Applied Animal Behaviour Science 284 (2025) 106548

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

# The effects of cow-calf-contact rearing on dairy animals' social traits – a pilot study

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A R T I C L E I N F O

*Keywords:*
Cattle
Ontogeny
Personality
Social competence
Isolation
Maternal behaviour

A B S T R A C T

Early separation of the calf from the dam, mostly within 24 h after birth, is common for dairy cows, but cow-calf contact (CCC) rearing gets increasing interest from both practice and science. CCC rearing allows calves suckling their dam or foster cows for several weeks after birth. The early social environment can impact the development of social behaviour and personality traits. In this study, we investigated the effect of CCC as compared to early separation and rearing in a calf group during the first three month of life on social traits. Eighteen female Black-and-White-German-Holstein heifers and calves reared in a CCC system (Contact, n = 9) or with early separation and milk from an automated milk feeder (Automat, n = 9) in the first 12 weeks of life were studied after weaning (at least 6 months old) in two situations – in their respective social group and in a sociality test. The spontaneous social behaviour was recorded for 5 h per animal in the home pen via direct observation. The sociality test was performed in a familiar environment and comprised an isolation phase of 5 min followed by a 5 min reinstatement phase. Behaviour during the sociality test was analysed from video recordings. In addition, video material from the calving pens provided insights into the type and quantity of maternal care six Contact animals had received on the 1st and on the 3rd day of their life. Treatments were compared using linear mixed models for observations in the home pen and ANOVA for the sociality test with treatment, group and, partly, their interactions, as well as age and weight as independent variables. Potential associations of maternal contact behaviour with Contact animals' affiliative interactions later in life were analysed by Spearman rank correlations. Contact animals showed more subordinate behaviours in the herd ($P = 0.004$). In isolation they were vigilant more often ($P < 0.001$) and looked longer towards the exit ($P = 0.014$) than artificially reared animals. However, we found no treatment effect on the frequency and duration of affiliative behaviour, nor animals' latency to re-join their peers during the reinstatement-phase. There was a positive correlation between the amount of maternal contact received in the first days of life and the initiated affiliative ($P = 0.043$) and received affiliative interactions ($P = 0.016$) of Contact animals later in life. The results of our pilot study add some evidence in line with earlier findings suggesting that the allowance of maternal contact affects animals' sociality and their social competence, i.e. reacting appropriately in social situations, later in life. In addition, the amount of maternal care seems to affect later affiliative behaviour. However, further research is needed with a larger number of animals and further social situations and challenges.

## 1. Introduction

A strong and lasting bond, persisting after weaning, characterizes the relationship between a mother cow and her calf (for review: Waiblinger et al., 2004, von Keyserlingk and Weary, 2007, Sirovnik et al., 2020). Mothers can give the best individual care by adapting their behaviour to the calf's condition, e. g. cows nurse calves of lower birth weight more frequently (Stěhulová et al. 2013), or provide protection from potential dangers (Flörcke et al., 2012). However, dairy calves are mostly separated from their mothers within 24 h after birth (for review: EFSA AHAW Panel 2023) due to economic benefits as compared to systems allowing calves to suckle their cow (cow-calf-contact, CCC) for several

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https://doi.org/10.1016/j.applanim.2025.106548
Received 5 February 2024; Received in revised form 29 January 2025; Accepted 5 February 2025
Available online 5 February 2025

weeks (Mogensen et al., 2022). CCC can affect the animal's welfare and behavioural development positively (for review: Johnsen et al., 2016, Beaver et al., 2019, Meagher et al., 2019, EFSA, 2023) reflected, for example, in higher weight gain, less diarrhoea (Weary and Chua, 2000, Roth et al., 2009, Valnickova et al., 2015) and less abnormal oral behaviours such as cross-sucking (Margerison, 2003, Roth et al., 2009, Fröberg and Lidfors, 2009, for review: EFSA, 2023).

In various species, early social experiences shape later (social) behaviour affecting the ability to cope with social and non-social challenges later in life (cichlid fish: Taborsky et al., 2012, zebra finches: Ruploh et al., 2014, chimpanzees: van Leeuwen et al., 2014; for review: Taborsky, 2016; Langenhof and Komdeur, 2018). Social experiences influence brain development through epigenetic modification (e.g. Nyman et al., 2018, for review: Champagne and Curley, 2005). Especially maternal behaviour, grooming and licking, were shown to affect behaviour of next generations (e.g. Garbugino et al., 2016, for review: Champagne and Curley, 2005). The complexity of the social environment beyond maternal contact, i.e. the size and composition of the social group the animal is living in, is also important for development of social traits such as social competence and sociability (for review, guinea pigs: Sachser et al., 1998; mice: Diamantopoulou et al., 2012, Fischer et al., 2018; macaques: Simpson et al., 2016; cichlid fish: Taborsky et al., 2012; Nyman et al., 2018). Social competence is defined as showing (status-) appropriate social behaviour in various social situations (Taborsky et al., 2012). This requires correct processing of social information (Williamson et al., 2019) and includes the ability to establish and respect dominance relationships (Sachser et al., 1998). In cattle, submissive postures and avoidance behaviour are used to signal respect for dominance, while social licking is exchanged between bonded animals, but also used for appeasement and seems to alleviate social tension (Mülleder et al., 2003, for review: Bouissou et al., 2001).

Also in cattle, the early social environment affects maternal and social behaviour (e.g. Le Neindre and Sourd, 1984, Le Neindre 1989a, b; for review see Cantor et al., 2019). CCC reared calves live in a more complex social environment and experience more social interactions (Waiblinger et al., 2020a). Accordingly, CCC reared animals showed higher social competence compared to early separated, group-reared animals both as calves towards an unfamiliar cow (Buchli et al., 2017) and as heifers when being integrated into the cow herd (Wagner et al., 2012, Kälber et al., 2015). Moreover, CCC reared calves showed a higher social motivation (to rejoin other cattle when isolated and to have social contact to unfamiliar calves), were more attentive to the presence of conspecifics, and tended to have lower increase of cortisol (Wagner et al., 2013). Primiparous cows that had been CCC reared cope more actively and seem to show stronger motivation to rejoin the herd when being isolated (Wagner et al., 2015).

Sociality (the extent of individual animals needing social companionship), sociability (the motivation to stay close to other group members) as well as the frequency of social interaction are elements of social behaviour reflecting animals' personality traits (Gosling and John, 1999, Erhard and Schouten, 2001, in cattle: Mülleder et al., 2003 Marino and Allen, 2017). To test for sociality, social isolation and reinstatement tests are used to investigate the motivation of animals to re-join their peers (for review: Erhard and Schouten, 2001; in cattle: Gibbons et al., 2010), but, to our knowledge, no study is published using such a test to investigate potential effects of CCC rearing in cattle. Further, potential lasting effects of CCC rearing were studied so far regarding behaviour in challenging situations, but not yet on social behaviour in a day-to-day, undisturbed group situations, while this may give insight in development of social strategies (Mülleder et al., 2003) and other social traits. In addition, the intensity of maternal licking in the first days of life may affect later social behaviour; positive correlations were shown in other species (e.g. Weaver et al., 2004).

Therefore, the aim of this study was to investigate the influence of early social experiences (CCC rearing vs. early separation and rearing in a calves group) on social behaviour of dairy cattle later in life focusing on social interactions in the home environment and the usual social group, and on sociality using a social isolation and reinstatement test. Furthermore, we analysed if maternal behaviour received after birth is associated with CCC calves' later affiliative behaviour. We hypothesised (1) that affiliative behaviour and social competence, reflected in higher use of submissive gestures, are enhanced in CCC reared animals, (2) that CCC reared animals show a higher sociality (motivation to end isolation) and (3) that animals' spontaneous affiliative behaviour correlates positively with received duration of maternal contact behaviour in the first days after calving.

