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# Friend or foe: effects of social experience and genetic line on responses of young gilts in a social challenge paired interaction test

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A B S T R A C T

The increased focus on group housing of sows in commercial pig production emphasises the importance of saving appropriate gilts which later become sows that are well-adapted to group housing systems. This study aimed to assess the short-term effects of social mixing experience and genetic line on social and exploration responses of young gilts in standardised 3-min social challenge paired interaction tests. The study included 96 gilts, from 26 litters, of two different genetic lines (Swedish Yorkshire and Dutch Yorkshire). These lines were chosen because the dam lines have been selected in group-housed and individual stall systems, respectively, a background which was hypothesised to have modified their social behaviour over time. The gilts were subjected to different early (opportunity to co-mingle with piglets in the neighbouring farrowing pen vs. no opportunity to co-mingle) and late (mixed with unfamiliar piglets at weaning vs. kept with familiar littermates after weaning) social mixing treatments, to test whether the enhanced social experience was beneficial in a socially challenging situation. Paired interaction tests were conducted at 5 and 20 weeks of age, and social and exploration behaviour of the gilts was recorded and analysed. The results showed that Swedish Yorkshire gilts explored the pen fittings more than Dutch Yorkshire gilts during the 5-week test, whereas Dutch Yorkshire gilts explored the pen fittings more than Swedish Yorkshire gilts during the 20-week test. No differences in play behaviour were found during the 5-week test, but in the 20-week test, gilts with early social mixing experience in their farrowing pen showed more locomotor play behaviour than gilts without this experience. Overall, these results suggest that genetic line and early social mixing experience can influence the social and exploration behaviours of young gilts in paired interaction tests. There was no support for the hypothesis that genetic selection in different housing systems has altered social behaviour, but it may have affected the level of exploration behaviour. There was little support for our prediction that early social experience has beneficial effects in a socially challenging situation.



## Implications

A future where sows are group housed requires pigs to be well-adapted to this system, ensuring their own health, sustainability and welfare, as well as resource efficiency and economic sustainability. This study showed that socialisation and genetic line can partly influence pig behaviour in a social challenge test situation. These findings improve understanding of how pigs' social abilities develop and should be taken into account when developing management strategies.

## Introduction

Wild boars (*Sus scrofa*) are highly social and live together in maternal groups with related females and their offspring (Petersen et al., 1989; Kaminski et al., 2005; Poteaux et al., 2009). In this social environment, pigs have the opportunity to create relationships and practise social behaviours with individuals other than littermates and the mother sow from approximately 10 days of age, when the sow reunites with the group after farrowing (Petersen et al., 1989; Kanaan et al., 2012, Salazar et al., 2018). Young females can thus form individualised social relationships that continue to adult age (Podgórski et al., 2014; Peden et al., 2018; Bieber et al., 2019).

The behavioural repertoire of domesticated pigs (*Sus scrofa domesticus*) has been documented to be as diverse as that of the wild boar (Stolba and Wood-Gush, 1989; D'Eath and Turner,

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2009) and their behavioural needs and capacity are adapted to different social contexts at different ages. Domesticated pigs have similar social needs to their wild counterparts (Goumon et al., 2020), but their social behaviour has to some extent been altered through domestication and modern breeding (Rydhmer, 2021). For example, some pig dam lines have been evaluated and selected based on performance in individual stalls and others on performance in group housing systems. Thus, even though social ability has not been included as a breeding trait, sows may have been indirectly selected for social behaviours favourable for these different systems. This is the case for Swedish and Dutch Yorkshire lines (**SY** and **DY** respectively), where SY has been evaluated and selected in group housing dry sow systems since the 1980 s and DY in stall systems.

In housing systems for intensive piglet production, piglets have few opportunities to socialise with pigs outside their own litters during the nursing period. This leads to stress and fights when they are mixed with unfamiliar pigs after weaning, which has become a welfare problem in pig production (Coutellier et al., 2007; Colson et al., 2012; Turner et al., 2017). In commercial housing systems, early socialisation, where piglets in adjacent pens are given access to each other by opening barriers between the pens, has been shown to alter social behaviour in piglets. Examples of this are that while piglets with extra social experience are quicker to initiate fighting when meeting unfamiliar pigs (Salazar et al., 2018), they show reduced fighting, both number and duration of the fights, and new hierarchies are established faster in new groups after weaning (e.g. D'Eath, 2005; Kanaan et al., 2012; Salazar et al., 2018; Camerlink et al., 2019; Weller et al., 2019; Oldham et al., 2020). Moreover, piglets that have been socialised with piglets in a neighbouring pen show more appropriate social behaviours than piglets without such social experience (Weller et al., 2019). This ability of animals to optimise their social behaviour to the demands of their social environment is known as social ability (Varela et al., 2020; Taborsky, 2021), and it is a multifactorial trait (Dingemanse and Wolf, 2013). Evaluating the social ability of pigs in their home pen environment and group is time-consuming and difficult to standardise; however, the social ability of individual pigs can be evaluated in standardised tests (e.g. D'Eath and Pickup, 2002; D'Eath, 2004; Koolhaas et al., 2013; Camerlink et al., 2015; Camerlink et al., 2019; Turner et al., 2020). In such tests, the immediate reaction and social response of the individual are evaluated within the specific social context of the test. The evaluation includes both the general activity of the individual, e.g. explorative and play behaviour, and behaviour during any social interactions. In animal welfare research, play has been identified as a potential indicator of positive animal welfare (Lawrence, 1987; Held and Špinka, 2011) and locomotor play, in particular, can be seen in response to access to larger and/or novel areas in pigs of different ages (Rauw, 2013, Horback, 2014).

In line with European Union (**EU**) regulations, group housing of dry sows has been mandatory since 2013, while there are ongoing discussions on the adoption of group housing for farrowing sows. Group housing systems, which allow for interactions between adult sows and piglets, have not been thoroughly examined in terms of their impact on the social learning abilities of piglets.

The aim of this study was to assess the short-term effects of social mixing and genetic line of gilts reared in loose housing pens on the social and exploration response in standardised social challenge paired interaction tests. The starting hypothesis was that gilts with extra social mixing experience and gilts of the Swedish Yorkshire line would explore their surroundings more, perform more locomotor play behaviour (associated with higher behavioural flexibility) and be more active and reactive in social interactions during paired interaction tests at both 5 and 20 weeks of age, compared with gilts of the Dutch Yorkshire line.

