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Effects of preferential social associations on pigs' response to weaning

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ABSTRACT

Farm animals can form preferential associations within their social group. Research has shown that the presence of familiar conspecifics can help to cope with stressful situations. Nonetheless, whether the strength of the relationship matters is largely unknown. Our aim was to investigate the influence of the strength of the social relationship between familiar partners during a stressful event. Pigs (n = 116) were observed pre-weaning for their social interactions and spatial proximity with littermates. From this, preferential associations were calculated based on sociality indices of non-agonistic social behaviours ($\mathbf{SI_{soc}}$) and spatial proximity ($\mathbf{SI_{prox}}$). Pigs were weaned into groups of unfamiliar pigs together with one littermate. The partner was selected based on the strength of their relationship pre-weaning, with pairs from across the SI_{soc} and SI_{prox} distribution. SI_{prox} and non-agonistic social behaviour (SI_{soc}) were included in the statistical analysis as measures of relationship strength. Focal pigs were observed postweaning for their social behaviour and spatial proximity, skin lesions and growth, and salivary cortisol concentration pre-weaning and at 4 h and 48 h postweaning. The strength of the social relationship pre-weaning did not significantly influence the behaviour or proximity towards the familiar partner post-weaning, or the amount of skin lesions or weight gain. Pigs who were weaned with a littermate with whom they were strongly affiliated based on active social behaviour (SI_{soc}) tended to have a lower proportional increase in their cortisol concentration after weaning ($P = 0.07$). Pigs differed in their behaviour towards the familiar partner as compared to the unfamiliar pigs, by directing more aggression towards unfamiliar pigs ($P < 0.001$), and more non-agonistic social behaviours towards the familiar pig ($P < 0.001$). The familiar partner was on average in 12.2% of the observations the nearest neighbour, which in small groups did not differ from random choice while in large groups, this occurrence was higher than expected by chance. The results show that pigs clearly distinguish between familiar and unfamiliar pigs, but that the strength of the relationship with a familiar partner seems to have limited effects at weaning. Although preferential associations in young pigs seem weak, studies on older pigs are needed to investigate whether this is due to the relatively little time they have to establish social preferences prior to weaning.

Implications

Many livestock species form preferential associations, but management practices may disrupt social relationships. Pigs clearly differentiated between familiar and unfamiliar pigs at weaning. However, the strength of the pre-weaning relationship had little effect on their social behaviour, spatial proximity towards their littermate, cortisol or other welfare measures in the week after weaning.

Introduction

Preferential associations between farm animals are increasingly shown in research studies, for example in cattle (Val-Laillet et al., 2009; Swain et al., 2015), sheep (e.g., Ungerfeld et al., 2018) and pigs (Durrell et al., 2004; Goumon et al., 2020). Associations are commonly assessed based on spatial proximity (e.g. Podgorski et al., 2014) or affiliative contact, such as allo-grooming (e.g., Val-Laillet et al., 2009), or both (e.g., Goumon et al., 2020). Strong preferential associations can have benefits to the individuals, such as by providing social support (Rault, 2012), but the importance of social preferences is commonly ignored in animal management, exampled by weaning and regrouping practices.

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Animals can form stronger social bonds with specific individuals of their group. For example, female baboons form their closest bonds with close relatives (Silk et al., 2006a). In macaques, more reconciliation is seen in opponents with strong affiliative ties, thereby confirming the 'relationship quality' hypothesis (Castles et al., 1996). The strength of the social relationship can also influence how much a partner responds to calls (Kern and Radford, 2016). Although comparisons exist between how farm animals respond to familiar conspecifics as compared to unfamiliar ones (e.g., Kanitz et al., 2014), the influence of the strength of the social relationship within familiar conspecifics has been rarely studied. In sheep, lambs prefer their mother over another familiar ewe, but this preference weakens after weaning (Ungerfeld et al., 2018).

The aim of this study was to investigate the influence of relationship strength between familiar partners during a stressful event. This was studied in pigs, as studies on social support show that pigs cope better with a stressful situation (restraint) in the presence of a known conspecific (Reimert et al., 2014) as compared to an unknown conspecific or being alone (Kanitz et al., 2014). Pigs show behaviours that, in specific context or situation, can have affiliative functions. These include social play (Horback, 2014), nose-to-nose contact (Newberry & Wood-Gush, 1986), allo-grooming (Meynhardt, 1982) and lying in contact (Newberry & Swanson, 2008). We hypothesised that partners with a stronger association would show more non-agonistic social behaviour towards each other at weaning and stay in closer proximity to each other than weakly associated partners, and that they would cope better with weaning in terms of a lower cortisol response and better growth.