## 2. Methods

### 2.1. Animals, housing and management

The project was discussed and approved by the institutional ethics committee (University of Veterinary Medicine) and performed in accordance with GSP guidelines and the German Animal Welfare Act (Federal Republic of Germany, 2020; animal experiment number V 244–18314/2019 MELUND Schleswig-Holstein). The study was conducted between April and June 2019 at the Thünen-Institute of Organic Farming (VTI, Federal Research Institute for Rural Areas, Forestry and Fisheries) in Trenthorst, Germany. Cows in this facility were kept in two dairy herds, separated by horn status (genetically hornless/with horns). Each dairy cow herd (maximum number 50 cows per herd) had a space allowance of 785 $m^2$ in a cubicle loose housing system (see Wagner et al., 2012 for more details). The barns were subdivided into a feeding area (total 43 m x 4 m), a cubicle equipped lying area (39 m x 3 m) and a walking area (43 m x 3 m) with transponder-controlled concentrate feeders. Cows of the two dairy herds were milked twice daily.

Eighteen offspring of cows of the two dairy herds were included in the study, all were female Black-and-White-German-Holstein cattle, half of them polled (genetically hornless, n = 9), the other half had horns (no disbudding is performed on the farm). All cows calved in an individual calving pen with an adjacent outdoor run. During working hours (5 am to 10 pm) all calves were offered at least 2 l of colostrum of the own dam by bottle within the first four hours after birth. Depending on the treatment (see 2.2.) calves had stayed with their mother in the calving pen either for less than one or seven days. Thereafter, calves were brought into a dynamic calf group, one per dairy herd, housed in an area adjacent to the respective cow herd. The calf area had a deep litter lying area (13 $m^2$) and a running area (54 $m^2$, partly outdoor, see also Wagner et al., 2013) and was equipped with a hay rack, a feeding place for silage, a drinker, a brush, an automatic concentrate feeder and an automatic milk feeder (FA Förster-Technik GmbH, Engen, Germany). Water, hay and silage were accessible ad libitum and concentrate portions were provided by an automatic feeder. Depending on treatment calves could either get milk from the automatic milk feeder or by suckling their dam (access the cow herd via transponder-controlled selection gates). Calves were weaned off milk at the age of 12 weeks (details see below in 2.2.) and, where applicable, separated from the mother thereafter and then moved to the youngstock barn where they stayed until 16 months of age.

The youngstock barn was in total subdivided into six pens where groups of calves or heifers were kept according to age and one breeding bull pen. The two heifer pens and calf pens comprising experimental animals were located next to each other, animals of these similar aged groups could have had visual and tactile contact. Heifers were housed on one side and pens were divided into four areas: (a) a feeding alley with feeding racks, (b) a lying area with two rows of cubicles (facing each other) bedded with a straw mattress, (c) three walking alleys with concrete floor and (d) a concrete outdoor area. Younger animals (< 12 months, named "calves" in this paper) were housed on the opposite side of the barn. These pens had (a) a feeding alley with feeding racks, (b) a deep litter bedded lying area and (d) a concrete outdoor area. Each pen provided ad libitum access to water, minerals, as well as an automatic brush; pens for younger animals additionally were equipped with hay racks, which were refilled when needed to allow constant ad libitum access to hay. For details regarding pen size and group composition see Table 1. During summer all animals were pastured. From May on the two heifer groups with experimental animals were pastured together (Pasture 1, 3.47 ha). The two calf groups were pastured together as well (Pasture 2) from June on in a rotational grazing system, switching to a new pasture section every week (6 sections in total, each 0.31 ha). As mentioned before, animals of the joined groups had visual and tactile contact to each other before to minimize possible negative effects of regrouping. Animals on pasture got concentrate in feeding troughs (heifers: 1 kg/day, calves: 0.5 kg/day) as well as ad libitum water and mineral access. Pastures were fenced with electric fences.

### 2.2. Experimental design

Social traits of female youngstock from two treatments differing in the social environment during the first three months of life were investigated (i) by observation of spontaneous social behaviour in the animals' home environment and (ii) by testing them in a social isolation and reinstatement test in a familiar environment outside the animals' home environment. The treatments had been applied already before weaning and selection of animals was based on availability of animals during the observation period of this study. In addition, the quality and quantity of maternal care that Contact animals had received in the first week of life was studied.

#### 2.2.1. Treatments and animal selection

The 18 experimental animals had been reared in the first 12 weeks of life according to two treatments either in a dam-calf contact system allowing full, whole-day, calf driven CCC with partly shared resources (Contact, n = 9, for more details see below) or reared artificially with an automatic milk feeder (Automat, n = 9,). **Contact** calves stayed with their mother in the calving pen for seven days. The cows were milked in the milking parlour twice daily. At day 8, each calf was moved to the calf area and trained to use the selection gate. The calves were weaned on day 90 by nose flap (hindering that calves could suckle their mother) and totally separated from the mother one or two weeks later. **Automat** calves were separated from their mother within 24 h after birth and moved to single calf igloos. In there, calves were fed with colostrum milk from their own mother three times daily at least for six days depending on the health status; at each meal, they were offered 3 l of colostrum. At day eight after birth, under precondition of a good health status, they were brought to the calf area and were taught to use the automatic milk feeder. The provided milk portions increased gradually to a maximum of 12 l per day/animal at the age of 17 days and remained constant until the 75th day of life. Then portions were continuously reduced by −0.8 l per day until weaning on day 90.

Animals were selected for inclusion in this study according to availability at the start of the observations of this study and a balanced design. That is, for Contact animals, all female youngstock that had been reared in CCC and of an age of at least 2 months after weaning and before the first insemination were selected; Automat animals were then selected according to a balanced distribution of age and group between treatments. This resulted in experimental animals being kept in four different groups with varying group size according to their age (Table 1). At the start of the study experimental animals were 5–16 months old (8 aged up to one year, 10 older).

### 2.3. Test procedures and data recordings

#### 2.3.1. Social behaviour observations in the home pen

Social behaviours were recorded mid of April until the beginning of May 2019, while the animals were housed in the barn in four groups (Table 1). For identification, experimental animals got collars with a distinct combination of two numbers while non-experimental animals didn't wear a collar and were not identified individually. The same person, who marked all experimental animals, also conducted all observations (VM). Because she also had to select the participating animals from a list of all animals, she was only partly blinded. She did not use any treatment marker throughout data recording, but she remembered treatment about one third of the animals. All social interactions (affiliative, aggressive, subordinate; ethogram see Table 2) and some non-social behaviours presumably indicative of poor (abnormal oral behaviours: tongue rolling, bar biting, cross-sucking) or good welfare (locomotor and object play behaviour) were recorded using focal animal sampling and continuous recording of behaviour (Martin and Bateson, 2011) in a data entry form on paper, with 10 min slots per focal animal (see below for more detail). For social interactions the actor and receiver of the behaviour were recorded.

The observation time span included periods of higher competition (feeding time) and typical periods for affiliative interactions. Usually, observations started right after concentrate feeding in the morning between 7:30 and 8:00 am and lasted until 16.00 pm in the afternoon with an approximate 1 h midday break in between. Additionally, observations were interrupted as soon as 10 % of the animals in the group laid down, because cattle's natural ruminating and resting phases reduced chances of the appearance of social interactions. A regular observation included two periods of higher competition phases per day, triggered in the morning by concentrate feeding as well as moving remaining food into position and silage feeding in the afternoon.