## Material and methods

The study was performed at the Swedish Livestock Research Centre, Lövsta, Uppsala, Sweden, during February 2018–April 2019.

### *Animals, housing and management*

This study included 96 gilts of two different genetic lines; 100% Swedish Yorkshire (SY) or at least 75% Dutch Yorkshire (DY). The gilts originated from 26 litters divided over seven batches (A-G) (i.e. 3 or 4 litters per batch) with the first batch born in January and the last in November 2018. These litters and their mother sows were housed in farrowing pens (total size: 3.35m × 2.0 m) including a concrete lying and feeding area (2.1 m × 2.0 m), a dunging area consisting of a slatted floor (1.25 m × 2.0 m) and a concrete-floored piglet corner with a heat lamp, a roof and floor heating, which only piglets could access. The average litter size at birth was 15 (15.0 ± 4.93 piglets, mean ± SE). At birth, the staff weighed (Table 1) and determined the sex of the piglets, and then four gilts from each litter were selected as focal animals for the study. All litters did not include four gilts; thus, the final number of gilts included in the study was 96. If there were more than four gilts in the litter, gilts with the best vitality, excluding the heaviest and the lightest gilts in the litter, were selected. For easier identification, the focal gilts of this study received ear tags of another colour (blue, red, white, green) than the colour (yellow) that the other piglets in the litter had. At the same time as the ear-tagging (3.9 ± 0.78 days), an iron supplement intramuscular injection of 1 mL (Uniferon, 200 mg/mL) was given. At approximately 2 weeks of age (13.1 ± 1.79 days), a second injection of the same amount of iron supplement was administrated.

The pens were manually cleaned every morning. Two days before the estimated date of farrowing, the sows were provided with straw (approximately 15–20 kg of chopped straw). Due to the slatted floor in the pen, the amount of straw gradually decreased and, as straw should always be available for sow and piglets in a farrowing pen (according to common Swedish management routines), additional straw was provided when needed. Sows were fed a standard commercial dry feed for lactating sows twice daily until the piglets were approximately 10 days old, and thereafter, sows were then fed three times a day until weaning. Dry creep feed (200 g per pig per day) for piglets was provided on the floor in the piglet corner, from when the piglets were about 2 weeks old. An *ad libitum* feeder was added in the piglet corner when the piglets reached approximately 3 weeks of age. The sow and the piglets had *ad libitum* water supply from two drinking nipples, placed at 0.1 m and 0.15 m above the slatted floor.

The sow stayed in the pen with the piglets until weaning, at approximately 5 weeks (34.3 ± 1.87 days) after the birth of the piglets. Piglets were individually weighed at weaning and at 9 weeks of age (Table 1). The piglets stayed in the pen until approximately 10 weeks of age (69.2 ± 1.72 days), when they were moved to a growing stable, focal gilts were separated out from the rest of the litter and housed in groups of four gilts per pen. The grower pens (3.96 m × 1.80 m) consisted of a concrete-floored lying and feeding area, and a slatted dunging area measuring 1.80 m × 1.0 0 m. The slatted dunging area was elevated 0.18 m from the concrete floor. The gilts were provided with dry feed three times per day, according to a standard feeding regime for breeding gilts, in the feeding trough (1.80 m × 0.23 × 0.15 m) placed along the short side and at the opposite end of the pen to the slatted floor. Water was available *ad libitum* from two drinking nipples, placed one over the other, at 0.43 m and 0.63 m above the slatted floor. Each pen was manually cleaned every morning and provided with approximately 350 g of straw each day. The health of the pigs was moni-

**Table 1**
Pig birth weights, weight at 5 weeks of age and weight at 9 weeks of age per genetic line (Swedish Yorkshire or Dutch Yorkshire), early social mixing (Access pen or Control pen) and late social mixing (Intact group or Mixed group).

| | Weights of focal gilts | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total | Genetic line | | Early social mixing | | Late social mixing | |
| | | SY | DY | AP | CP | IG | MG |
| N | 96 gilts | 42 gilts | 54 gilts | 49 gilts | 47 gilts | 50 gilts | 46 gilts |
| (Mean ± SD) | | | | | | | |
| Birth weight | 1.6 ± 0.26 | 1.7 ± 0.22 | 1.5 ± 0.28 | 1.6 ± 0.25 | 1.6 ± 0.28 | 1.5 ± 0.22 | 1.7 ± 0.26 |
| Weight at 5 weeks of age | 11.9 ± 2.11 | 12.2 ± 1.73 | 11.6 ± 2.35 | 11.8 ± 2.14 | 11.9 ± 2.10 | 11.6 ± 2.25 | 12.1 ± 1.95 |
| Weight at 9 weeks of age | 28.9 ± 4.26 | 29.3 ± 3.50 | 28.5 ± 4.78 | 29.3 ± 4.10 | 28.5 ± 4.43 | 28.2 ± 4.56 | 29.6 ± 3.82 |

Abbreviations: SY = Swedish Yorkshire; DY = Dutch Yorkshire; AP = Access pen; CP = Control pen; IG = Intact group; MG = Mixed group.

tored daily by farm staff, and any deviation from normal health was treated and documented.

*Early social mixing treatments*

In each farrowing batch, two litters were assigned to an early socialisation treatment, and two were assigned to a control treatment. A pop-hole (0.35 m × 0.30 m) was placed in the piglet corner between two pens (Fig. 1) making it possible for piglets, but not sows, to move between the two pens, thus creating an extended co-mingling social mixing environment) for the litters in the access pen (**AP** treatment). The pop-hole was opened when the litters reached 2 weeks of age (13.1 ± 1.79 days), which corresponds to the time when piglets would socialise with new piglets in a sow group in the wild (Jensen, 1986) and hence provided a relatively natural early social mixing environment in a conventional setting. The pop-hole was closed at weaning.

The other two pens in each farrowing batch did not have a pop hole and were used for the control treatment (**CP**). The design was balanced with two AP and two CP pens per batch, and two DY and two SY pens per batch, which meant that the piglets in the AP treatment met piglets of the other genetic line. However, due to the lack of available SY litters, two of the 13 litters of piglets in the AP treatment did not have the opportunity to co-mingle with a litter of the opposite breed. Instead, two DY litters met and co-mingled in the AP treatment in one batch, while in another batch, a DY litter met and co-mingled with a crossbreed litter (SY*DY piglets). The litter of SY*DY piglets was not included in the analysis.

