in the following order: tyre–ball–rope (two litters), rope–tyre–ball (two litters) and ball–rope–tyre (one

Table 1. Ethogram of behaviours recorded continuously or instantaneously* during six days post-weaning.

Behaviour	Description
Lying*	Belly or side of body in contact with the floor and feet not in direct contact with the floor with eyes opened or closed
Sitting*	Hind part or carpal joints in contact with the floor and only two feet in direct contact with the floor without performing any other described behaviour
Standing*	Standing still with all four feet on the floor without performing any other described behaviour
Being in creep*	Inside creep area and out of sight for the observer
Feeding*	Head down in feeder or standing close to and with head directed towards the feeder while chewing
Explore floor*	Snout within 5 cm (sniffing) in contact with (touching) or moving repeatedly forwards and backwards (rooting) the floor or substrate on the floor
Other*	Other instantaneously recorded behaviours that were rarely observed, for example drinking
Explore fixtures	Snout within 5 cm (sniffing) or manipulating with mouth or tongue (nibbling, biting, licking or sucking) part of the pen above floor level, except objects
Littermate manipulation	
Body	Oral manipulation (biting, nibbling, licking or sucking) directed toward the body of another piglet, except the belly or tail. The definition includes single bites, nibbles, licks and sucklings as well as longer bouts of manipulation where the piglet alternates between behaviours within the definition. The recipient piglet is relatively inactive (sitting or lying down)
Belly	Oral manipulation (biting, nibbling, licking or sucking) or snout moving up and down (massaging) against the belly of another piglet that is lying down on its side
Tail	Oral manipulation (biting, nibbling or sucking) of another piglet's tail
Social play	
Nose-to-nose	Gentle nose-to-nose or cheek-to-cheek contact with another pig while rapid movements of the head. If the pig pauses for 2 s or longer or switches to another receiver between the same behaviour it is recorded as a new bout
Head knock	Rapid, lateral movements of the head, once or continuously, against any part of the body of another piglet. If the pig pauses for 2 s or longer or switches to another receiver between the same behaviour it is recorded as a new head knock
Mounting	Standing on back of another piglet with front legs, from behind or from the side of the other piglet that is standing
Lever	Attempt to, or successfully, lifting another piglet with snout from under the other piglet's belly or from between its legs
Locomotor play	
Scamper	Running with vertical and horizontal bouncy movements with at least two forward hops, occasionally accompanied with head toss. Walking with fast speed or running was included in the definition if the piglet ran or walked fast in order to turn to a different direction and then continued to scamper directly after the turn
Leap	Jumping up and down on spot or with one forward jump, sometimes turning slightly toward a different direction but not as much as during pivot and is occasionally accompanied with head toss
Flop	A rapid drop from an upright position to sternal or lateral recumbence. The piglet appears as to have fallen down by itself and not as a result of a slip or being pushed by another piglet
Pivot	Jumping and turning around on spot so that the body is rotated at least 90̊ in the horizontal plane, occasionally accompanied with head toss
Object interaction	
Rope	Manipulating rope with mouth (biting, nibbling, licking or sucking), touching rope with snout or head (nudging or pushing), holding rope in mouth while moving backwards or sideways (pulling) or holding rope in mouth while making rapid side to side movements with the head (shaking)
Tyre	Manipulating tyre with mouth (biting, nibbling, licking or sucking), touching tyre with snout or head (nudging or pushing), holding tyre in mouth while moving backwards or sideways (pulling) or holding tyre in mouth while making rapid side to side movements with the head (shaking)
Ball	Manipulating ball with mouth (biting, nibbling, licking or sucking), touching ball with snout or head (nudging or pushing), holding ball in mouth while moving backwards or sideways (pulling) or holding ball in mouth while making rapid side to side movements with the head (shaking)

litter). This was done as we wanted to observe if piglets were affected differently by having certain objects at certain ages. Due to the few litters for each age, this data is not presented here (see Hultman, 2013). Each day, the objects were provided at 09:00 h and taken out at 15:00 h. The objects were first introduced to the O litters one day before the first observations and were attached with a chain to a dividing wall in front of the creep area (Figure 1), approximately 15 cm above the floor. The reason for hanging them and not leaving them loose on the floor was that the sow should not be able to swallow the objects or move them around, and because a previous study (Van de Perre et al., 2011) has shown that if the objects get dirty pigs lose interest in them. Piglets had no access to objects from the last day pre-weaning testing until one day post-weaning.