Material and methods

Animals and housing

Piglets (145 males (51%), 138 females (49%)) of 23 clinically healthy sows (purebred Large White) were before weaning observed for their behaviour, proximity to littermates, and BW. Of these 238 piglets, 116 (60 females, 56 males) were followed after weaning.

Pre-weaning, sows and their piglets were housed in BeFree farrowing pens (Schauer Agrotronic GmbH, Prambachkirchen, Austria, dimensions 2.22 m $\times$ 2.86 m), in which the sow was kept loose at all times except during piglet handling. Piglets had a covered and heated creep area (1.25 m $\times$ 0.61 m), one drinker (*ad libitum* water) and received a commercial piglet feed (pre-starter meal) from seven days of age. Lights were on between 0700 and 1600 h, and the temperature was set at 20 °C. Average litter size at birth was 14.3 piglets (range 2–19). Cross-fostering was applied if the number of piglets exceeded the number of functional teats of the sow, occurring within the first 72 hours postpartum. Within 48 h after birth, piglets' teeth were ground, and each piglet was weighed and marked with a non-invasive coloured Kinesiology tape around the tail for identification (as described in Camerlink et al., 2022). Males were castrated around two weeks of age under general anaesthesia. Piglets were ear-tagged at approximately 19 days of age.

Piglets were weaned at 26 ± SD 1.3 days of age. After weaning, 78 piglets from Batch 1 and 52 piglets from Batch 2 were further studied. Batch 1 was weaned into eight pens of 8–10 piglets each and Batch 2 was weaned into four pens of 12–14 piglets each. At weaning, litters were divided into new groups so that each new group contained maximum one pair of littermates (selection of dyads described below). Thus, in the new groups, focal pigs were familiar to one pig (a littermate) and for the rest encountered unfamiliar pigs. The weaning pens measured 3.1 $\times$ 4.7 m and had a concrete partly slatted floor. Each pen included a covered, heated creep area of 1 $\times$ 3 m, in which straw or wood shavings were provided as bedding material. Pens had a round multi-space feeder with *ad libitum* commercial piglet meal diet and four drinkers. Temperature was regulated through fans and a wall curtain on each side of the room. The temperature was 22.3 ± 1.53 °C (mean ± SD, min: 21.1, max: 25.0).

Behavioural observations

Social behaviours were recorded using the ethogram in Table 1, while noting the actor and recipient of the behaviour. Behaviours were mutually exclusive. Play fight was included in agonistic behaviour due to the fine line between play fighting and escalation into aggression. Behavioural observations were performed using the Animal Behaviour Pro App, version 1.2 (University of Kent, Canterbury, United Kingdom) with the '*ad libitum*' recording function. Live behavioural observations were conducted by two observers pre-weaning once a week (days 4, 11, and 19 postpartum) and over the three consecutive days after weaning (days 28, 29 and 30). Observations were carried out between 1030–1230 h and 1300–1600 h using instantaneous scan sampling. Scan sampling was chosen to obtain more frequent observations on pigs within the limited time frame around weaning, although for short-lived social behaviours, continuous sampling may give a more accurate count. Pre-weaning, two-minute scan sampling per pen was conducted every 12 minutes, resulting in 25 scan samples per pig per day (75 scans in total pre-weaning). Postweaning, five-minute scans were used per four pens (60 scan samples per day and 180 in total postweaning). Observers rotated between the pens for observations. Animals were marked with a marker pen (pre-weaning) or animal marker spray (postweaning) on their back in the morning before observations for better identification, leaving at least a 30-minutes break before the start of the observations. Inter-observer reliability was calculated for the two observers from a 30-min video observation block with BORIS (Friard and Gamba, 2016)

Table 1
Ethogram for social behaviours in pigs. Previously published in Camerlink et al. (2022), licenced under a Creative Commons Attribution 4.0 International Licence (CC BY 4.0), https://doi.org/10.1016/j.applanim.2021.105540. No changes were made to the previously published version. Behaviours were recorded as mutually exclusive.