*Late social mixing treatments*

At approximately 10 weeks of age (67.9 ± 7.66 days), focal gilts were moved to an experimental growing pig stable and allocated into groups of four in one of two late social mixing treatments. Selected gilts were either placed in an intact group (**IG**), where they were housed with gilts from their own farrowing litter, or allocated to groups of four with gilts from two birth litters so that each gilt was mixed with one familiar and two unfamiliar gilts in mixed groups (**MG**). The remaining piglets left the study.

This design resulted in four combinations of social experience balanced over genetic lines:

- Early social experience AP and late social experience MG (11 SY gilts and 15 DY gilts)
- Early social experience AP but no late social experience IG (8 SY gilts and 15 DY gilts)
- No early social experience CP, but late social experience MG (12 SY gilts and 8 DY gilts)
- No early social experience CP and no late social experience IG (11 SY gilts and 16 DY gilts)

An overview of the experimental design is given in Fig. 2.

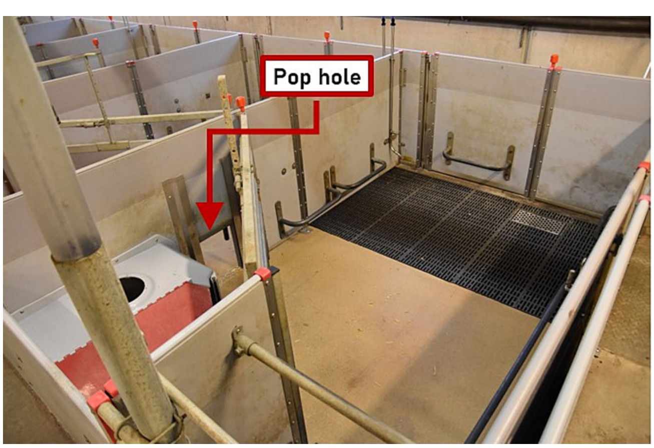


**Fig. 1.** Picture of empty and cleaned access pens (AP), created from conventional loose housing farrowing pens for pigs with a pop-hole located between the piglet corner in each pen.

*Paired interaction tests*

*Paired interaction test at 5 weeks of age*

At weaning, when the gilts were approximately 5 weeks old, the first paired interaction test (designated PIT5w) took place. Each focal gilt was paired with an unfamiliar opponent gilt, reared in the same farrowing unit and farrowing batch, but from a regular conventional pen and from a litter without any of the focal gilts included in the study. Gilts were weighed the day before testing, and the opponent gilt had as similar weight as possible to the focal gilt (0.1 ± 1.78 kg weight difference). The paired interaction test (**PIT**) at 5 weeks was performed in the farrowing stable where the gilts were held, in a separate arena unfamiliar to all gilts (Fig. 3). The test arena (7.5 m × 1.5 m) had a concrete floor (5.0 m × 1.5 m) and a metal tread plate (covering the manure system) at each end of the area (1.25 m × 1.5 m each). They were not habituated to the test area.

The focal gilt and the opponent gilt were taken separately from their home pens and guided using a driving board to separate sides of the test arena. A technician thereafter started the PIT at 5 weeks by opening the gate separating the pigs so that they both had access to the whole test arena. The interaction test lasted 3 min, after which the focal gilt and the opponent gilt were guided back to their home pens. A camera (Garmin VIRB Ultra 30) located on the focal gilt side of the test pen was used to record the test. A technician stood outside the test arena to intervene if the social interactions became too aggressive or stressful and therefore overstepped the endpoints. The endpoint and termination of the ongoing PIT were reached if the pigs caused puncture wounds, injuries, or harmed themselves by slipping on the surface. Intervention was however never needed.

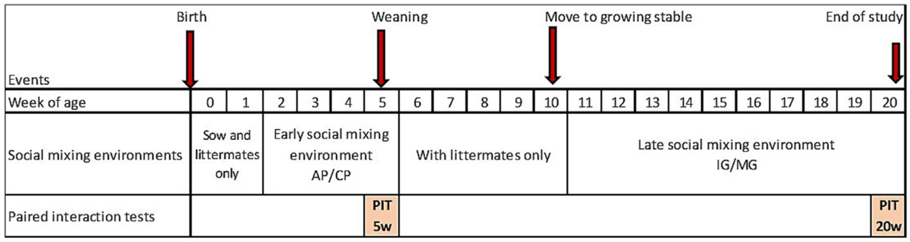


**Fig. 2.** Timing of early social mixing environment (Access Pen (AP) or Control pen (CP)), late social mixing environment (Mixed group (MG) or Intact group (IG) and paired interaction tests (PITs) in the gilt's life in relation to weeks of age.

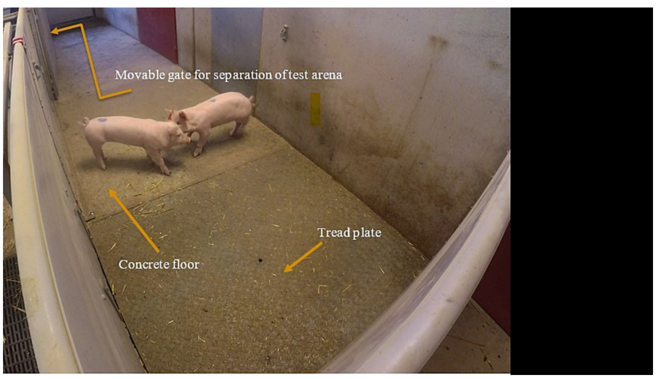


**Fig. 3.** The test arena for pigs in the paired interaction test at 5 weeks of age (PIT5w).

*Paired interaction test at 20 weeks of age*

When the gilts were 20 weeks old, the second paired interaction test (PIT20w) took place in a new test arena, located in the corridor outside the stable. The area was enclosed by movable gates that were 0.91 m high (Fig. 4). The test arena measured 10.25 m × 3. 50 m and had a concrete floor, although about one-third of the floor consisted of metal tread plates. As previously, the gilts were not habituated to the test arena.