Post-weaning object placement

One day after weaning the five object litters received all three objects, one object of each type, at 09:00 h and then they had continuous and simultaneous access during the following six days. The objects were attached with a chain as in the pre-weaning phase (Figure 1). The dividing wall in the pen was opened at weaning (Figure 1). The placement (left, right or middle) of the objects on the dividing wall was random in each pen.

Behavioural observations

Four focal piglets from each litter were selected randomly if they met the following criteria; (1) Two males and two females, (2) Piglets from the sow's own piglets, (3) Piglets close to the median birth weight. Since there was only one female from the sow's own

piglets in one of the control litters, an adopted female piglet (8 days older than her own piglets) was selected as the second female focal piglet. The focal piglets were individually marked on the morning of the first day of observation with commercial pig marking spray of different colours.

Live observations were performed during each of the six days after weaning, starting with 24 h post-weaning. The observer scored behaviour during two time periods, 10–12 h and 13–15 h, from the corridor in front of the pens. The observer started observing the left pen closest to the door the first day and from the right pen closest to the door the next day and, thereafter, alternated between the left and right side. The observer waited for one minute before starting observations in order to habituate piglets to her presence. The four selected piglets were observed as focal animals for one minute each, before the observer moved to the next pen and carried out the observations in the same way, and so on until all pens had been observed. Every pen was observed for 2×4 min in the morning and 2×4 min in the afternoon, resulting in a total of 16 min of observation per litter per day (6 days $\times$ 16 min = 96 min in total). Behaviours recorded and their definitions are described in Table 1. Long-duration behaviours were scored instantaneously using a time sampling method at 15 s sample intervals during one minute, while short-duration behaviours and interactions with the objects were scored as frequencies within the same minute. The ethogram was tested before the study started and behaviours that appeared regularly and lasted for at least several seconds were chosen to be recorded instantaneously, as for example explore floor, while behaviours of short duration or that appeared seldom were recorded continuously as for example explore fixtures. Due to that, there were relatively few recordings of each of the individual behaviours, the following behaviours were merged before data analysis: littermate manipulation, social play, locomotor play and object interactions. Interaction with straw was not recorded since it was difficult to separate it from the explore floor and that the short cut straw was difficult to manipulate for the piglets.

Body weight recordings

The piglets were weighed individually within 24 h after birth, at weaning and at 11 days after weaning. Before weaning, piglets were picked up and put on a scale (Profilvågen, Maxicap AB, Sweden) located outside their pen, whereas at weaning and 11 days post-weaning, piglets were prompted to go onto the scale by themselves. From body weight recordings, the average daily gain (ADG) was calculated from birth to weaning (pre-weaning ADG) and from weaning until 11 days after weaning (post-weaning ADG).

Statistical analysis

The data were analysed in SAS Software version 9.3 (Statistical Analysis Systems, SAS Institute, Cary, NC, USA). Data were plotted in a histogram, by the procedure UNIVARIATE, to determine their distribution. The data residuals of the recorded behaviours followed a Binomial distribution or Poisson distribution, while the ADGs followed a normal distribution. Homogeneity of variance was analysed with a Levene's and a Cochrań's test for equality of variance using the procedure t-test.

The behaviours recorded in the litters and the object interactions recorded in the O litters were analysed using a Logistic Regression with a generalized linear model (proc GENMOD) with a logit link function and type 3 Wald statistics. Piglet nested within sow was included as a repeated factor. The statistical models for the behaviours included treatment (O and C litters), day post-weaning (6 days) and their interaction. Sex (females and males) and breed (YxY, YxL) were included in the original models, but as they were not significant for any behaviour they were removed. Post-weaning ADG was included as a covariate because piglets having a high weight gain could have behaved differently than piglets with a lower weight gain. There were few recordings of sitting and this behaviour was not statistically analysed (O litters median 0.3% (CI 0, 0.52); C litters median 0.5% (CI 0.52, 1.04)). The model for being in the creep area did not converge with the interaction between treatment and day. The model for locomotor play did not converge when the effect day post-weaning was included; hence the model only included treatment. The statistical model for object interaction included object type (i.e. rope, ball, and tyre), breed and sex as the main factors. An additional model tested the effect of day post-weaning on object interaction.