Item	Behaviour	Description
Total non-agonistic	Nose-to-nose contact	Pig's nose disc or snout makes physical contact with snout or nose disc of another pig, without allo-grooming.
	Allo-grooming	Pig gently nibbles or licks the face (may include the snout, ear, eye region and eye lashes) or body of another pig without causing acute skin damage to the recipient.
	Other non-agonistic social interactions	Pig is nosing the face of another pig, without allo-grooming; is engaged in social play (with other group mates runs, hops, flops or tosses; excluding play fight); or is jointly exploring whereby their heads are in <30 cm proximity whilst engaged in an activity.
Agonistic behaviour	Agonistic behaviour	Pig is engaged in fighting, biting, head knocking, threat or play fight (alternates displays of play and agonistic elements, without causing injury to the partner).
Other	Other	All other behaviour.

using Cohen's Kappa, with a time interval of 5 seconds (average $K = 0.755$).

Nearest neighbour proximity

Proximity was recorded by noting the nearest neighbour when pigs were lying down (either inactive or sleeping) through instantaneous scan sampling, for at least 10 observations per pig per week for weeks 1–5 of life using the Animal Behaviour Pro App with the 'ad libitum' function. Proximity was recorded when at least half of the animals were lying down. Observations were made with at least 30 minutes between each other to avoid pseudoreplication, or <30 minutes when pigs had all changed location (based on observed activity). In case, piglets could not be distinguished due to piling behaviour then the observation was done on the next occasion. Nearest neighbour proximity was classified into lying in body contact or not, and in addition whether they were, or were not, lying in full body contact (minimum 75% in contact) and if they were lying in a head-to-head position or not. Each neighbour was recorded as a single entry, resulting in multiple entries when, for example, a pig was sleeping in body contact with three equally close neighbours. Entries with multiple equally close neighbours at the same time counted towards one sampling moment, in order to have at least ten separate time points per pig per week.

Selection of dyads

Observations of non-agonistic social behaviour (on average 7 per pig) and spatial proximity (on average 23 per pig) prior to weaning were converted into sociality indices. Non-agonistic social behaviour was the sum of nose-nose contact, allo-grooming and other non-agonistic social interactions. The frequency of interactions for the dyad was divided by the frequency of all dyadic interactions of the individual. This is similar to the Simple Ratio, $x/x + y$, which is suitable when all individuals are present in each observation (Cairns and Schwager, 1987). The ratio was divided by the litter size to adjust for the number of animals in a group, as this influences the number of interactions and possible partners.

The value was then divided by the average of the study population to obtain a value which reflects how much a dyad deviates from the average value of 1 (Silk et al., 2006b). This resulted in a sociality index **(SI)** for non-agonistic social interactions between dyads (**SI_{soc}**) and one for the proximity between each possible dyad (**SI_{prox}**). The two measures did not correlate (Spearman correlation between behaviour and proximity across all pigs on individual level: $r = 0.01$, $P = 0.53$) and were therefore kept separate. In the absence of a correlation, combining these measures was not justified (Camerlink et al., 2022).

Fifty-eight dyads (116 pigs) were selected from the study population while aiming for similar scores for both non-agonistic social behaviour and spatial proximity within dyad (based on the two scores falling in the same quartile of the distribution). Dyads were, where possible, balanced for sex and BW. This resulted in the formation of 24 male–female dyads, 18 female dyads and 16 male dyads. Dyads were selected from across the distribution with a focus on the tails of the distribution (Fig. 1).

Salivary cortisol

In total, 88 pigs were selected from across the distribution of the sociality index and had saliva samples taken at 24 hours before weaning, 4 hours postweaning and 48 hours postweaning. Sampling took place consistently at midday (1100–1400) to minimise the influence of the circadian rhythm. Samples were collected using the Salimetrics Children Swab (SalivaBio Children's Swab, Salimetrics) with Salivette®. During the preparation, collection and storage of the samples, the handlers wore gloves to avoid contamination of the sample. The swab was secured with a plastic zip tie that was held at all times by the person to prevent the pig from swallowing the swab. Half of the swab (6.25 cm long × 0.8 cm diameter) was introduced in the pigs' lower buccal mucosal region of the mouth, leaving the pig free to open or close the mouth. The swabs were left in for 45 seconds, and if the pig rejected the swab by spitting it out, then the swab was reintroduced for maximum of another 15 seconds. The Salivette® with sample was then put in a cooling styrofoam box on dry ice and transferred to the freezer, before being brought to the University lab for storage (−80 °C freezer) and further laboratory processing. Saliva samples were thawed on ice and centrifuged for 20 minutes at 4 °C at 1 500*g*, with the supernatant transferred to a tube kept at −20 °C until being assayed.