The two gilts participating in the test were taken from their pens and placed in starting pens on either side of the test arena. Two technicians then opened the gates to the test arena so that the gilts entered the arena at the same time. The gate to the test arena was closed when each gilt had entered the arena with all legs. In contrast to the PIT at 5 weeks of age, where the gilts met gilts from litters that were not included in the study, the gilts in the PIT at 20 weeks of age instead met another gilt from the study. The gilts were always matched with a gilt from the other early social environment, but limitations due to the number of gilts in each batch meant that genetic line and late social environment could not always be taken into consideration. The test lasted 3 min and was filmed using a camera (Garmin VIRB Ultra 30) placed approximately 1.5 m above the ground in a corner of the test pen. After the test, the gilts were separated using a driving board and led back to their home pens. Two technicians stood outside of the test arena ready to intervene if necessary, but intervention was never needed.

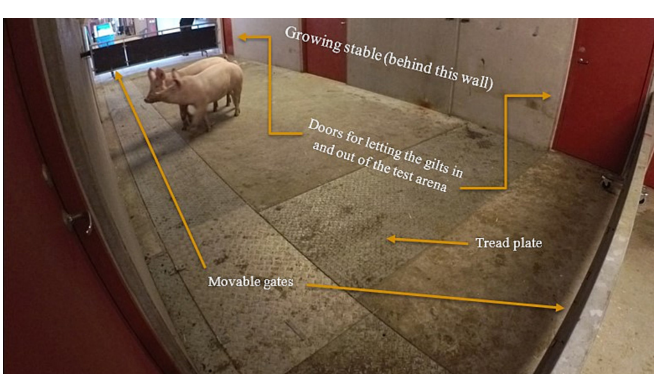


**Fig. 4.** The test arena for pigs in the paired interaction test at 20 weeks of age (PIT20w).

*Behavioural observations*

Behavioural observations were made from the videos recorded during both PIT occasions, and all observations were performed by the same trained observer. All focal gilts were continuously observed for 3 min. In the PIT at 5 weeks, the video analysis started when the door between the gilts was opened, while in the PIT at 20 weeks, the video analysis started when both gilts had all four legs within the test arena. As both gilts in the PIT at 20 weeks were focal animals, these films were analysed twice, once per focal gilt. All behaviours were observed continuously and recorded individually for each focal gilt and test (observation) minute. In the continuous recordings, a change in behaviour or a pause of a specific behaviour lasting at least 3 sec was set as a criterion for it to be recorded as a new behaviour. Social interactions were classified as an interaction between two pigs, and the gilt which was the performer (initiated the social behaviour) and the receiver (responded to the social behaviour) was noted. The event-logging software BORIS v. 7.9.8 – 2020-01-28 (Friard and Gamba, 2016) was used for all behavioural observations. Body posture and the distance between gilts, details of the first interaction, locomotor play behaviours, activity and social behaviours were recorded using an ethogram (Table 2), which was developed from ethograms used in previous studies (e.g. Xin et al., 1989; De Leeuw and Ekkel, 2004; Welfare Quality, 2009) and from pilot studies within the research project (Nihlstrand, 2016; Hannius, 2019; Vahlberg, 2019; Emriksson, 2021).

*Statistical analyses*

Data from BORIS were exported to and edited in Microsoft Excel 2016 for statistical analyses. The statistical analyses of the PIT at 5 weeks included 95 gilts, as data for one gilt of the genetic line SY in early social treatment CP were missing due to camera failure. In the PIT at 20 weeks analyses, 94 gilts were included, due to missing observations related to video quality for two gilts of the genetic line DY in the CP and MG treatment combinations. Statistical analyses were performed using the R software (R Core Team, 2021), implementing all models in the R package stats-package (R: The R Stats Package, 2021; R Core Team 2021). Level of significance was set at $P < 0.05$. The statistical models used were developed based on backward stepwise selection of effect, includ-

**Table 2**
Ethogram of behaviours recorded and variables analysed in the paired interaction test (PIT) carried out on gilts at 5 and 20 weeks of age.

| Behaviour category | Variable name | Definition | Variable type in statistical analysis or reason for not analysed further |
|---|---|---|---|
| **Body posture & distance** – Scan sample every 15 s, statistical unit; observation minute per focal gilt | | | |
| | Lying on the belly | Lying on the belly, with head in a nearly vertical position, front legs not outspread to the side | Did not occur |
| | Lying on the side | Lying on the side, head/legs on the side | Did not occur |
| | Sitting | Front feet on the ground, back legs in lying position | Did not occur |
| | Standing | On all four feet, standing or walking | The focal gilts always stood up during recordings |
| | Distance | 0 = The distance between the pigs is less than an equal size pig<br>1 = The distance between the pigs is greater than an equal size pig | Binary |
| **First interaction** – Recorded once per test, focal gilt statistical unit | | | |
| | Latency | Seconds from start of the test until first touch (snout touching the other pig) | Continuous (s) |
| | Meeting on focal gilt side | First touch appeared on the same side as the focal gilt started on | Binary |
| | Focal gilt approached first | The focal gilt was the first to approach (touch) the other pig | Binary |
| **Locomotor play behaviour** – continuous sampling, statistical unit; observation minute per focal gilt | | | |
| | Hop/spring | Jumping up and down in one spot while facing in one direction | Binary |
| | Scamper | A sudden forward movement of at least two hops in rapid succession | Binary (merged with "Sprint") |
| | Sprint | A sudden forward motion either towards or away from conspecific | Binary (merged with "Scamper") |
| | Pivot | Jumping or whirling around to face in a different direction | Binary |
| | Toss head | Exaggerated lateral displacement of the head and neck in the horizontal plane, involving at least one full movement to each side | Binary |
| | Play at all | Any of the play behaviours (hop/spring, scamper, pivot or toss head) | Binary |
| **Activity** – continuous sampling, statistical unit; observation minute per focal gilt | | | |
| | Explore pen fitting | Amount of times the snout touched the pen fittings | Continuous |
| | Explore pen floor | Amount of times the snout touched the pen floor | Continuous |
| **Social interactions** – statistical unit; observation minute per focal gilt | | | |
| **Social interaction performing pig** -continuous sampling | | | |
| | Nose to body | Snout touching the receiving pig's body | Binary |
| | Nibbling/biting | The pig nibbles or bites the receiving pig | Binary |
| | Climbing | Stepping and lying on top of the receiving pig | Binary |
| | Levering | The pig puts its snout under the body of the receiving pig and lifts the pig up in the air | Binary |
| | Pushing | Displacing the receiving pig by pushing any region of the body | Binary |
| | No sound | Either the pig is silent or it is not possible to identify where the sound is coming from | Binary |
| | Grunt | The pig is producing a low-frequency vocalisation | Binary |
| | Scream | The pig is screaming, barking or squealing | Binary |
| **Social interaction receiving pig**- continuous sampling | | | |
| | No reaction | No change in body position or activity | Binary |
| | Avoiding | Moving away from the performing pig | Binary |
| | Nose to body | Snout touching the receiving pig's body | Binary |
| | Pushing | Displacing the receiving pig by pushing any region of the body | Binary |
| | Nibbling/biting | The pig nibbles or bites the receiving pig | Binary |
| | No sound | Either the pig is silent or it is not possible to identify where the sound is coming from | Binary |
| | Grunt | The pig is producing a low-frequency vocalisation | Binary |
| | Scream | The pig is screaming, barking or squealing | Binary |