Pre- and post-weaning ADG were analysed using a Logistic Regression with a generalized linear model (proc GENMOD) with the individual piglet as the experimental unit. The statistical model included treatment, sex and breed as main effects. Birth weight was included as a covariate in the model for pre-weaning ADG and weaning weight was included as a covariate in the model for post-weaning ADG, because these weights could have influenced the piglets' ability to grow pre- vs. post-weaning.

Spearman rank correlation test (proc CORR Spearman) was performed between play behaviours and pre- and

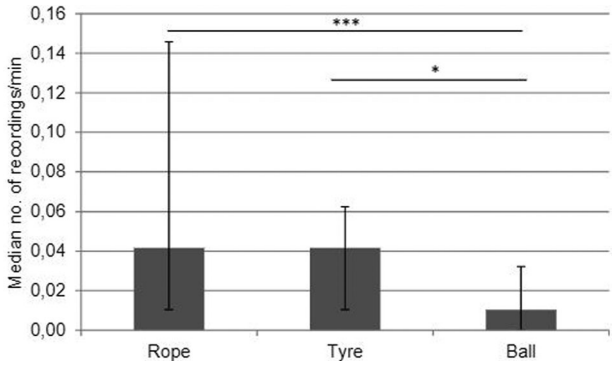


Figure 2. Median number of recordings per minute per piglet (95% Confidence Intervals (CI)) of interaction with different objects (rope, ball and tyre) in piglets during the post-weaning period (*$P < 0.05$, ***$P < 0.001$, $n = 20$ piglets within 5 object litters).

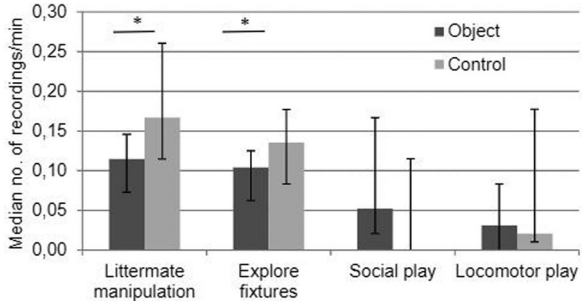


Figure 3. Median number of recordings per minute per piglet (95% Confidence Intervals (CI)) of littermate manipulation, exploring pen fixtures, social play and locomotor play in piglets that had access to three different types of objects (object) or no access to objects (control) during 6 days post-weaning (*$P < 0.05$, $^{t}P < 0.1$; $n = 20$ piglets within 5 litters/treatment).

post-weaning ADG. Spearman rank correlation was also used to test for correlations between object interactions and play behaviours. All behaviours were calculated first as means per piglet within the litter, and then as means per litter and thereafter as medians per treatment or day with 95% confidence intervals (CI). The pre- and post-weaning ADG were calculated per piglet and then as mean g per day per treatment with standard error (SE). The significance level was set to $P < 0.05$.

Results

Object interaction

In O litters, 5of the 20 focal piglets did not interact with any of the provided objects during the observations. Of the remaining 15 piglets, two interacted with all three objects, seven with two of the objects and six with only one of the objects during the observations. The frequency of manipulating a particular object differed significantly ($Chi^2 = 125.00$, $DF = 2$, $P < 0.001$, Figure 2) with a rope being the most preferred object and a ball the least. The number of days post-weaning tended to affect object interaction ($Chi^2 = 9.73$, $DF = 5$, $P < 0.1$), but there were almost no object interactions between days 3 and 5 and quite high confidence intervals, therefore no figure is shown.

Behaviour

Piglets in C litters performed significantly more littermate manipulation ($Chi^2 = 5.49$, $DF = 1$, $P < 0.05$) and tended to perform more exploration of pen fixtures ($Chi^2 = 3.32$, $DF = 1$, $P < 0.1$) compared to O litters (Figure 3). There were no effects of treatment on the number of recordings of social play ($Chi^2 = 2.11$, $DF = 1$, $P > 0.1$) and locomotor play ($Chi^2 = 1.18$, $DF = 1$, $P > 0.1$) (Figure 3). Lying had the highest percentage of recordings among the long-term behaviours where C-piglets tended to have a higher percentage of lying than O-piglets, but a lower percentage of being in the creep area (Table 2). There

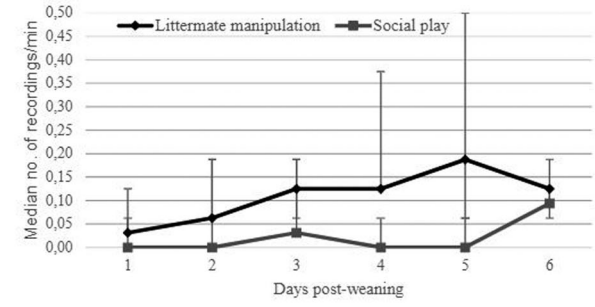
Table 2. Median with CI for percentage of recorded behaviours in piglets given objects (object litters) or no objects (control litters) during the first six days post-weaning.