Each animal was observed continuously for a total of 5 h. Within the group, the observer switched between focal animals (only experimental

**Table 1**
Overview of group composition and pen size (according to floor plan) during barn-housing of the four groups as well as allocation of groups to pasture side 1 or 2 after transfer from the barn to pasture). "Calves" refer to groups where all animals aged below one year, 'heifers' refers to groups where animals were older than one year. Experimental animals of the two treatments were distributed over the four groups as indicated. Groups stayed stable throughout the observations. o.

| | Calves 1 | Calves 2 | Heifers 1 | Heifers 2 |
|---|---|---|---|---|
| Number of experimental animals (Automat/Contact) | 4/2 | 1/1 | 3/4 | 1/2 |
| Total group size [n] | 8 | 16 | 13 | 8 |
| **Average group age [months]** | 5.1 ± 0.55 | 8.2 ± 1.72 | 13.8 ± 2.55 | 16.9 ± 0.84 |
| **Average group weight [kg]** | 139 ± 25.1 | 197 ± 35.6 | 311 ± 42.4 | 392 ± 31.9 |
| Total space pen [$m^2$] | 152.4 | 304.8 | 304.8 | 304.8 |
| Feeding alley [$m^2$] | 30.30 | 60.6 | 60.6 | 60.6 |
| Walking alleys, length x width [m] | - | - | 5×2.5<br>5×1.5<br>12 x 3 | 5×2.5<br>5×1.5<br>12 x 3 |
| Lying area [$m^2$] | 47.10 | 91.45 | 41.75 | 41.75 |
| Outdoor area [$m^2$] | 72.09 | 145.80 | 145.80 | 145.80 |
| Pasture side | Pasture 1 | Pasture 1 | Pasture 2 | Pasture 2 |

**Table 2**
Behaviours and their definitions for the observations of social interactions in the home pen and behaviours of the social isolation and reinstatement test. A, Actor; R, receiver; D, duration; F, frequency.

| **Observations in the home pen** | |
|---|---|
| **Affiliative behaviours** (definitions modified from Menke et al. 1999, Mülleder et al. 2003) | |
| Licking (D, F) | A licks at the body of R except the ano-genital region |
| Licking invitation (F) | A approaches R with stretched lowered head |
| Head play (D, F) | A leans with forehead on forehead of R both rubbing forehead against each other, sometimes lateral rubbing and pressing head against the head or neck of the other animal. |
| Head rubbing (D, F) | A moves her head repeatedly along the body of R in a friendly manner (not exclusively with horns, not frontal with forehead, no pressure, apart from head and neck area to distinguish from head play) and R shows no withdrawal reaction |
| **Aggressive behaviours** (definitions modified from Menke et al. 1999, Mülleder et al. 2003) | |
| Pushing (F) | A butts R 1–2 times with head, resulting in R moving away or changing the position, also strong rubbing with forehead (horns) at any part of the body except the head leading to displacement |
| Pushing strong (F) | A butts R very strongly more than two times directly after one another with head or A pushing with running into R and R moving away or changing position. |
| Pushing gentle (F) | A butts or pushes R once gently (with head, R moving away or changing position |
| Threatening (F) | A adopting a typical threat posture (front-nose-line builds a 90°angle or lower to the back line of the animal) without touching R, and R moving away or changing the position |
| Threat no success (F) | A using threat posture against R but R does not move away |
| Threat or Pushing (F) | Displacing but uncertain if body contact is involved (pushing) or not (threatening) |
| Butting (F) | A butting R with its head, but R staying in place |
| Shoving (F) | A displacing R by using its body (whole body or body parts) |
| Fighting (F) | A standing in front of R and both animals putting their foreheads against each other with forcefully mutual pushing, always ends with a winner and looser (often the winner is chasing the looser in the end over a short distance) |
| Chasing (F) | A displacing R and running after R for at least 2 m |
| **Subordinate behaviours** (definitions modified from Menke et al. 1999, Mülleder et al. 2003) | |
| Submissive gesture (F) | A lowering head in an outstretched way in response to R's action (e.g. R moving to, threatening) |
| Avoiding (F) | Evading another animal being closer than 2 m away without visible precursory threat |
| **Social isolation and reinstatement test** | |
| Looking at door (D, F) | Looking directly at door when farther away or, when standing within 50 cm in front of the door, orienting at the door within angle of 45° of each side of the medial axis of the head |
| Vigilance (D, F) | Head position above horizontal to the withers, ears erected |
| Head high (D, F) | Head position above horizontal to the withers but without ears erected |
| Head normal (D, F) | Head position horizontal to or below horizontal to the withers |
| Exploration (D, F) | Sniffing or licking on floor, door or fence |
| Walking (D, F) | More than two moving steps with forelegs resulting in a change of position |
| Vocalisation (F) | Any vocalisation of the animal (measured directly during testing) |
| Self-grooming (D, F) | Licking, rubbing and scratching the own body |
| Startle response (F) | Jumping or running away in response to door opening |
| Startle response other (F) | Short wince, jumping or running away in response to an undefined stimulus |
| Looking at camera (D, F) | Looking/orienting directly at camera |
| Elimination (F) | Defecation and urination |
| Grazing (D, F) | Eating grass from outside the pen |
| Escape attempts (F) | Jumping against and trying to get over the barrier |
| Solitary play (D, F) | Locomotor play (gallop, leap, jump, buck, turn) & object play (butting bars in a playful manner); both according to Jensen and Kyhn (2000) |
| Latency front legs | Time from opening door until the animal overstepped the door entrance with its two front legs |
| Latency hind legs | Time from opening door until the animal overstepped the door entrance with its two hind legs |
| Latency obstacle | Time from opening door of the isolation pen until the animal stepped on the scale platform (obstacle) with its two front legs |
| Latency alley end | Time from opening door until the test animal reached the end of the alley next to waiting pen |

animals) every 10 min to allow phases of competition and of affiliative behaviour to be observed for each animal. The observation order of the animals within each group remained stable over each day but was balanced between days, so that every observation day started with a different animal. One group was observed for several days, as many as necessary, until the 5 h observation time was reached for all experimental animals of this group. Only after finishing observations of one group the next group was observed so that the four groups were observed one group after the other and there was no switching between the groups. This was necessary because some groups were moved to pasture earlier than others, and thus observations in the barn had to be finished beforehand. Most of the time the person who conducted observations was standing indoors. Animals being outside were visible from indoors due to transparent panelling and if not, time was stopped until the person followed the animal by walking behind the building to the outdoor area.

### *2.3.2. Social isolation and social reinstatement test*

On four different days in May and June 2019 all 18 experimental animals were tested once, animals of group Pasture 2 (Table 1) were tested mid of May after about two weeks on pasture and animals of group Pasture 1 were tested end of June about three weeks after transfer to pasture. During that time, animals were pastured in two different herds on two distinct pasture sites. The test setting was located close to pastures and comprised two asymmetrical pens connected with each other by a 12.65 m long alley (Fig. 1). The left-sided pen was used as isolation pen and the right-sided pen as waiting pen. Both pens were fenced with metal horizontal bars, so that the animal could observe its surroundings, the alley and some parts of the other pen, while being either in the waiting or isolation pen. The top metal bar of fences in the isolation pen were marked with red tape in 1 m intervals to create a grid for data recording. Between the isolation pen and the alley was a door (Fig. 1c), which could be opened with the help of a lever mechanism from outside of the alley. The alley comprised a scale and an

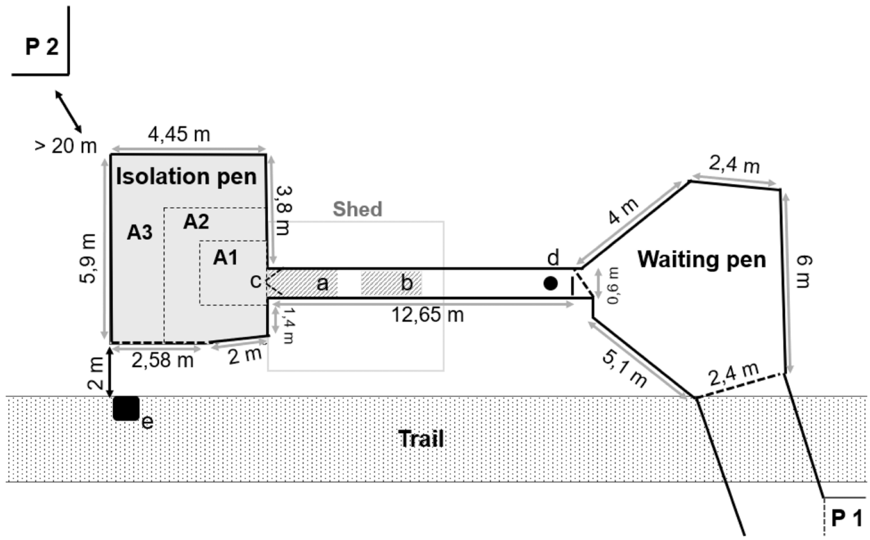


**Fig. 1.** Sketch of the social isolation test setting with pastures of experimental heifers (P1) and calves (P2). Test setting included a waiting pen and an isolation pen connected by an alley, that included one (a) examination sector, (b) scale and a door (c) Cameras were installed (d) at the alley end and (e) held in position by an experimenter, who stood on a ladder. For analysis the isolation pen was marked with red tape at the fence every meter to finally be able to subdivide it in three areas (A1, A2, A3).