ing all possible interactions between effects. The aim of model development was to create harmonised models for clusters of variables with the same characteristics, taking into account the statistical significance of the effects, best possible fit of the model (based on AIC and BIC) and biological relevance. PITs at 5 weeks and PITs at 20 weeks were analysed separately. Compared to the models for the PIT at 5-weeks, the models for the analyses of the PIT at 20 weeks also included effects of the late social mixing environment of the focal gilt, and the genetic line and late social environment of the opponent gilt. As the gilts in the PIT at 20 weeks always met a gilt with the opposite early social mixing treatment, this was not part of the model.

The response variables "Latency", "Meeting on focal gilt side" and "Focal gilt approached first" were analysed with focal gilt as the statistical unit. "Latency" was analysed with a Gaussian generalised linear model, while "Meeting on focal gilt side" (first touch on the same side as the focal gilt started: yes (1) or no (0)) and "Focal gilt approached first" (first touch by the focus gilt: yes (1) or no (0)) were analysed with binomial generalised linear models. For analyses of "Latency", "Meeting on focal gilt side" and "Focal gilt approached first" in the PIT at 5 weeks, genetic line and early social mixing environment were set as fixed effects, including interactions between the fixed effects. For the PIT at 20 weeks, genetic line, early social mixing environment, late social mixing environment, opponent's genetic line and opponent's late social mixing environment were set as fixed effects.

The response variables "Distance", "Play", "Performing social interactions", "Receiving social interactions", "Explore floor" and "Explore pen fitting" were analysed with observation minute per focal gilt as the statistical unit. "Distance" (percentage of 15-sec scans the gilts spent close to each other each minute) was analysed with a Gaussian generalised linear model. "Play" (performing during the observation minute: yes (1) or no (0)), "Performing social interactions" (performing during the observation minute: yes (1) or no (0)) and "Receiving social interactions" (receiving during the observation minute: yes (1) or no (0)) were analysed with binomial generalised linear models. "Explore floor" (counts per observation minute) and "Explore pen fitting" (counts per observation minute) were analysed with Poisson generalised linear models. For analyses of "Distance", "Play", "Performing social interactions", "Receiving social interactions", "Explore floor" and "Explore pen fitting" in the PIT at 5 weeks, genetic line, early social mixing environment and observation minute were set as fixed effects, including interactions between the fixed effects. For the PIT at 20 weeks, genetic line, early social mixing environment, late social mixing environment, observation minute, opponent's genetic line and opponent's late social mixing environment were set as fixed effects, including interactions between the fixed effects.

In order to compare classes of fixed effects and combinations of classes of interactions between fixed effects in all models, ANOVA tables were created using the function joint:tests from the R package emmeans (Lenth et al., 2022). *Posthoc* pairwise comparisons were carried out with the function emmeans from the emmeans package for the significant variables identified in the joint:test table. Resulting *P*-values were adjusted using the Bonferroni method.

## Results

Descriptive statistics of gilt responses in the 5-week test are presented in Tables 3 and 4 and for the 20-week test in Tables 5 and 6.

### *Effects of genetic line and minute of interaction on gilt responses during the 5-week test*

Treatment effects were observed for genetic line and minute of interaction, but not for early social mixing. The SY gilts explored the pen fittings more than the DY gilts (1.83 ± 0.11 and 1.30 ± 0.10 (LSMeans ± SE) times per observation minute, respectively (F = 12.70; df = 273; $P$ < 0.001). Both SY and DY gilts explored the pen fittings more in the last observation minute of the test than in the first and second observation minute (1.3 ± 0.13, 1.4 ± 0.13, 1.9 ± 0.13 times per min (LSMeans ± SE) in observation minutes 1,2 and 3, respectively) (F = 6.26; df = 273; $P$ = 0.002).

The gilts spent less time close together during the first observation minute of the test than during the second and third observation minutes (60.5 ± 2.16, 82.6 ± 2.16 and 79.1 ± 2.16% (LSMeans ± SE) in observation minutes 1,2 and 3, respectively) (F = 30.03; df = 273; $P$ < 0.0001).

The response behaviour of receiving pigs to avoid a social interaction increased over the duration of the test (80.5 ± 2.93, 15.9 ± 3.97 and 25.3 ± 4.78% (LSMeans ± SE) in observation minutes 1, 2 and 3, respectively) (F = 4.29; df = 273; $P$ = 0.014).

### *Effects of genetic line, minute of interaction and early and late social mixing on gilt responses during the 20-week test*

Treatment effects were observed for genetic line, early social mixing and minute of interaction, but not for late social mixing. Gilts from the genetic line SY were closer to the opponent gilt than gilts from the DY line (73.8 ± 2.46 and 65.0 ± 2.30 (LSMeans ± SE) % of scans close the other pig per observation minute, respectively) (F = 6.89; df = 232; $P$ = 0.009). Distance to the other pig varied between observation minutes of the test (69.3 ± 2.74, 79.1 ± 2.74 and 62.8 ± 2.74% (LSMeans ± SE) in observation minutes 1, 2 and 3, respectively) (F = 7.84; df = 232; $P$ < 0.001), with gilts being close to each other most often during the second observation minute of the test.