Behaviour	Object litters Median (CI)	Control litters Median (CI)	Treatment Chi^2	Day Chi^2	Treatment*Day Chi^2
Lying	56.5 (42.58; 61.20)	64.1 (57.72; 69.01)	3.56	39.51	4.60
			$P = 0.06$	$P = 0.0001$	$P = 0.47$
Standing	3.6 (2.08; 5.21)	2.9 (1.30; 7.29)	0.43	3.53	7.60
			$P = 0.51$	$P = 0.62$	$P = 0.18$
Explore floor	10.4 (3.12; 13.28)	6.8 (5.47; 14.38)	0.75	41.70	22.38
			$P = 0.38$	$P = 0.0001$	$P = 0.0004$
Being in creep	13.9 (9.37; 16.15)	8.4 (0; 12.76)	3.39	78.70	Not converging
			$P = 0.07$	$P = 0.0001$	
Feeding	8.3 (3.38; 14.35)	8.2 (7.34; 9.11)	0.08	8.74	5.16
			$P = 0.77$	$P = 0.12$	$P = 0.40$
Other	9.9 (7.29; 11.46)	7.3 (3.12; 11.20)	1.78	0.98	3.99
			$P = 0.18$	$P = 0.96$	$P = 0.55$

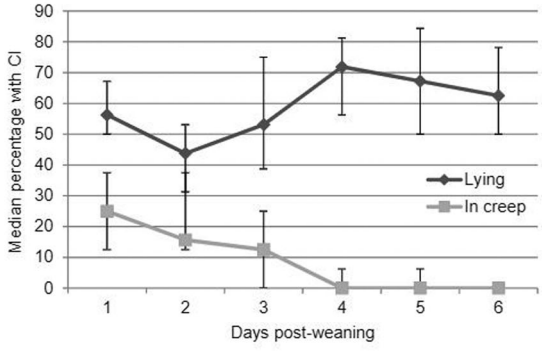
Note: Chi^2-values and *P*-values for the effect of treatment, day post-weaning and their interactions from the Logistic Regression ($DF = 1$, $n = 20$ focal piglets within 5 sows/treatment).

were no effects of treatment on the other behaviours recorded (Table 2).

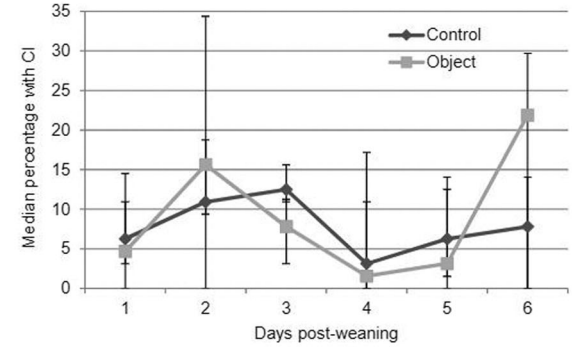
The number of days post-weaning, affected littermate manipulation ($Chi^2 = 18.09$; DF = 5, $P < 0.01$), social play ($Chi^2 = 14.85$; DF = 5, $P < 0.05$), lying, being in the creep area and exploring the floor (Table 2). However, it did not affect exploration of pen fixtures ($Chi^2 = 9.14$, DF = 5, $P > 0.1$; data not shown). Post hoc comparisons between the days showed that littermate manipulation increased from day 1 to day 5, while social play increased on day 3, then decreased the next 2 days and increased again on day 6 (Figure 4(A)). After three days post-weaning, piglets spent almost no time in the creep area, but performed more lying (Figure 4(B)). There was a treatment × day interaction for exploring floor (Table 2, Figure 4(C)). Post hoc comparisons between the days showed that O litters had the highest percentage of exploring the floor on days 2 and 6 and a low percentage on days 4 and 5, whereas C litters had the highest percentage on days 2 and 3 post-weaning. There were no other significant effects of treatment, day or their interaction on other behaviours post-weaning (Table 2).