Saliva samples were analysed for free cortisol concentrations by ELISA (Saliva Cortisol Enzyme Immunoassay Kit No. 1-3002, Salimetrics, Carlsbad, CA, USA), running each sample in duplicate. Not all pigs had sufficient aliquots in the saliva sample at each time point, and only the pigs that had at least 50 µl in the pre-weaning sample and at least one other sample (4 hours post or 48 hours post) were analysed. Consequently, samples from 42 pigs were excluded and the remaining samples from 46 pigs were analysed (total 122 samples). Samples from the same individual were analysed on the same plate to minimise the influence of inter-assay variation according to the within-subject sampling design. Samples with an intra-assay CV > 10 were reanalysed, and after reanalysis had a CV < 5%, with an overall average CV of 2.27%.

Skin lesions, BW and health measures

Piglets were weighed on day 2, 25 (day before weaning), 28 and 33 days of age (two and seven days postweaning, respectively). Average daily gain (**ADG**) in g/d was calculated between weaning and 2 days postweaning, and between 2 and 7 days postweaning (5 days). A skin lesion score was recorded 2 days after weaning on a scale of 0–4, based on the number of fresh skin lesions (red, without scab formation) on the total body surface due to aggression. The scores were assigned as, Score 0: <5 lesions; Score 1: 5–10 lesions; Score 2: 11–20 lesions; Score 3: 21–50; and Score 4: >50 lesions (categories were based on the Welfare Quality® protocol for pigs but extended to better capture variation in regrouping aggression). Joint inflammation, facial dermatitis, knee scabs, diarrhoea, skin condition and body condition were scored but are not further reported due to a lack of variation in the scores (nearly all zeroes and a body condition score around 3 (2.9 ± 0.33)).

Data analysis

Data were analysed in SAS version 9.4. The behaviour and nearest neighbour proximity pre-weaning was only used for the selection of dyads and not further analysed here (pre-weaning data were reported in Camerlink et al., 2022). Pre-weaning cortisol and all postweaning observations were analysed as follows. All dependent variables were assessed for normality of the model residuals and homogeneity. All posthoc comparisons were adjusted for multiple testing using the Tukey-Kramer adjustment. *P*-values below 0.05 are considered significant whereas *P*-values between 0.05 and 0.10 are mentioned as tendencies.

Social behaviour and spatial proximity data

Social behaviour and spatial proximity data are first presented descriptively. Due to the low occurrence of nose-to-nose contact and allo-grooming, these were pooled with 'Other non-agonistic social interactions' for the statistical analyses, creating the variable

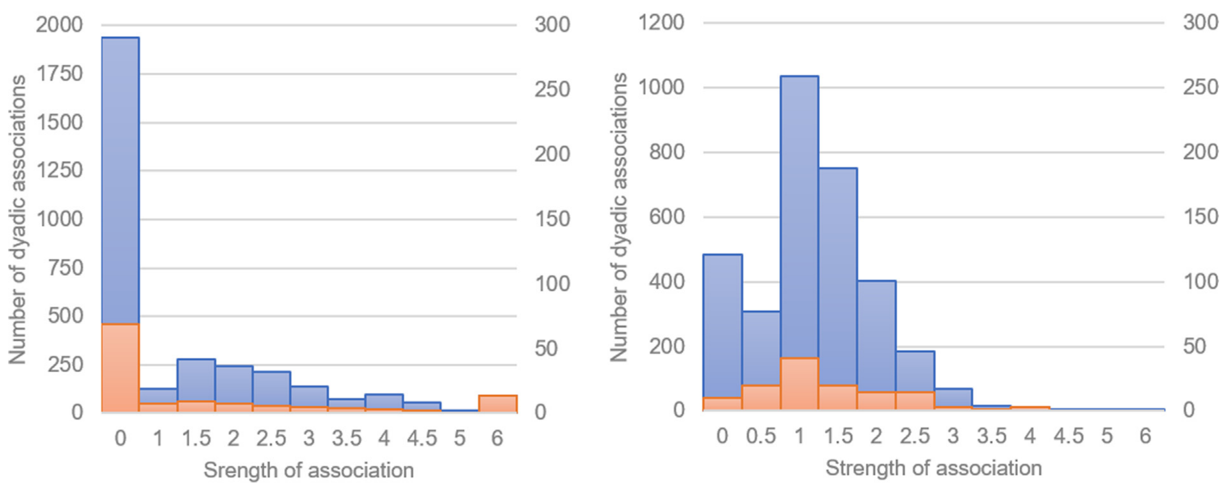

Fig. 1. The distribution of the strength of the dyadic associations pre-weaning, based on non-agonistic social interactions (left) and spatial proximity (right) (observed between 1 and 3 weeks of age), for all possible dyad combinations on the primary *y*-axis (in blue) and the selected piglets on the secondary y-axis (in orange).