examination sector, because usually the setting was used for medical examinations and weighing procedures during summer. Due to the combination of different sections, the alley ground was uneven. The ground was made of metal (scale) and concrete. Animals had to step over three small steps (e.g. scale platform) to reach the end of the alley. All animals were familiar with the test setting (except of the ladder outside the pen for the filming person), but heifers had more experiences because they were pastured for the second year, while calves had gone through the scale at least once before the test. A familiar environment was chosen to test for behavioural reactions in animals that emerge only due to the spatial isolation from its peer and not because of novelty.

For testing, a group of seven animals was separated from the herd on pasture and was slowly and in a calm manner moved into the waiting pen. A group of seven animals was chosen instead of taking the whole herd because of limited space availability in the waiting pen, to avoid stress. Out of this group, one experimental animal was randomly selected and moved through the alley to the isolation pen. As soon as the animal was in the isolation pen, the door of the isolation pen connecting it with the alley (Fig. 1, c) was closed by an experimenter and the test started.

The test comprised a 5 min isolation phase in the isolation pen that was followed by a 5 min reunion phase. After 5 min had passed, the door of the isolation pen was opened (from outside) and the experimental animal was free to walk through the alley to the waiting area (where the remaining six herd members were located) for the next 5 min (reunion phase). As soon as either the animal reached the end of the alley or the available 5 min were over, the test ended. The waiting pen door remained closed during testing to keep animals waiting there. Thereby, tested animals in the reunion phase could not go into the waiting pen but could walk close to it until only a fence separated the animal from its peers.

Always the same three experimenters executed the testing of the animals, one of these was only helping to move the animals, one was additionally closing and opening the doors as well as taking some direct measures (see below), the last one was moving the animals as well as filming the behaviour of the tested animal with a camcorder by standing stationary on a ladder 2 m besides the isolation pen (see below). During testing, the experimenters remained silent, stationary and hidden behind the shed, except the filming person or when operating the door. All tests were conducted between 08.30 h and 10.00 h in the morning. The isolation pen floor and the alley were swept between animals in case an animal had eliminated during the test.

Number of vocalisations performed by the tested animal were recorded directly, as well as the latency from opening the door of the isolation pen (Fig. 1, c) until the test animal reached the end of the alley next to the waiting pen. All tests were video recorded. One camera (Sony HD, HDR-CX730) was held in position by one experimenter (see above). A second camera (Sony HD, HDR-CX250) was fixated with a self-constructed adapter on the metal bar that connected the two fences forming the alley and was centrally located above the alley 2 m away from the waiting pen to record behaviours in the alley. Both cameras were out of animal's range.

Further behaviours were recorded continuously with the software BORIS (Friard and Gamba, 2016) from videos. Behavioural parameters included e.g. head positions, walking, explorative behaviour and latencies that could not be assessed directly during testing (Table 2). Latency until the animal stepped on the scale platform (obstacle) with its two front legs was included for analysis, because animals could have hesitated to pass the scale. The red tapes at the fence functioned as a marker to create a grid laid over the isolation pen, that was used to measure the positions of the animal. The four fields (1 m x 1 m) next to the door were subsumed to area 1, the eight middle fields (1 m x 1 m) to area 2 and the eight outer fields (1 m x 1,8 m) to area 3, however in further analysis only area 1 was used.

For inter- and intra-observer reliability two videos including 5 min isolation and 5 min reunion phase of two different animals were coded and Cohen's Kappa was calculated via the reliability function of BORIS. The events of some behaviours (startle response, escape attempts, elimination, grazing, locomotion and object play) could not be tested, because they were not or only rarely occurring. For intra-observer reliability calculation of the Cohen's Kappa revealed an 'almost perfect agreement' for head normal (0.93), exploration (0.88), looking at door (0.89), looking at camera (0.90) and a 'substantial agreement' for head high (0.83), walking (0.80) and vigilance (0.78) (Landis and Koch, 1977). For inter-observer reliability the outcome was an 'almost perfect agreement' for looking at door (0.82), a 'substantial agreement' for head normal (0.77), head high (0.80), exploration (0.77), walking (0.75), vigilance (0.77) and a 'moderate agreement' for looking at camera (0.66) (Landis and Koch, 1977).

### 2.3.3. *Maternal behaviour observations*

Permanently installed video cameras (Mobotix M15 AllroundDual)

**Table 3**
Recorded behaviours and definitions for observation of maternal behaviour. D, duration; F, frequency.

| | |
|---|---|
| **Individual Behaviour** | |
| Standing (D) | Animal is in upright position, elevated on all four legs |
| Lying (D) | Animal's body is on the ground, legs bearing no weight |
| Solitary Play (D) | Animal is performing locomotor play (i.e. gallop, leap, jump, buck, turn) or object play (e. g. butting bars in a playful manner) according to Jensen and Kyhn (2000) |
| Disturbance (D) | Keeper intervene e.g. perform medical inspection, bottle-feed calf and/or mother cow's head is fixated in the head lock so that she cannot walk away/change her position |
| Out of sight (D) | Animal is not visible e.g. in outside area or behind other animal |
| Head lock (D) | Mother cow's head is in the head lock while head lock is not closed, she is eating and can move freely |
| Outdoors alone (D) | Cow (or calf) is outside (with hindlegs over border) while calf (or cow) is indoors with all body parts |
| No outdoor access (D) | The door to the outdoor run is closed |
| **Contact behaviour** | |
| Contact (D) | Muzzle of the cow (or calf) in close proximity (< 10 cm) to (any part of) the calf's (or mother's) body -including licking, sniffing, nudging |
| Suckling (D) | Calf standing antiparallel to mother cow with head under mother cow's body (>10 sec) |
| Potentially suckling (D) | Calf standing behind mother cow's body in a potential suckling position but is covered by its mother, suckling not visible |
| Head play (D) | Animals leaning with foreheads on each other both rubbing forehead against each other, sometimes lateral rubbing and pressing head against the head or neck of the other animal. |
| Covering up calf (F) | Mother cow is covering up her calf with straw |
| **Orientation** | Only when mother cow is lying, neglecting short side movements (e.g. head throw to flick flies) |
| Head binocular directed to calf (D) | Mother cow's head is directed directly towards her calf, calf is positioned within an angle of 45° to each side of the medial axis of the head thus within the binocular visual field. |
| Head monocular to calf (D) | Mother cow's head is directed towards her calf, calf is positioned in an area more than 45° up to 90° angle from the medial axis of the cow's head thus in the monocular visual field |
| Head directed away (D) | Mother cow's head is directed away from her calf, calf is positioned 180°−260° from midpoint of mother cow's head, between her ears |
| **Proximity** | |
| Within body length (D) | Distance between the head of the mother cow and the calf is less than the cow's body length |
| Larger than body length (D) | Distance between the head of the mother cow and the calf is larger than the cow's body length |

in calving pens were used to record cow's maternal behaviour and behaviour performed by calves of the Contact treatment. There were no video data of the three oldest experimental animals available, thus, videos of only six Contact animals and their mothers were available. A camera system was used with time-lapse recording which captured the indoor and outdoor part of the calving pens. For analysis, two pictures per second were used to enable a continuous playback. To investigate behaviours in early life, the first 12 h after birth were analysed. Additionally, 4 h on the third day of life, when the calf was more active, were examined. For this purpose, a time span that included activity phases and very little disturbances was chosen. It turned out that time spans between 11:00 am to 1:00 pm and 2 h directly after evening milking (starting from 6:30 pm) met the criteria.