A. Littermate manipulation and social play



B. Lying and being in the creep



C. Exploring floor

Figure 4. Medians and 95% Confidence Intervals (CI) during each of the 6 days post-weaning that piglets were: (A) manipulating littermates and performing social play in all litters, (B) lying and being in the creep area in all litters, and (C) exploring the floor for object vs. control litters due to a significant interaction between treatment and day, when having access to three objects of different type (object) or no access to objects (control), ($n = 20$ piglets within 5 litters/treatment).

Weight gain

Body weight data of piglets in different treatments are shown in Table 3. Piglets from O litters had a significantly lower pre-weaning ADG compared to piglets from C litters ($Chi^2 = 4.36$, DF = 1, $P < 0.05$). There was no effect of breed ($Chi^2 = 1.11$, DF = 1) and sex ($Chi^2 = 0.25$, DF = 1) on pre-weaning ADG and no effect of treatment ($Chi^2 = 2.23$, DF = 1), sex ($Chi^2 = 0.21$, DF = 1) or breed ($Chi^2 = 1.95$, DF = 1) on post-weaning ADG (overall $P > 0.1$). The covariate post-weaning ADG was significant for lying ($Chi^2 = 7.52$, DF = 1, $P < 0.01$, Estimate 1.84) and exploring floor ($Chi^2 = 17.45$, DF = 1, $P < 0.0001$, Estimate −3.19). Piglets with a higher ADG post-weaning were lying more and exploring the floor less. The covariate post-weaning ADG was significant for locomotor play ($Chi^2 = 4.42$, DF = 1, $P < 0.05$, Estimate −18.85), with piglets having a higher ADG post-weaning showing less locomotor play. No other covariates were significant.

A positive correlation between the number of recordings of social play and locomotor play was found for C litters ($P < 0.01$, $r = 0.64$, $n = 20$), but not for O litters ($P > 0.1$, $r = 0.15$, $n = 20$). The correlation analysis also revealed that social play was negatively correlated with pre-weaning ADG ($P < 0.01$, $r = -0.50$, $n = 40$) and post-

Table 3. Body weight (mean ± SE) within 24 h after birth (birth weight), at weaning and at 11 days post-weaning of focal piglets with access to three types of objects (object) or without access to objects (control).

Measures	Object Mean ± SE	Control Mean ± SE
Birth weight (kg)	1.5 ± 0.08	1.7 ± 0.08
Weaning weight (kg)	11.0 ± 0.59	12.8 ± 1.09
Weight 11 days post-weaning (kg)	14.6 ± 0.81	17.1 ± 1.18
Pre-weaning ADG (g/day)	289.3^{a} ± 21.99	334.3^{b} ± 21.62
Post-weaning ADG (g/day)	318.2^{a} ± 35.65	384.1^{a} ± 22.21

Note: Average daily gain (ADG) (mean ± SE) from birth to weaning (pre-weaning ADG) and ADG from weaning to 11 days post-weaning (post-weaning ADG) ($n = 20$ focal piglets/treatment). Within a row, means with different superscripts differ significantly.

weaning ADG ($P < 0.01$, $r = -0.50$, $n = 39$). Furthermore, the locomotor play was negatively correlated with post-weaning ADG ($P < 0.05$, $r = -0.33$, $n = 39$).

Discussion

In this study, we aimed to focus on positive behaviours which may be affected by stress, such as play at weaning in pigs. As predicted, we found that piglets provided with objects (i.e. rope, ball, tyre) before and after weaning manipulated littermates and explored pen fixtures less after weaning than piglets without these objects (control litters). In contrast to our hypothesis, piglets in the object litters had a lower weight gain pre-weaning and there was no difference post-weaning. Performance of play behaviour (i.e. social and locomotor play) was similar between treatments and was negatively related to piglets' weight gain. Our further finding is that exposure to objects had an effect on the pigs' behaviour, especially on exploring the floor. Noteworthy, despite the fact that our results are based on small sample size (5 litters per treatment) and one-fourth of the 20 piglets provided with access to the additional enrichment devices did not use them during our observations, they point out the complexity of effects the environmental enrichment might have on commercial pigs.