'total non-agonistic interactions'. Animals with fewer than six observations on nearest neighbour proximity (n = 22) were removed from the data on proximity, as it was considered too few to provide a reliable estimate of a preferred lying partner. Proximity was expressed as percentage of observations lying in physical contact with the familiar partner as compared to unfamiliar pigs. The same was done for lying in full body contact and lying head-to-head.

As there were between 8 and 14 pigs per group, the chance of directing a behaviour towards a penmate randomly was 7–14%. To test whether behaviours were directed more towards the familiar partner than could be expected by chance, total non-agonistic and agonistic interactions and lying in contact were tested against the conservative chance level of 14% (h0 = 14) using one-sample *t*-test.

The proportion of total non-agonistic social interactions directed to the familiar partner after weaning was analysed as a response variable in a general linear mixed model with as predictor variables SI_{soc}, SI_{prox}, their interaction, sex, weaning weight and group size. Batch and group nested within batch were included as the random variables. The model residuals were normally distributed.

Due to a low frequency of agonistic behaviours towards the familiar partner (described in results), the data were transformed to a binary variable and analysed in a generalised linear mixed model (GLIMMIX Procedure) with a binary distribution and logit link function. The predictor and random variables were the same as in the model for non-agonistic interactions.

The percentage of lying in physical contact with the familiar partner after weaning was analysed as response variable in a general linear mixed model with as predictor variables SI_{soc}, SI_{prox}, their interaction and group size. Batch and group nested within batch were included as random variables. The percentages of lying in full body contact and lying head-to-head are described descriptively, as they did not meet the model assumptions, also not after transformation.

Cortisol data

Cortisol concentration, as well as the relative change in cortisol between the three sampling points, was analysed as response variable in a linear mixed model (MIXED Procedure) with repeated observations per animal. The predictor variables were SI_{soc}, SI_{prox}, their interaction, the sampling time point (basal/4 hours post-weaning/48 hours postweaning), the interactions between SI_{soc} and sampling time point and SI_{prox} and sampling time point, sex (male/female), BW at weaning (covariate) and skin lesion score (0–4). Batch and group nested within batch were included as random variables, with pig ID as repeated measure (using the Option 'subject =' statement). Given the large number of variables, the model was stepwise reduced to achieve the best model fit based on the AIC and BIC values.

Skin lesion and BW data

The skin lesion score (0–4) was analysed as response variable in a generalised mixed model (GLIMMIX Procedure) with multinomial distribution and cumlogit link. The predictor variables were SI_{soc} and SI_{prox}, their interaction, sex and BW at weaning. Batch and group nested within batch were included as random variables.

Similarly, ADG in the 48 hours (two days) after weaning and ADG from two to seven days postweaning (5 days) were analysed as response variables in a linear mixed model with SI_{soc} and SI_{prox}, their interaction, sex and weight at 2 days of age. Batch and group nested within batch were included as random variables.

Results

Social behaviour

The social behaviours constituted on average 20.8% of the scans during the behavioural observations after weaning, with 16% being non-agonistic social behaviours (Table 2). The non-agonistic social behaviours were on average in 23% of the observations directed towards the familiar partner when shown. The chance of randomly directing a behaviour to another pig was 7–14%; therefore, the total of non-agonistic interactions were directed towards the familiar partner more often than expected by chance (t_{115} = 4.78, P < 0.001) while agonistic behaviour was directed towards the familiar partner less often than expected by chance (t_{115} = −6.93, P < 0.001). In fact, while 94% of the pigs showed agonistic behaviour, only 19.8% of the pigs showed agonistic behaviour towards their familiar partner during the observations.

The proportion of all non-agonistic social interactions with the familiar partner, and the agonistic behaviour towards unfamiliar pigs, were not influenced by the strength of the relationship (SI_{soc} and SI_{prox}) pre-weaning (both P > 0.10). There was also no interac-

Table 2
Behaviour of pigs (n = 116) in the 3 days postweaning (day 28, 29 and 30 of age), as observed through scan sampling (180 scans/pig across the 3 days). Values are the average number of scans (with SD) in which the behaviour was observed; the percentage of pigs observed performing the behaviour; the average percentage of the scans (with SD) in which this behaviour was directed to the familiar partner by all focal pigs; and the average percentage of the scans (with SD) in which this behaviour was directed to the familiar partner only for the subset of pigs observed performing the behaviour.