Behaviour parameters focused on interactions between mother and calf such as contact initiated by calf or cow, suckling, proximity and mother cow's orientation towards her calf (for definition of behaviours see Table 3). Sniffing and licking on the video recordings were difficult to distinguish, these two elements were combined. All behaviours were recorded using focal animal sampling and continuous recording of behaviour (Martin and Bateson, 2011) with the open-source software BORIS (Friard and Gamba, 2016). Coding was performed by one person (VM) who was blind to the identity of the calf.

For intra-observer reliability 10 different video samplings each 30 minutes long from 5 different animals were observed twice from the same observer. Some behaviours and conditions (disturbance, out of sight, outdoors alone, solitary play, head play, covering up) were not or only rarely observed and could not be included in the calculation. Calculation of the Cohen's Kappa revealed an 'almost perfect agreement' for proximity within body length (0.91), proximity above body length (0.85), lying with head binocular directed to calf (0.82), lying with head monocular directed to calf (0.87), lying with head away from calf (0.88), standing in head lock (0.99), contact (0.91) and suckling (0.97) (Landis and Koch, 1977).

## 2.4. *Statistical analysis*

Statistical analyses were carried out in SPSS (version 25, IBM SPSS. year 2017). All data were analysed descriptively and graphically first (box plots/scatter plots). Statistical models were calculated for all behaviours that were of interest for our prediction and that occurred in sufficient frequency to allow for analysis (see below for behaviours analysed). To test model assumptions, residuals were checked for normality using a Shapiro-Wilk test and visually for homogeneity of variance. In the results section all model results regarding the treatment and all other significant factors are reported, non-significant factors are not reported.

The **social behaviour in the home pen** as actor or receiver were analysed separately and the main variables were the frequency and duration of affiliative behaviours and the frequency of aggressive as well as subordinate behaviours. Further, the relative weight of experimental animals in the group was determined by subtracting the individual weight from the average group weight, because weight might have an influence on social dominance and agonistic social behaviour and therefore relative weight was included in the model of agonistic behaviour. Linear mixed models were calculated with treatment (Contact/Automat) as fixed effect and age and, for aggressive and subordinate behaviour, relative weight as covariate as well as group (Heifer 1/Heifer 2/Calves 1/Calves 2) as random effect.

For the **social isolation and reinstatement test**, the isolation phase and reunion phase were analysed separately. Duration of looking at the door was the main variable for the isolation phase. Furthermore, the duration of being positioned in area 1 (close to the door), duration and frequency of vigilance, frequency of vocalisations and durations of exploration and walking were tested for the isolation phase. In the reunion phase the main variables of interest were the latency to enter the alley (i.e.pass the door) with front legs, pass the door with hind legs, to clear the obstacle and to reach the end of the alley, i.e. running closest to their peers. If the animal did not reach any of these locations before the end of the test, the latency was set to five minutes, i.e. the test duration.

**Table 4**
Linear mixed model results for social interactions in the home pen (F, frequency; D, duration) of animals reared with cow-calf contact (*Contact* n = 9) and animals reared artificially (*Automat* n = 9). Estimated means of frequencies or durations (in seconds) of behaviours per 5 h observation are shown for experimental animals being Actor or Receiver of the interaction. Only treatment and other factors with p ≤ 0.05 are reported. SE, standard error; df, degrees of freedom.

| | | Estimated means ± SE | | | | |
|---|---|---|---|---|---|---|
| **Being actor** | | Contact | Automat | F | df | P |
| Affiliative behaviour, F | treatment | 18.6 ± 5.11 | 16.4 ± 5.16 | 014 | 1,12 | 0.709 |
| Affiliative behaviour, D (sec) | treatment | 163.7 ± 72.64 | 94.3 ± 73.19 | 0.59 | 1,13 | 0.456 |
| Aggressive behaviour, F | treatment | 13.2 ± 3.14 | 13.4 ± 3.15 | 0.04 | 1,12 | 0.952 |
| | relative weight | | | 8.65 | 1,13 | **0.011** |
| Subordinate behaviour, F | treatment | 11.1 ± 1.72 | 4.2 ± 1.74 | 12.07 | 1,12 | **0.004** |
| | relative weight | | | 53.58 | 1,13 | **< 0.001** |
| **Being receiver** | | | | | | |
| Affiliative behaviour, F | treatment | 14.8 ± 2.60 | 13.4 ± 2.60 | 0.13 | 1,15 | 0.725 |
| Affiliative behaviour, D (sec) | treatment | 69.9 ± 36.68 | 111.7 ± 37.04 | 1.10 | 1,13 | 0.313 |
| Aggressive behaviour, F | treatment | 16.0 ± 4.54 | 11.1 ± 4.59 | 0.94 | 1,12 | 0.350 |

Additionally, vigilance and duration of exploration and walking were evaluated. For the social isolation and reinstatement test ANOVA models were calculated with treatment (Contact/Automat), group (Pasture 1/ Pasture 2) and their interaction as fixed effects, as well as absolute age and weight as covariate. For the reunion phase the total test time was added as covariate for variables other than latencies, because it varied between animals.

Observations after calving regarding **maternal and calf behaviour** were analysed descriptively and the maternal behaviour 'contact' was tested for correlations with later affiliative behaviour. Sample size was reduced to 6 Contact calves' mothers due to lacking videos as described above. The distribution of lying orientation binocular directed to the calf and one-ocular directed to calf were consistent within individuals, e.g. Cow 1 who often lied binocular directed to calf, also lied often monocular directed to calf. Due to this result, these two variables were summarized to 'Cow lying towards calf'. To test preliminarily for associations between maternal behaviour after calving and affiliative interactions of experimental animals in the herd, Spearman rank correlation coefficients were calculated between the total duration of the cow's behaviour 'contact' during the complete observation time (sum of the first 12 h after calving and the 4 h of the 3rd day) and later frequency and duration of affiliative behaviour of calves.

## 3. Results

### 3.1. Social behaviour observations

During the 5 h of observation per individual, one animal of the Contact group performed tongue rolling (14 times/5 h) and one Automat animal performed bar biting (5 events/5 h). Cross-sucking was not observed. Contact animals showed more subordinate behaviours than artificially reared animals (Table 4). Animals with higher relative weight were showing subordinate behaviour less often (regression coefficient: −0.293). The two treatments did not differ in the frequency and duration of affiliative behaviour or aggressive social interactions as actor or receiver (Table 4). Animals with higher relative weight initiated aggressive behaviour more often (regression coefficient: 0.245, Table 5).

### 3.2. Social isolation and reinstatement test

Flight attempts and any play behaviour were not observed in both treatment groups during the social isolation and reinstatement test. Only one event of startle response in response to the door opening was observed in one artificially reared animal. During the 5 min social isolation, Contact animals looked longer to the closed door that led to the peers (Table 5), tended to spend more time closer to the door, i.e. in Area 1, and showed more events of vigilant behaviour than Automat animals (Table 5). No treatment effects were found for the duration of vigilance, exploration and walking, or for the frequency of vocalisations (Table 5). Regarding age, weight and group (Pasture 1/Pasture 2) no effects were found. Self-grooming was observed only in Automat animals.