Gilts with additional early social mixing experience were more likely to display locomotor play behaviours in the PIT at 20 weeks of age than gilts without (binary, i.e. percentage of gilts playing at least once during the observation period 59.2 ± 4.73 (AP) and 43.7 ± 5.78 (CP) % (LSMeans ± SE) (F = 4.12; df = 232; $P$ = 0.042). The $P$ of playing varied between the observation minutes (70.0 ± 5 .68, 42.1 ± 6.25 and 41.3 ± 6.32% (LSMeans ± SE) in observation minutes 1, 2 and 3, respectively) (F = 6.54; df = 232; $P$ = 0.001), with gilts showing more locomotor play behaviour during the first observation minute.

The DY gilts explored the pen fittings more than the SY gilts (1.34 ± 0.11 and 0.93 ± 0.10 times per observation minute, respectively (LSMeans ± SE) (F = 7.75; df = 232; $P$ = 0.005). Exploration of pen fittings increased over the duration of the test (0.8 ± 0.11, 1.0 ± 0.12 and 1.7 ± 0.15 times per minute (LSMeans ± SE) in observation minutes 1, 2 and 3, respectively) (F = 11.92; df = 232; $P$ < 0.001), with more exploration in the last observation minute of the test compared with the 1first and second minutes.

Exploration of the floor also increased over time during the test (2.6 ± 0.19, 2.8 ± 0.20 and 3.9 ± 0.23 times per minute (LSMeans ± SE) in observation minutes 1, 2 and 3, respectively) (F = 13.23; df = 232; $P$ < 0.001), and the gilts explored the pen floor more in the last observation minute of the test. Moreover, differences in exploration behaviour were observed in the interaction between genetic lines and late social mixing environments (F = 9.41; df = 232; $P$ = 0.002) (Fig. 5).

## Discussion

The initial hypothesis in this study was that gilts with extra social experience and gilts of the SY genetic line would exhibit greater exploration of their surroundings, engage in more locomo-

**Table 3**
Responses in the paired interaction test at 5 weeks of age for gilt of the genetic lines (Swedish Yorkshire or Dutch Yorkshire) and early social environments (Access pen or Control pen) for the non-binary variables: latency (unit: seconds), close distance (unit: percentage of time), explore pen fitting (unit: the number of times that explore pen fitting was observed) and explore floor (unit: the number of times that the behaviour of exploring the floor was observed).

| | Genetic line | | Early social environment | |
|---|---|---|---|---|
| | SY | DY | AP | CP |
| Item | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| Latency (s) | 21.3 ± 13.75 | 23.6 ± 15.60 | 24.2 ± 16.64 | 21.0 ± 12.51 |
| Close distance (% of time) | 0.7 ± 0.22 | 0.7 ± 0.23 | 0.7 ± 0.23 | 0.7 ± 0.23 |
| Explore fitting (N times) | 1.8 ± 1.35 | 1.3 ± 1.19 | 1.4 ± 1.21 | 1.7 ± 1.36 |
| Explore floor (N times) | 3.2 ± 1.51 | 3.5 ± 1.46 | 3.6 ± 1.40 | 3.1 ± 1.53 |

Abbreviations: SY = Swedish Yorkshire; DY = Dutch Yorkshire; AP = Access pen; CP = Control pen.

**Table 4**
Social interaction behaviours (binary variables) shown by the pigs under the paired interaction test (PIT) at 5 weeks divided over the genetic lines (Swedish Yorkshire and Dutch Yorkshire) and early social environments (Access pen and Control pen).

| | 5-week paired interaction test – binary variables | | | |
|---|---|---|---|---|
| | Genetic line | | Early social environment | |
| | SY | DY | AP | CP |
| Unit | % | % | % | % |
| First interaction | | | | |
| Meeting on focal gilt side | 48.8 | 57.4 | 46.9 | 60.9 |
| Focal gilt first | 31.7 | 42.6 | 30.6 | 45.7 |
| Activity | | | | |
| Hop/spring | 0.0 | 1.2 | 0.0 | 1.4 |
| Scamper | 18.7 | 16.0 | 15.0 | 19.6 |
| Pivot | 8.9 | 8.0 | 6.8 | 10.1 |
| Toss head | 0.0 | 3.1 | 2.0 | 1.4 |
| Play at all | 22.8 | 21.6 | 17.7 | 26.8 |
| Social behaviour- performing | | | | |
| Nosing body | 67.5 | 72.2 | 69.4 | 71.0 |
| Nibbling/biting | 16.3 | 4.9 | 12.2 | 7.2 |
| Climbing | 4.9 | 0.6 | 3.4 | 1.4 |
| Levering | 4.1 | 2.5 | 2.7 | 3.6 |
| Pushing | 10.6 | 7.4 | 10.9 | 6.5 |
| Social at all | 75.6 | 75.3 | 73.5 | 77.5 |
| Social more than once | 45.5 | 38.3 | 38.8 | 44.2 |
| Sound at all | 37.4 | 27.2 | 28.6 | 34.8 |
| Sound more than once | 10.6 | 8.0 | 8.2 | 10.1 |
| No sound | 59.3 | 58.6 | 57.8 | 60.1 |
| Grunt | 35.8 | 27.2 | 27.2 | 34.8 |
| Scream | 2.4 | 0.0 | 2.0 | 0.0 |
| Social behaviour receiving | | | | |
| No reaction | 51.2 | 46.3 | 49.7 | 47.1 |
| Avoiding | 17.9 | 16.7 | 14.3 | 20.3 |
| Nosing body | 25.2 | 30.9 | 28.6 | 28.3 |
| Pushing | 4.1 | 3.1 | 3.4 | 3.6 |
| Nibbling/biting | 6.5 | 7.4 | 7.5 | 6.5 |
| Social at all | 74.0 | 71.0 | 71.4 | 73.2 |
| Social more than once | 12.2 | 8.0 | 8.2 | 11.6 |
| Sound at all | 27.6 | 18.5 | 21.1 | 23.9 |
| Sound more than once | 9.8 | 6.8 | 4.8 | 11.6 |
| No sound | 65.0 | 65.4 | 64.6 | 65.9 |
| Grunt | 25.2 | 17.3 | 18.4 | 23.2 |
| Scream | 3.3 | 2.5 | 2.7 | 2.9 |

Abbreviations: SY = Swedish Yorkshire; DY = Dutch Yorkshire; AP = Access pen; CP = Control pen.