A reduction in manipulative activities toward littermates and pen fixtures in piglets with objects may indicate that these piglets experienced different psychosocial consequences at weaning compared to piglets in the control litters. The effect of objects in addition to the straw on the redirected manipulative behaviour has been mentioned before in piglets of the same age (Oostindjer et al., 2011) as well as in younger pigs (for review see Oostindjer et al., 2014). Other studies found a similar effect when comparing the following enrichments to a barren environment at different stages of the piglet's life: straw, logs and branches to piglets weaned at five weeks (Petersen et al., 1995), mushroom compost on a rack to finishing pigs (Beattie et al., 2001), extra space including an area which contained peat and straw in a rack from birth to slaughter at 21 weeks (Beattie et al., 2000), a foam rubber mat on the pen wall, rubber nipples, a Bite-Rite Tail Chew and a soil-filled tray to piglets weaned at two weeks (Bench & Gonyou, 2006), shredded paper or natural fibre rope during the nursing period (Lewis et al., 2006). A more recent study tested wood in the form of small logs and briquettes on 28 days old piglets, newly weaned and mixed, and found that this generated exploratory behaviour (Barbari et al., 2017). Following these findings, we suggest that piglets having objects in our study redirected their manipulative behaviour from the pen and littermates toward the objects. It may be important to redirect piglets' manipulative behaviour towards objects early in life, as manipulative activities toward littermates have been shown to develop into high levels of harmful social behaviours, such as tail biting and belly nosing (Petersen et al., 1995; Beattie et al., 2000, 2001). These behaviours are detrimental to the welfare of pigs and have a negative effect on productivity (Chaloupková et al., 2007; Munsterhjelm et al., 2009).

There was no effect of objects on locomotor and social play, which could be due to different reasons. Firstly, the behavioural elements of locomotor play, such as scampering and pivoting, involve much movement and are therefore probably more dependent on the available space (Oostindjer et al., 2011) than on the materials provided to the pen. Thus piglets, regardless of treatment, had equal possibilities to play as the space allowance was the same. Secondly, the object litters and the control litters in our study were provided daily with equal amount of fresh chopped straw. Straw may provide the most highly valued environmental enrichment for piglets. Thus, the environment may have been sufficient to stimulate similar levels of play with no difference in the level of unpredictability of the environment, which seems to be important for promoting play (Chan & Newberry, 2011). Thirdly, lying behaviour, which gradually increased over the six days, and being in the creep area which decreased, were scored in both treatments as the most pronounced behaviours, although piglets in the object litters tended to lie less. Based on these results, and the fact that lying can be seen as a sign of boredom (minks: Meagher & Mason, 2012) and stress (pigs: e.g. Zupan et al., 2012), we may assume that weaning conditions were less stressful for object piglets, but not to the degree to significantly change their play behaviour compared to the control piglets. Our data on manipulative behaviour, together with the data on the use of the creep area, further support this. However, since the observation time was short (16 min/litter/day), piglets were most likely playing outside these observation periods.

The present study showed that pre-weaning, but not post-weaning, average daily weight gain (ADG) of piglets in the control litters was significantly higher compared to piglets in the object litters. Oostindjer et al. (2011) found a higher pre-weaning weight gain in piglets housed in enriched pens compared to barren pens. The most possible reasons for the difference in the results may be the use of different types of enrichment, the amount of environmental stimuli provided and in the presentation method. In the study by Oostindjer et al. (2011), piglets

were housed in a barren or enriched (increased space allowance, with straw, wood shavings, peat and branches) pen with a confined or loose-housed sow pre-weaning, and then at weaning, at 29 days, they were relocated to a barren or enriched post-weaning pen. Further reasoning could be the daily procedure of hanging in and taking out the objects, which may initially have disturbed our sows and led to reduced milk production. Assuming that the objects had an enriching effect and were valuable to the piglets it can be argued that they became frustrated during times that the objects were not present, as can often be seen in captive animals (Latham & Mason, 2010). This leads us to believe that our pre-weaning treatment may have caused some negative effects on the piglets that may have overtaken the hypothesized benefits of enrichment. We, therefore, propose that in future studies provision of enrichment should be as stable as possible.

Conclusions

Providing piglets with additional objects to straw pre- and post-weaning was found to direct the piglets' attention away from their littermates and pen fixtures post-weaning. This could lead to reduced problems with tail biting and other manipulations of littermates that could be detrimental to their health and welfare. Average daily weight gain was negatively affected by the access to objects before weaning, but not after weaning. A further unexpected finding was that the provision of objects did not affect locomotor and social play, but that piglets performing more play behaviours grew less. The rope stimulated object interaction more than the tyre and the ball, which may indicate that the rope is the most suitable enrichment material.

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