In the reunion phase, 11 out of 18 (Contact = 5, Automat = 6) experimental animals were able to reach the end of the alley to meet their peers. Only one artificially reared animal performed locomotion play (1 event/5 min). The rearing treatment did not affect animals' latency of reaching the alley end, passing the obstacle and passing the door with front legs and hind legs, but there was a treatment effect for latency to pass the door with front legs depending on group, i.e. a treatment*group interaction, with shorter latency in Contact animals than Automat animals in the heifers (Pasture 2) but no difference in calves (pasture 1; Table 5). Further, no treatment effect could be found for the frequency of exploration and frequency and duration of vigilance behaviour during the reunion phase (Table 5). A group effect was found: calves from pasture 2 explored longer than heifers from pasture 1 (Table 5). The latency until animals

reached the alley end influenced the duration of exploration (Table 5). Age influenced animals' latency to pass the door with their hind legs with younger animals being quicker (regression coefficient: −2.433), as well as weight influenced the latency to pass the obstacle with heavier animals being quicker (regression coefficient: 3.020, Table 5).

### 3.3. Maternal behaviour observations

In the first 12 h after calving, the six experimental animals of the Contact group had received close maternal contact (e.g. licking, sniffing) for 1.25 h (cow 11) up to 2.21 h (cow 15). The first sniffing or licking contact between cows and calves occurred within 0.08 min up to 8.02 min after birth. Three out of six cows ate the placenta and three cows were observed to cover up her lying calf with straw (cow 10 = 9 events/12 h, cow 11 and cow 15 = each 1 event/12 h).

On the third day of calf's life, the observed maternal contact during 4 h initiated by cows 1, 7 and 11 was relatively low with 2 min, 0.5 min and 5 min, while cows 2, 10 and 15 spent 13 min, 16 min or 19 min sniffing or licking their calves. Thus, during the third day cows spend 1.3 % - 4.8 % of their time during the 4 h observation period with sniffing and licking their calf. Again, the calf of cow 15 received the longest duration of maternal contact.

Most of the time (74.6 % 92.3 %) the calf was within its mother's body length on the first day after calving; the longest duration was observed for cow 15 (11.08 h). On the third day cows spent 58.5 % (cow 2) up to 70.9 % (cow 10) of the 4 h observation in such close proximity to the calf (within body length).

**Table 5**
ANOVA results for behaviour (F, frequency; D, duration) of experimental animals (*Contact* n = 9, *Automat* n = 9) during the social isolation and reinstatement test with estimated mean ± standard error. All treatment effects and other factors with p ≤ 0.1 are reported. SE, standard error; df, degrees of freedom for group, for cases per animal; $n^2$, eta-squared effect size.

| | | Estimated mean ± SE | | ANOVA | | | |
|---|---|---|---|---|---|---|---|
| **Isolation Phase** | | Contact | Automat | F | df | P | $\eta^2$ |
| Looking at door (D) | treatment | 72.20 ± 12.31 | 52.55 ± 11.92 | 8.04 | 1,12 | **0.014** | 0.388 |
| | weight | | | 4.00 | 1,12 | 0.069 | 0.250 |
| Area1 (D) | treatment | 111.91 ± 19.50 | 78.07 ± 18.89 | 5.47 | 1,12 | 0.072 | 0.550 |
| Vigilance (F) | treatment | 9.42 ± 1.51 | 5.06 ± 1.46 | 25.72 | 1,12 | **< 0.001** | 0.666 |
| Vigilance (D) | treatment | 44.7 ± 16.52 | 33.92 ± 16.00 | 0.30 | 1,10 | 0.651 | 0.156 |
| Exploration (D) | treatment | 86.07 ± 15.00 | 82.08 ± 14.53 | 0.03 | 1,12 | 0.891 | 0.021 |
| Walking (D) | treatment | 53.96 ± 9.37 | 65.49 ± 9.07 | 0.13 | 1,12 | 0.781 | 0.107 |
| | treatment x group | | | 6.57 | 1,12 | **0.025** | 0.354 |
| | Pasture 1 | 32.25 ± 16.51 | 75.91 ± 18.68 | | | | |
| | Pasture 2 | 75.67 ± 29.37 | 55.07 ± 21.43 | | | | |
| Vocalisation (F) | treatment | 7.29 ± 2.48 | 2.55 ± 2.40 | 0.48 | 1,12 | 0.608 | 0.305 |
| | treatment x group | | | 4.13 | 1,12 | 0.065 | 0.256 |
| **Reunion Phase** | | | | | | | |
| Exploration (D) | treatment | 49.08 ± 9.60 | 31.86 ± 9.28 | 2.82 | 1,11 | 0.261 | 0.632 |
| | group | | | 8.92 | 1,11 | **0.011** | 0.426 |
| | latency alley end | | | 8.50 | 1,11 | **0.014** | 0.436 |
| Vigilance (F) | treatment | 3.91 ± 1.84 | 1.23 ± 2.18 | 0.04 | 1,16 | 0.873 | 0.021 |
| Vigilance (D) | treatment | 8.32 ± 21.831 | 29.18 ± 21.11 | 0.78 | 1,11 | 0.489 | 0.325 |
| Latency front legs | treatment | 57.81 ± 32.46 | 140.54 ± 31.44 | 0.71 | 1,12 | 0.548 | 0.397 |
| | treatment x group | | | 4.98 | 1,12 | **0.046** | 0.293 |
| | Pasture 1 | 199.80 ± 57.20 | 185.62 ± 64.73 | | | | |
| | Pasture 2 | −84.17 ± 70.60 | 95.46 ± 74.25 | | | | |
| Latency hind legs | treatment | 140.64 ± 40.86 | 171.83 ± 39.58 | 0.89 | 1,12 | 0.410 | 0.212 |
| | age | | | 4.86 | 1,12 | **0.048** | 0.288 |
| | weight | | | 4.23 | 1,12 | 0.062 | 0.261 |
| Latency obstacle | treatment | 159.33 ± 40.48 | 180.22 ± 39.21 | 0.31 | 1,12 | 0.626 | 0.117 |
| | age | | | 4.67 | 1,12 | **0.052** | 0.280 |
| | weight | | | 0.31 | 1,12 | **0.048** | 0.287 |
| Latency alley end | treatment | 173.43 ± 39.18 | 187.87 ± 38.05 | 0.13 | 1,12 | 0.755 | 0.062 |
| | age | | | 4.00 | 1,12 | 0.069 | 0.250 |
| | weight | | | 4.52 | 1,12 | **0.055** | 0.274 |

In the first 12 h after calving, total lying duration of the cow ranged from 2.34 h to 6.09 h. Cows were orientated 1.07 h up to 5.58 h of their lying time towards the calf, therefore cows spent 41.9 % up to 97 % of their total lying time in orientation towards their calf. Cow 7 was the only cow, who spent more time lying away than towards the calf. The shortest measured duration of lying away from the calf was measured for cow 10 (0.05 h), who also had the shortest duration of total lying (2.34 h) on the first day.

Regarding the development of the calves in the first days of life, observation revealed that four calves suckled within 12 h, they needed 59 min up to 185 min for the first successful suckling. Calf 10 did not suckle within 12 h and calf 11 only with help (guiding to teat several times) after 6.59 h. All calves born during the day got additional colostrum by a caretaker within 3 h, the other calves (calf 1, 7), got it on the next day, 4.56 h and 6.20 h after birth. The same three animals, who suckled for a reasonable amount of time in the first 12 h after calving (calf 1, 7, 15), also performed playing behaviour within the first day. Additionally, these calves spent a higher amount of time playing in the four hours of observation on the third day than the other three calves. Calf 15 who received the most maternal contact by its mother, cow 15, engaged the most time in solitary play on the first day. Calf 11, who received the least maternal contact of all calves, did not show any play behaviour and suckling duration was relatively short, even on the third day of life.

#### *3.3.1. Association with later calf social behaviour*

Maternal contact behaviour during the first and third day of life correlated with later affiliative behaviour of the six Contact animals. Both the frequency of initiated affiliative behaviours ($r_s$=0.943, p = 0.005) and the duration ($r_s$=1.000) was higher with longer maternal affiliative behaviour (Fig. 2). Regarding the received affiliative behaviour, the frequency still correlated highly ($r_s$=0.928, p = 0.008), but duration did not ($r_s$=0.348, p = 0.499).