**Table 5**
Responses in the paired interaction test at 20 weeks of age for gilt of the genetic lines (Swedish Yorkshire or Dutch Yorkshire), early social environments (Access pen or Control pen) and late social environments (Mixed group or Intact group) for the non-binary variables: latency (unit: seconds), close distance (unit: percentage of time), explore pen fitting (unit: the number of times that explore pen fitting was observed) and explore floor (unit: the number of times that the behaviour of exploring the floor was observed).

| | Genetic line | | Early social environment | | Late social environment | |
|---|---|---|---|---|---|---|
| | SY | DY | AP | CP | MG | IG |
| Item | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| Latency (s) | 11.8 ± 6.75 | 11.5 ± 6.60 | 11.5 ± 6.77 | 11.8 ± 6.57 | 11.8 ± 7.30 | 11.4 ± 6.06 |
| Close distance (% of time) | 0.7 ± 0.21 | 0.7 ± 0.29 | 0.7 ± 0.26 | 0.7 ± 0.26 | 0.7 ± 0.25 | 0.7 ± 0.27 |
| Explore fitting (N times) | 1.0 ± 1.10 | 1.4 ± 1.35 | 1.3 ± 1.27 | 1.2 ± 1.25 | 1.2 ± 1.25 | 1.3 ± 1.27 |
| Explore floor (N times) | 2.8 ± 1.87 | 3.4 ± 1.81 | 3.2 ± 1.85 | 3.2 ± 1.87 | 3.2 ± 1.86 | 3.2 ± 1.86 |

Abbreviations: SY = Swedish Yorkshire; DY = Dutch Yorkshire; AP = Access pen; CP = Control pen; MG = Mixed group; IG = Intact group.

tor play behaviour, and show increased activity and reactivity in social interactions during socially challenging paired interaction tests at both 5 and 20 weeks of age. The results showed that gilts with early social mixing experience were more likely to display locomotor play behaviour during the 20-week test than gilts in the control treatment, confirming that social experience can influence gilts' responses in this challenging scenario. Among the SY gilts, but not the DY gilts, experience of late social mixing meant that they were more likely to explore the pen floor during the 20-week test than gilts in the control treatment. Thus, the effects of genetic line on responses in the socially challenging paired interaction test were confirmed. Moreover, SY gilts explored the pen fittings more than DY gilts during 5-week test, as predicted. During the 20-week test, however, DY gilts explored the pen fittings more than SY gilts. During our observations, it was clear that social interactions of different types occurred during the social challenging tests (Tables 4 and 6). However, the occurrence of social behaviour was not clearly influenced by social experience or genetic line.

**Table 6**
Social interaction behaviours (binary variables) shown by the pigs under the paired interaction test (PIT) at 20 weeks divided over the genetic lines (Swedish Yorkshire and Dutch Yorkshire), early social environments (Access pen and Control pen) and late social environments (Mixed group or Intact group).

| | 20-week paired interaction test – binary variables | | | | | |
|---|---|---|---|---|---|---|
| | Genotype | | Early social environment | | Late social environment | |
| | SY | DY | AP | CP | IG | MG |
| Unit | % | % | % | % | % | % |
| First interaction | | | | | | |
| Meeting on focal gilt side | 41.5 | 56.6 | 70.8 | 28.3 | 44.0 | 56.8 |
| Focal gilt first | 26.8 | 26.4 | 20.8 | 32.6 | 29.4 | 24.4 |
| Activity | | | | | | |
| Hop/spring | 4.9 | 10.7 | 11.6 | 4.4 | 10.9 | 5.2 |
| Scamper | 37.4 | 54.7 | 48.3 | 45.9 | 56.5 | 37.0 |
| Pivot | 13.0 | 15.7 | 15.6 | 13.3 | 13.6 | 15.6 |
| Toss head | 4.1 | 1.3 | 1.4 | 3.7 | 4.1 | 0.7 |
| Play at all | 45.5 | 59.7 | 57.1 | 49.6 | 61.9 | 44.4 |
| Social behaviour- performing | | | | | | |
| Nosing body | 72.4 | 64.2 | 67.3 | 68.1 | 71.4 | 63.7 |
| Nibbling/biting | 22.8 | 13.8 | 19.7 | 15.6 | 21.1 | 14.1 |
| Climbing | 4.1 | 0.0 | 2.0 | 1.5 | 0.7 | 3.0 |
| Levering | 0.8 | 0.6 | 1.4 | 0.0 | 1.4 | 0.0 |
| Pushing | 4.1 | 3.1 | 2.0 | 5.2 | 2.7 | 4.4 |
| Social at all | 79.7 | 66.0 | 72.1 | 71.9 | 74.8 | 68.9 |
| Social more than once | 42.3 | 33.3 | 37.4 | 37.0 | 41.5 | 32.6 |
| Sound at all | 9.8 | 7.5 | 6.8 | 10.4 | 12.2 | 4.4 |
| Sound more than once | 2.4 | 0.6 | 1.4 | 1.5 | 2.7 | 0.0 |
| No sound | 78.0 | 62.9 | 68.7 | 70.4 | 71.4 | 67.4 |
| Grunt | 9.8 | 7.5 | 6.8 | 10.4 | 12.2 | 4.4 |
| Scream | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Social behaviour receiving | | | | | | |
| No reaction | 34.1 | 39.6 | 32.7 | 42.2 | 38.3 | 36.2 |
| Avoiding | 14.6 | 25.2 | 13.6 | 28.1 | 20.6 | 20.6 |
| Nosing body | 46.3 | 47.8 | 51.0 | 43.0 | 48.9 | 45.4 |
| Pushing | 3.3 | 1.9 | 2.0 | 3.0 | 2.8 | 2.1 |
| Nibbling/biting | 8.9 | 9.4 | 10.9 | 7.4 | 7.8 | 10.6 |
| Social at all | 54.5 | 62.9 | 57.8 | 60.7 | 60.3 | 58.2 |
| Social more than once | 19.5 | 23.3 | 19.0 | 24.4 | 22.0 | 21.3 |
| Sound at all | 7.3 | 6.3 | 8.2 | 5.2 | 5.0 | 8.5 |
| Sound more than once | 1.6 | 1.3 | 0.0 | 3.0 | 0.0 | 2.8 |
| No sound | 68.3 | 72.3 | 67.3 | 74.1 | 66.0 | 75.2 |
| Grunt | 5.7 | 5.0 | 8.2 | 2.2 | 5.0 | 5.7 |
| Scream | 1.6 | 2.5 | 1.4 | 3.0 | 0.0 | 4.3 |

Abbreviations: SY = Swedish Yorkshire; DY = Dutch Yorkshire; AP = Access pen; CP = Control pen; IG = Intact group; MG = Mixed group.