Behaviour	Mean ± SD	% pigs performing	% directed to the familiar partner	% directed to the familiar partner out of the pigs performing the behaviour
Nose-to-nose contact	1.8 ± 1.73	71	13.6 ± 27.33	19.2 ± 30.8
Allo-grooming	4.8 ± 4.17	40	11.3 ± 30.85	28.4 ± 44.0
Other non-agonistic social interactions	9.4 ± 5.16	100	22.0 ± 20.26	22.0 ± 20.26
Agonistic behaviour	4.8 ± 4.17	94	5.0 ± 13.93	5.4 ± 4.32

Table 3
Spatial proximity between pigs (n = 116) in the 3 days postweaning (day 28, 29 and 30 of age). Observations were on lying in (any) physical contact, which was additionally scored as lying in full body contact (>75% of bodies touching) and lying head-to-head (not mutually exclusive). Values are the percentage of pigs (%) and number of observations of lying in contact; the percentage of pigs and number of observations out of all observations (n = 1 013) in which pigs were lying next to the familiar partner; and the percentage in which the subset of pigs observed performing the behaviour were lying next to the familiar partner.

Spatial proximity	% of pigs performing (n obs.)	% of pigs with the partner as nearest neighbour (n obs.)	% of pigs with the partner as nearest neighbour, out of the pigs performing the behaviour
Lying in contact	94.9 (961)	10.9 (110)	11.4
In full body contact	49.0 (496)	6.0 (61)	12.3
Head-to-head	57.5 (582)	7.3 (74)	12.7

Abbreviation: n obs. = number of observations.

tion between SI_{soc} and SI_{prox}. A larger group size resulted in a reduction in non-agonistic social behaviour towards the familiar partner (b = −4.4 ± 1.89%/pen mate; $F_{1,85}$ = 5.56, P = 0.02), as well as a reduction in agonistic behaviour towards the familiar partner (b = −0.5 ± 0.16; $F_{1,85}$ = 8.62, P = 0.004). Sex and weaning weight did not significantly influence the occurrence of social behaviours towards the partner (all P > 0.10).

Spatial proximity

Pigs were lying in 94.9% of the observations in physical contact with their nearest neighbour after weaning; mostly in a head-to-head orientation and half of the time in full body contact (Table 3). The familiar partner was the nearest neighbour in 11.8% (120) out of the 1 013 observations on proximity. Percentages were similar for lying in contact, fully body contact and head-to-head with the partner, when based on the occurrence of the behaviour (Table 3). The percentage of lying closest to the familiar partner as compared to an unfamiliar pig (mean ± SD: 12.2 ± 11.93%) was not significantly different from the expected chance level of 14% (t_{99} = −1.45, P = 0.15) but did differ from 7% (t_{99} = 4.42, P < 0.001). This means that in small groups (eight in a group), whether the nearest neighbour was familiar or unfamiliar was random chance, while when the group size was larger (14 pigs in a group), this was not random. The percentage of lying in contact with the familiar partner was unaffected by the strength of the relationship to the partner pre-weaning (SI_{soc} and SI_{prox}).

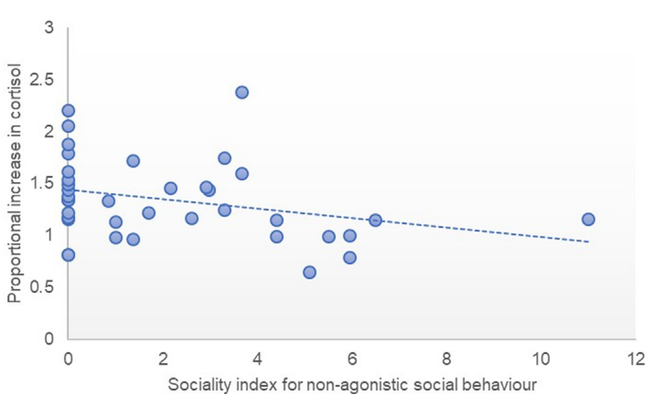

Fig. 2. Proportional increase in salivary cortisol concentration between baseline (pre-weaning) and 48 hours postweaning in pigs (n = 46) in relation to their pre-weaning sociality index for non-agonistic social behaviour. A stronger sociality index indicates that the pair of pigs interacted more often. The relationship shows a non-significant tendency (P = 0.07).