## 4. Discussion

Our results confirm a link between development of social traits and early social environment with or without contact to the mother. The results confirm previous ones with regards to a higher use of subordinate behaviour in CCC reared animals suggesting higher social competence. Behaviours during an isolation test are also in line with previous studies suggesting some links with sociality. The social reinstatement time did reveal differences only in the heifers, i.e. animals older than one year, probably due to limitations in our study design (see below). Our preliminary results on the correlations of maternal behaviour and later social affiliative behaviour also support the existence of a link between individual maternal behaviour and social traits although we have to be very cautious due to the low sample size. In sum our hypotheses were confirmed partly.

### *4.1. Spontaneous social behaviour and rearing system*

Contact animals performed more subordinate behaviour in the home pen compared to artificially reared animals. This is in line with our hypothesis and confirms previous results in heifers confronted with a social challenging situation, i.e. integration into a new herd (Wagner et al., 2012), and calves that were confronted with an unfamiliar cow (Buchli et al., 2017). Subordinate behaviours play a major role in dominance relationships by signalling animals' inferior status towards a conspecific thus avoiding further aggressions (Phillips, 2002, pp.89). From the latter, one can assume that displaying the subordinate status is an important social competence. Cows reared with CCC, who perform

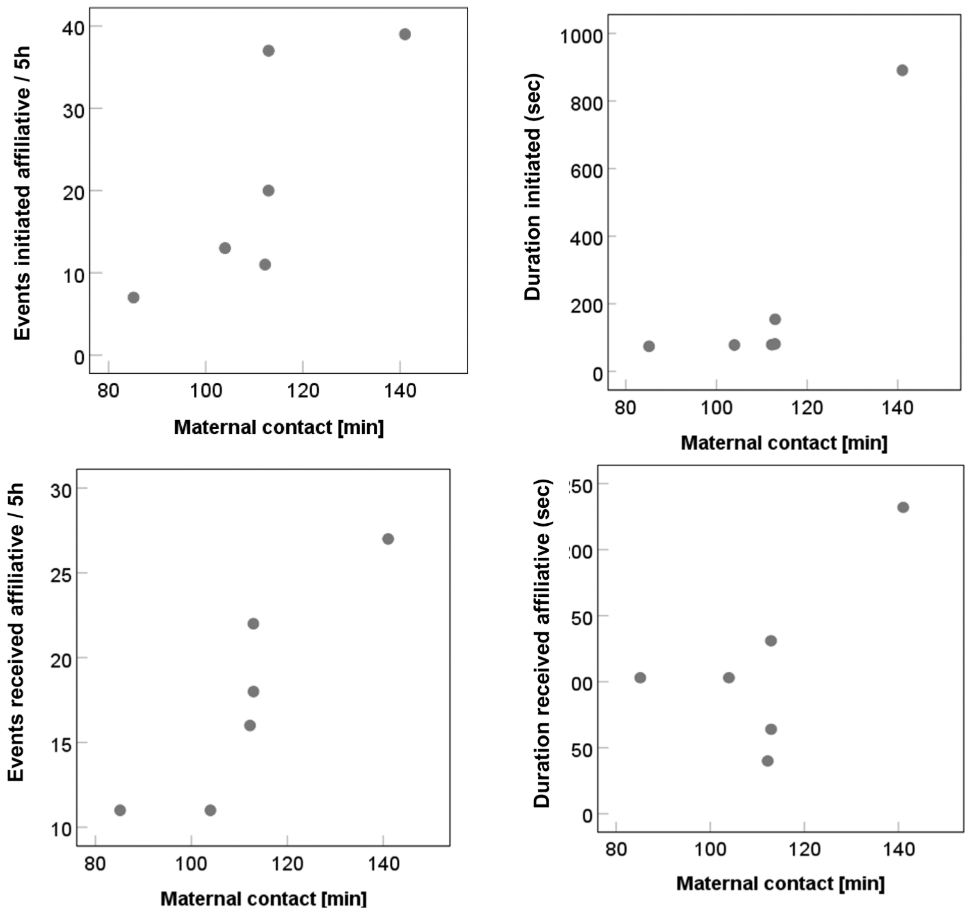


**Fig. 2.** Scatterplot of the total amount of maternal contact experienced by Contact animals (n = 6) on the 1st and 3rd day of life (x-axis) and the frequency (left graphs) or duration (right graphs) of affiliative behaviour of Contact calves being actor (upper graphs) or receiver (lower graphs) later in life during 5 h of observations.

more submissive gestures, might have social benefits by avoiding aggressions (Wagner et al., 2012).

No consistent differences between treatments in initiating and receiving affiliative behaviours, as well as aggressive behaviours were found. This confirms results in challenging situations, such as integration into a herd (Wagner et al., 2012) or confrontation test with conspecifics (Wagner et al., 2013, Buchli et al., 2017). All experimental animals were housed most of the time in groups (Automat animals: maximum of six days single housed after birth) and had therefore social contact. General social contact is one important condition to establish social competence (Cantor et al., 2019). Maternal contact might not be crucial for the development of positive and agonistic species-specific social behaviour per se. Social contact with other calves has beneficial effects on later social behaviour compared to single housed, isolated reared animals (Duve and Jensen, 2011; De Paula Vieira et al., 2012). However more subtle differences in social skills or competence, i.e. to use social behaviours appropriate to the situation including subordination, was shown to be enhanced in a more complex social environment during ontogeny in several species (Taborsky et al., 2012, Ruploh et al., 2014) and this holds true also for some social behaviours in this and in previous studies (see above). In this study animals were only observed for a limited time interval, which may have been not sufficient to detect more subtle differences in aggressive or affiliative behaviours. In addition, the number of agonistic, and especially aggressive social interactions is strongly linked to social dominance (Sambraus, 1970, Bouissou et al., 2001) besides personality traits (Bouissou et al., 2001, Mülleder et al., 2003). This is supported by our results on relative weight: animals with higher weight are expected to have higher social status and thus to show more threats and other aggression to display their dominance, in line with our findings. On the other hand lighter animals, of lower status, signal their subordinance.

### 4.2. *Social isolation test and reinstatement test*

Contact animals' propensity to look longer towards and, by trend, to stay longer close to the door during the social isolation test can be interpreted as being more attracted to the peers than artificially reared animals which is in line with our hypothesis of higher motivation to end isolation, i.e. higher sociality.

In other studies, animals reared with CCC spent more time near the walls (Le Neindre, 1989a), showed more active flight attempts as calves (Wagner et al., 2013) and more exploration of the environment, including high amounts of vigilance as cows (Wagner et al., 2015) in isolation, which was as well interpreted as higher motivation to re-join the group. However, no escape attempts during isolation were observed in our study and almost no escape attempts in the Buchli et al. (2017) study. Differences in behavioural responses could be explained by the fact that animals of our study had visual contact to their peers all the time, the Buchli-study calves had company from a cow, while in the other studies barriers where opaque.

Higher sociality may ease formation of affiliative relationships and exert beneficial effects: Affilitative relationships in cattle are characterised through spatial proximity, reduced agonistic interactions, enhanced affiliate interactions and tolerance in competitive situations (Bouissou, 1976 Bouissou et al., 2001). A higher sociality may thus also enhance their ability to seek and get social support in challenging situations and lead to more stress-resilient animals (Bouissou et al., 2001, Færevik et al., 2006). Social support reflected by stress reduction in challenging situations increases from an unfamiliar conspecific to familiar (Takeda et al., 2003) and is best with bonded partners (Waiblinger et al., 2006).