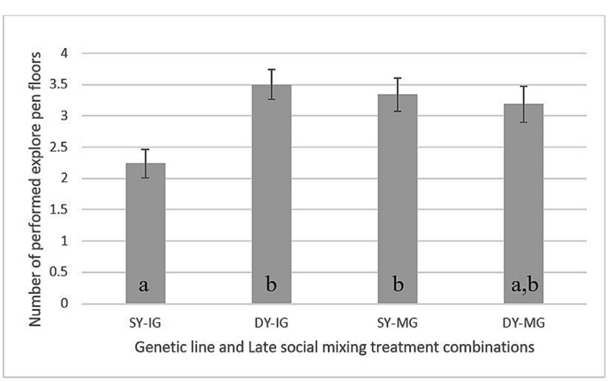


**Fig. 5.** Number of 'explore floor' events performed by the focal gilts per treatment (genetic line: Swedish Yorkshire (SY) or Dutch Yorkshire (DY) and late social mixing environment: Mixed group (MG) or Intact group (IG)) combinations in the paired interaction test at 20 weeks of age (PIT20w) (Least Square Means ± SE). Different letters (a,b) for different observation minutes indicate pair-wise differences at $P < 0.05$.

*Effects of social treatments*

Overall, the social mixing experience had minor effects on the gilt's behavioural responses in the PITs. Behaviours indicating negative social behaviours were very low, and instead, the effects related to the positive welfare indicator of play behaviours were observed. Play is a cognitively demanding activity which reduces attentiveness to external threats, so play behaviour generally occurs when animals perceive their situation as safe (Špinka et al., 2001). In this study, we expected gilts with extra social experience (AP and/or MG) to exhibit more locomotor play behaviour, as their greater exposure to complex situations might make them perceive the situation as safer compared to gilts with less social experience (CP and/or IG). Although extra pre-weaning social experience had no effect on locomotor play behaviour at the 5-week test, it did lead to more locomotor play behaviour by the 20-week test. This suggests that gilts with additional pre-weaning social experience (AP/MG) may have developed better social skills and perceived the test situation as relatively safe, or at least less negative, compared to gilts with less social experience. This is in line with previous findings that early socialised animals have higher behavioural plasticity (Edwards and Telkänranta, 2024) and occurred despite no prior habituation to the arena. The extra socialisation pre-weaning perhaps provided an additional level of complexity to the social environment (Edwards and Telkänranta, 2024) in the early development of AP/MG gilts, since besides the early social experience, they also experienced a change of environment.

*Effects of genetic line*

Social ability is not included as a breeding trait in modern pig breeding and is thus not directly selected for, but sow lines have been indirectly selected for social behaviours favourable for the environment in which they were evaluated and selected. The SY line has been evaluated and selected in group housing systems since the 1980 s, while in the same period, the DY line has been indirectly selected for social behaviours favourable for individually stalled systems. Therefore, we expected gilts of the SY line to display more social behaviour and be more alert to their surroundings than gilts of the DY line. But, in contrast to previous findings of indirect genetic effects on aggressive behaviour (Canario et al., 2012; Camerlink et al., 2013), we observed no differences in social behaviour between the genetic lines. Interestingly, gilts from the SY line spent more time in close proximity to the opponent gilt during the 20-week test, indicating perhaps that they sought social support in the new and unknown environment. However, as there were no differences in social interactions between the genetic lines, this finding should be interpreted with caution.

We also expected gilts of the SY line to explore their surroundings more, because the SY line has been selected to thrive in a more complex group housing social environment than gilts of the DY line. We found that SY gilts explored the pen fittings more in the 5-week test, but not in the 20-week test (where DY gilts showed more exploration behaviour than SY gilts). SY gilts with the late social mixing environment of IG also showed less exploration of the floor during the 20-week test. In a novel situation and arena, exploration of the pen interior may indicate that the pig is not startled and is calm enough to show interest in the surrounding environment.

*Changes in behaviour over time*

Even though the social challenging test was only 3 min long, changes in behaviour during the test were observed in both the 5- and 20-week tests. In the 5-week test, gilts spent less time in close proximity during the first minute of the test and they explored the pen fittings more in the last minute. They also showed an increase in avoidance of social interactions when approached by the other individual over time in the test. In the 20-week test, gilts expressed most locomotor play during the first minute, spent more time close to one another during the second minute and spent more time exploring both floor and fittings of the test arena during the last minute of the test. These appear to be logical changes in behaviour over time in the test, with initial excitement in the novel area, resulting in locomotor play (Rauw, 2013, Horback, 2014), and thereafter increased interest in the other pig and the pen fittings and floor.

Previous studies have shown that additional social experience gained from meeting new individuals during the suckling period improves piglets' social skills and reduces the duration of aggression (e.g. D'Eath, 2005; Salazar et al., 2018; Morgan et al., 2014; Martin et al., 2015). However, all those studies were carried out in conventional crated systems or in experimental settings. In the present study, commercial loose housing pens were used. Furthermore, in previous studies of co-mingling, the test piglets have been intended for slaughter rather than as breeding sows in piglet production. As loose housing of farrowing sows is becoming the new standard in the EU and may be mandatory if the proposed ban on sow crates is introduced (European Union, 2023), additional investigations into loose housing systems are required.

## Ethics approval

The experiment and all procedures involved were approved by the National Ethics Committee for Animal Experiments in Uppsala (Registration number: 5.8.18-16279/2017).

## Data and model availability statement

None of the data have been deposited in an official repository. The data that support the study findings are available from the authors upon request.

## Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) did not use any AI and AI-assisted technologies.

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## Declaration of interest

None.

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