Cortisol

The saliva cortisol concentration increased after weaning and peaked at 48 hours postweaning, with a strong time effect ($F_{2,74}$ = 17.31; P < 0.001). Cortisol at 48 hours postweaning was significantly higher (0.238 ± 0.009 µg/dL) than the basal level pre-weaning (0.188 ± 0.008 µg/dL; P < 0.001) and at 4 hours postweaning (0.203 ± 0.009 µg/dL; P < 0.001). The cortisol values did not significantly differ according to the SI_{aff} and SI_{prox}, sex, skin lesions scores, BW or the social interactions (all P > 0.10).

Pigs with a stronger preference for their partner based on behaviour pre-weaning (SI_{soc}) tended to have a smaller proportional increase in cortisol concentration than pigs with a weaker association (b = −0.03 ± 0.015; $F_{1,58}$ = 3.51; P = 0.07; Fig. 2) across the time points, with no significant interaction between SI_{soc} and time point (P > 0.10). The proportional change between sampling points differed between the time points ($F_{2,58}$ = 3.76; P = 0.03), with the proportional increase being smaller between basal and 4 h postweaning than between basal and 48 hours postweaning (P = 0.03). The proportional change in cortisol did not differ according to SI_{prox}, sex, skin lesions, BW or the social interactions (all P > 0.10).

Skin lesion score and BW

The skin lesion score had similar percentages of pigs per category (score 0: 27%, 1: 20%, 2: 22%, 3: 22%, 4: 9%). The only significant predictor for the skin lesion score was weaning weight ($F_{1,82}$ = 17.31; P < 0.001), with the average BW for pigs without lesions being lower than for pigs with higher lesion scores (score

0: 6.9 kg ± 2.15 (mean ± SD); 1: 7.5 ± 1.68 kg; 2: 7.6 ± 1.46 kg; 3: 8.7 ± 1.19 kg; 4: 8.5 ± 1.27 kg).

BW at weaning was on average (mean ± SD) 7.7 ± 1.75 kg. ADG from weaning to 2 d later was 0.05 ± 0.146 g/d (range −0.45 to 0.35) and from 2 to 7 d postweaning 0.09 ± 0.134 g/d (−0.34 to 0.44). None of the predictor values, including SI_{soc} and SI_{prox}, significantly influenced ADG at 2 hours or 7 days postweaning, but females tended to gain more weight from 2 to 7 days postweaning (mean ± SE: 0.12 ± 0.055 g/d) than males (0.07 ± 0.055 g/d) ($F_{1,90}$ = 3.64; P = 0.06).

Discussion

Overall, the results showed no clear effect of the strength of social relationships pre-weaning on the behaviour and physiology postweaning.

There was no significant effect of the strength of the pre-weaning relationship on the behaviour or spatial proximity post-weaning, but pairs with a stronger association based on their pre-weaning behaviour (SI_{soc}) tended to have a smaller cortisol response to weaning than pairs with a weaker association. While this was non-significant, it suggests that the strength of pre-weaning relationships might matter, as has been shown in primates (Crockford et al., 2008; Wittig et al., 2008). SI_{soc} was based on a small number of non-agonistic social interactions given piglets' inactivity in their first three weeks of life. This result would therefore benefit from confirmation with a dataset with more hours of observation, continuous sampling and preferably observations closer to weaning when piglets are more active (see also Camerlink et al., 2022). However, such design would be considerably more labour intensive and leave little time for selection of the dyads prior to weaning.

Overall, the results suggest that the strength of the social preferences prior to weaning is generally weak. The lack of strong social preferences in pigs has been mentioned previously (Durrell et al., 2004; Goumon et al., 2020). Newberry and Wood-Gush (1986) reported that young pigs in a semi-natural environment have social preferences but that these do not persist over time. They postulated that this is an adaptive behaviour in which fitness benefits are derived from equal group relationships rather than selective relationships. Remaining as a group together, rather than preferentially associating with some, may indeed be beneficial for prey species as it supports group cohesion. Evans and Morand-Ferron (2019) showed that black-capped chickadees (*Poecile atricapillus*) prioritise social cohesion over preferential contact, thereby supporting the 'social cohesion hypothesis' over the 'social preference hypothesis'. However, it should be taken into consideration that the pigs in this study were very young and that the first three weeks of life may provide relatively little time to establish strong relationships.