Similarly to the studies of Wagner et al. (2013), (2015), more vigilant behaviour was observed in CCC reared animals compared to artificially reared animals during isolation. The authors already discussed the ambivalent notion of vigilance, in which it can be interpreted as fear or as environmental scanning related also to contact seeking behaviour meaning to search for auditory or visual contact to conspecifics. Looking to the door and vigilance were linked in our study. It is reasonable that in this test setting vigilance was used as environmental scanning to search for contact to conspecifics.

The treatment had no effect on the frequency and duration of exploration in isolation and the reunion phase, which is in line with the study of Wagner et al. (2013). However, heifers from pasture 2, who had experienced the test setting for the second year, explored less during the reunion phase compared to calves from pasture 1, likely due to a lower familiarity of the environment for the calves (Herskin et al., 2004, Phillips, 2002).

Vocalisations during isolation are the result of a strong stress response (van Reenen et al., 2004). The function of vocalisation in cattle is to remain in contact with bonding partners (Phillips, 2002) and we may expect higher levels in more sociable animals as it was observed in CCC reared calves compared to Automat calves in a test arena with solid wooden walls (Wagner et al., 2013). However, in our study the animals had constantly visual contact to their peers which may have affected the motivation for vocal communication and explain why treatment had no effect. It could also be that the presence of a person during the test may have reduced the vocalisation behaviour as it has been observed in sheep in tests on reactivity towards humans where the human was present in the animal's area and may have reduced the level of stress during isolation from conspecifics (Le Neindre et al., 1993, Boivin et al., 2000). In our study the human was positioned outside the test arena in 2 m distance and our animals were habituated to this person standing outside their enclosure during the social behaviour observations in their home pen.

In cattle, more walking is associated with higher fear in social separation but is less distinctive in a familiar environment (de Passillé et al., 1995). No significant differences in the duration and frequency of walking between treatments were found in this study, which is an indication for similar levels of fear between the two treatment groups. We deliberately chose a familiar test pen to minimize the potential confounding effect of the personality trait fearfulness, which may be influenced by ontogenetic social experience as well (e.g. Boissy and Bouissou, 1988), on the other behaviours of our experimental animals. The lack of a difference in walking behaviour thus supports our setting regarding the isolation part.

Contrary to our expectation, there was no general difference in latencies to pass the alley and thus to rejoin their peers. However, the shorter latency to enter the alley leading to the peers (i.e. shorter latency to pass the door with front legs) for the heifers on pasture 2, is in line with the hypothesis of higher sociality as well. Heifers had more experience with passing the alley compared to calves which may have contributed to this group*treatment interaction. The higher level of exploration in calves (pasture 1) compared to heifers (pasture 2) during the reunion phase supports this interpretation that a higher degree of novelty for the calves may have obscured potential social motivations to rejoin the peers.

### 4.3. Maternal care and calf behaviour

The maternal contact behaviour of our cows confirm previous observations in beef suckler or dairy cows (Kiley-Worthington et al., 1983, Jensen, 2011): in the first hours postpartum, cows spent a lot of their time licking the calf, but less on day 3 after calving and on both days there was high inter-individual variation. The intense licking on the first day after calving is important for bonding between cow and calf (von Keyserlingk and Weary, 2007) but also stimulates the neonate calves improving their vitality (Edwards and Broom, 1982; Lidfors, 1996) The observed placentophagia (eating placenta) was described as natural behaviour of cattle before (Hudson and Mullord, 1977, Edwards, 1983, Kiley-Worthington et al., 1983).

Interestingly, half of the observed mother cows (n = 3) covered up their calves with straw, pushing the straw with their head, a behaviour that could be interpreted as nestbuilding-like behaviour, which is rarely observed in cattle (von Keyserlingk and Weary, 2007). Wehrend et al. (2006) described a similar behaviour in 33 out of 87 cows before parturition. On pasture calves prefer to lay covered in high vegetation (Langbein and Raasch, 2000). Cow 10, who's calf did not suckle during the first 12 hours covered up her calf 9 times; she may have adapted her maternal care to the needs of her calf as suggested by Stěhulová et al. (2013).

The average distance between cow and calf increases over the first hours after calving (Edwards, 1983) and percentage of time near the calf decreases over time post partum (Kiley-Worthington et al., 1983). Similar results were found in our study, with an average of 85 % in close proximity in the 12 h after calving and 65 % on the third day of calves' life. But it has to be considered that at least the space allowance of the indoor area of the calving pen (= lying area) was only 3 m x 4 m, which could have contributed to the high percentage. Using smaller distances as limits (contact, half the cows body length and body length) would likely lead to higher differentiation. At best the pens would have marks so that assessment of distances in steps of 1 m would be possible. However, this is difficult to apply in a calving pen.

Calves who suckle within 12 h after birth also performed locomotor play on the first day and they also performed more playing behaviour on the third day compared to animals who did not suckle within 12 h which may be linked to their energy intake being higher (Krachun et al., 2010). Alternatively, or additionally, these calves showed lower vitality reflected in both later and less suckling and playing. A positive correlation between calf's activity and first-time suckling was already described (Ventorp and Michanek, 1991). Furthermore, licking stimulates calves' activity (von Keyserlingk and Weary, 2007). This would be in line with our descriptive results that the calf who received the most maternal contact performed the most observed solitary play while the calf who received the lowest amount of maternal care did not play at all.

Affiliative behaviour later in life correlated with the maternal contact these animals received after birth confirming our hypothesis. It is possible that the amount of maternal care received is linked to the oxytocin release in the calves with subsequent organisational effects on the brain finally affecting social behaviour (Lupoli et al., 2001, for review: Uvnäs-Moberg et al., 2001, 2005; Carter, 2003, Vargas-Martinez et al., 2014). However, we cannot exclude a genetic influence accounting for differences in maternal affiliative behaviour and affiliative behaviour of the offspring. To differentiate genetic effects a cross-fostering paradigm would be interesting. This would also enable investigating potential differences in dam cow-calf- contact rearing and foster cow-contact rearing.

### 4.4. General discussion – limitations and future research

Despite a relatively low sample size we could confirm differences between treatments in line with our hypotheses for most of the key parameters supporting the strength of the effects. However, this was not the case for all parameters which may be due to some limitations of the study. First of all, a larger sample size of animals of the same age could be advantageous to identify more subtle differences. In addition, we already discussed the difficulties regarding aggressive and affiliative social interactions in the home pen due to interactions with dominance relationships and limited observation time. Thus, in future research it may be advantageous to apply more extensive observations and take into account hierarchy. In addition, test situations where different social behaviour would be predicted as being socially appropriate would merit further research.

Regarding the social reinstatement test, the alley for rejoining the herd was suboptimal. The steps, the different material on the ground and the need to move in the direction of somewhat lower light intensity (from the unroofed isolation pen to the roofed alley) are all factors known to hinder cattle movement (Grandin, 1993). Thus, insecurity and the motivation to explore the ground likely interfered with social motivation, especially for the calves on pasture 1.

Regarding the link of maternal behaviour received and later social (affiliative) behaviour, our sample size was very low and thus needs confirmation with more animals. Further, longer observations and the use of cross-fostering to exclude genetic effects could be performed in future studies.

## 5. Conclusion

Our pilot study provides evidence that in dairy animals cow-calf contact rearing in the first three months of life has long term effects on social traits. The results suggest that cow-calf contact as compared to early separation enhances social competence and sociality. Furthermore, the amount of maternal care seems to be associated positively with later affiliative behaviour. However, further research is needed with a larger number of animals and further social situations. Together with previous findings results of this pilot study support the importance of the social environment early in life on the development of cattle's' social behaviour.

## CRediT authorship contribution statement

**Magierski Viola:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Waiblinger Susanne:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Barth Kerstin:** Writing – review & editing, Supervision, Resources, Project administration, Methodology.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

We are grateful to the staff at the Thünen Institute of Organic farming for their help during tests and data recording. VM's stay at the Thuenen Institute for data collection was supported by an Erasmus+ Student Mobility for Traineeships (SMT) scholarship; no other funding was received.

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