The sociality indices (**SI**) were based on non-agonistic social behaviour and spatial proximity (nearest neighbour), which were kept as separate measures based on earlier analysis showing that these two variables do not correlate in indoor-housed pigs, which may be partly due to the effect of temperature on spatial proximity (Camerlink et al., 2022). The measures were included as continuous variables, in line with their distribution. Categorising the SI into strong versus weak associations has the benefit of creating a stronger statistical contrast but is based on subjective thresholds (Silk et al., 2013) or a bimodal distribution, which does not reflect the true distribution we observed. Based on the results related to cortisol, as well as previous work (Goumon et al., 2020; Camerlink et al., 2022), non-agonistic social behaviour pre-weaning seems to be a better candidate than spatial proximity (based on recording the nearest neighbour) for future studies aiming to determine preferential associations, at least in indoor-housed pigs. However, different measures of spatial proximity (*e.g.,* nearest neighbour, distance, orientation) may result in different outcomes and may depend on the housing conditions, such as space allowance and the number of resting areas. Therefore, spatial proximity may be of relevance under circumstances where spatial preferences can be more clearly expressed, i.e. when provided with more space. Similarly, careful consideration of the types of non-agonistic behaviour is required as nose contact and social play positively correlate with agonistic behaviour (O'Malley et al., 2022). Nose contact in pigs has multiple functions (Camerlink and Turner, 2013), and the distinction may lie in the nuance between nose-to-nose proximity and physical nose contact. As these behaviours may be expressed with different intentions (e.g., to affiliate, communicate or assess each other) and may be perceived by the recipient in different ways (e.g., as positive or negative), non-agonistic social behaviours can be ambiguous and are, at least in pigs, not easily categorised as affiliative or exclusively positive.

Focal pigs did markedly differ in the behaviour towards their familiar partner as compared to the new unfamiliar group mates, by showing less agonistic behaviour and more non-agonistic social behaviour to their familiar partner. This is in line with previous studies that compared the behaviour towards familiar and unfamiliar pigs (Camerlink et al., 2014; Verdon et al., 2019), and is related to the need to establish dominance relationships with unfamiliar pigs (Meese and Ewbank, 1973), with hierarchies being established and maintained through agonistic behaviour. In the current study, pigs were regrouped with one familiar littermate, which allows no option to show a preference among familiar conspecifics within a challenging situation (as in Kanitz et al., 2014). Future studies could therefore look at the effect of social preferences during challenging situations when there are multiple familiar conspecifics as potential partners, as well as the effect of social preference during less intense situations than after weaning. A larger group size resulted in less non-agonistic and agonistic behaviour towards the partner, which is likely a consequence of the need to divide interactions over more group members. In larger groups (of 80), pigs maintain the ability to assess familiarity but show markedly less aggression, possibly as a strategy to conserve energy in the establishment of dominance relationships (Turner et al., 2001).

In groups of 14 pigs, the familiar partner was the nearest neighbour more often than by chance but this was not the case in small groups of seven. This is in contrast to the literature, where groups of six pigs kept a closer spatial proximity to familiar rather than unfamiliar pigs (Camerlink et al., 2014). In a larger group of eight free-range litters, piglets preferred littermates until eight weeks of age and thereafter preferred non-littermates as nearest neighbour (Petersen et al., 1989), although the social integration in the aforementioned study was gradual rather than abrupt. The reason for our finding related to group size is unclear, but we speculate that in the small groups, pigs may have stayed closer together for thermoregulation (Camerlink et al., 2022), as the space allowance per pig was larger.

The strength of the pre-weaning relationship did not influence skin lesions or growth performance after weaning. Familiarity to other piglets at weaning has been shown to result in fewer skin lesions (e.g., Salazar et al., 2018) and keeping familiar pigs together instead of mixing unfamiliar pigs results in a better growth performance (e.g., Stookey and Gonyou, 1994). Heavier pigs had more skin lesions, which has been found across studies (e.g., Turner et al., 2006).

Overall, familiarity between pigs at weaning strongly influenced their social behaviour whereas the strength of the familiar relationship had only few apparent effects, based on the measures collected within this study.

Ethics approval

The study protocols were approved by the Ethical Committee (ETK) of the University of Veterinary Medicine (Vetmeduni), Vienna, Austria (reference ETK-04/01/2019) and the R(D)SVS Veterinary Ethical Review Committee, Edinburgh, UK (reference 57.19).

Data and model availability statement

The data/models were not deposited in an official repository. Data are available upon request to the corresponding author.

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Declaration of interest

None.

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