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Effect of social interaction in development of cognitive abilities of dairy animals- A Review

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A B S T R A C T

Standard practice in the dairy industry is to separate the calf and dam immediately after birth and raise calves in individual pens during the milk-feeding period. But this practice is disputed because of animal welfare concerns. The weaned calves are often offered colostrums/milk in buckets, teat bucket or bottles which does not always satisfy the calf's motivation to suckle. Social isolation early in life impair cognition aspects. Cognition is the mental process of knowing through perception or reasoning. Negative effects of social deprivation early in life also have been shown in adulthood, which include impaired maternal care, increased aggression, and impaired social recognition. Social deprivation can influence neural development and brain function as well as behavior. Dairy cattle, are often exposed to novel events, such as changes in diet, changes in pen location, regrouping with new social partners, and new milking procedures. Therefore cognitive abilities e.g. learning and retention abilities by animals makes it easier to train the animals to use new devices and reallocation of preferred areas to rest, recognition of stock people by dairy animals helps in decrease of animal's fear of stock people, greater ease of handling and less negative interference in the production. Cattle are naturally social and show signs of fear and distress when separated from their companions. Individually housed calves exhibit more non-nutritive behavior than do paired or group-housed calves are slower to start feeding when introduced into a new pen and therefore gain less weight in the days after grouping. So, social experience early in life of calf can have profound effects on affective and cognitive development, ultimately affecting calf welfare and growth as well as calf responses to novel events.

Introduction

Shortly before parturition, cows tend to separate themselves from the herd and give birth in a secluded area (Lidfors *et al.*, 1994). Once the calf is born, a series of maternal behaviors are observed, including licking of the calf and specific vocalizations (Keyserlingk and Weary, 2007). The newborn calf completely depends on the milk provided by the dam and will nurse approximately 8 to 12 times daily with each

suckling bout lasting approximately 10 min during the first week of life (Reinhardt and Reinhardt, 1981; Day *et al.,* 1987; Lidfors, 1996). After few days, the calf and mother reintegrate into the herd (Bouissou *et al.,* 2001). Calf starts to increase the distance from the dam from second week of life and starts interacting with peers, and sometimes may form small groups with other calves (Vitale *et al.,* 1986; Sato *et al.,* 1987).

Calves that are reared with their dams and other conspecifics start grazing and ruminating at approximately 3 wk of age and graze regularly with the herd at 3 to 6 months of age (Reinhardt and Reinhardt,1981; Vitale *et al.,* 1986). Calves reared without dam contact had higher heart rate than calves reared with cow-contact at beginning of trial but heart rate of calves was similar at end of trial ($F_{2,99}$ = 5.39, P = 0.006) (Buchli *et al.,* 2016). They further investigated that during confrontation phase, calves reared without cow-contact approached the unfamiliar cow more often than calves reared with cow-contact ($F_{1,27}$ = 12.22, P = 0.002).

Calves that were reared without dam-contact less often displayed a response to threatening behavior of the cow compared with calves reared with cow-contact ($F_{1,26}$ = 14.77, P < 0.001) i.e. threatening behavior of the cow caused calves reared with cow-contact to display submissive behavior more often than calves reared without cow-contact ($F_{1,26}$ = 16.94, P < 0.001). So from above it is concluded that rearing with cow-contact affected the cardiac stress reaction which lead to a more adaptive social behavior compared with traditional rearing without cow-contact.

The succession from maternal care to independence is an important period of learning for young foragers (Provenza and Balph,1987), and there is a influence of peermates on diet selection by young ruminants (Nolte *et al.,* 1990; Provenza *et al.,* 2003).

In summary, as we know ruminants are social animals they start making social relationships starting from birth, initially with the dam and then with other individuals. Also during the milk-feeding period, the calf relies on social cues from the dam and other conspecifics that influence behavioral development. In contrast social isolation has potential negative effects on social and feeding behaviors and future production and performance of animals. In addition to the effects outlined above, social isolation may have important effects on cognitive development of calves.

Social interactions and animal's cognition ability/performance

Animal cognition refers to the mechanisms by which animals acquire, process, store and act on information from the environment (Shettleworth, 2001). Cognition includes perception, learning, memory and decision making, in short, all ways in which animals take in information about the world through the senses, process, retain and decide to act on it. Such processes play an important role in dealing with their physical and social environments (Shettleworth, 2001).

History of development of science of animal cognition

Two monumental moments in the history of human thought place the study of animal behavior and learning squarely at the forefront of philosophical and scientific inquiry:

- Descartes's distinction between humans and brutes
- Charles Darwin's hypothesization of mental continuity between human beings and non-human animals.

Descartes (1637/1994) believed that human beings were fundamentally different from brutes. They had intricate bodily mechanisms that controlled their physiology and behavior, but they lacked what humans alone possessed a rational soul. Descartes believed that animals were incapable of using words or other signs to declare their thoughts to others, if indeed they had any such thoughts, and that animals were bound to respond innately, without the intervention of intelligence.

Against this backdrop of Cartesian thinking, Darwin made evolutionary proposal that humans and animals were not fundamentally different from one another nor did they have different origins. In stark contrast to Descartes, Darwin viewed both communication and intelligence from a natural scientific perspective; rudimentary antecedent or even highly advanced forms of each of these behavioral abilities were to be found throughout the animal kingdom, thus disclosing mental continuity between human and non-human animals. As Domjan (1987) observed that Darwin's ideas made the study of animal behavior relevant to, and in fact crucial to, the understanding of human behavior.

Basis of learning in animals

Associative learning - pavlovian conditioning or classical conditioning

Classical conditioning is a form of associative learning where a conditioned stimulus (biologically neutral) is paired with an unconditioned stimulus (biologically potent) which leads to an involuntary unconditioned response (UR) from the animal.

After repeated exposure the behavioral response can be induced by the CS alone. For example, the action of being milked (US) is linked to the milk let down response (UR). After a few milkings, milk let down is often induced by simply entering the milking parlour or even the crowd pen (CS) (Willis and Mein, 1983).

Instrumental conditioning

Operant conditioning is a process of behavioral modification in which the likelihood of a specific behavior is either increased or decreased using reinforcement or punishment, respectively. Cattle approaching a milking unit of an automatic milking system in response to an auditory cue used to give food as a reward (Wredle *et al.,* 2006)

In this study a small box emitting an acoustic signal was attached to a collar on each cow and cows were rewarded for visiting the target area in response an audio cue.

Effect of social isolation on the dairy calves

Calves typically provided little or no social contact on dairy farms showing detrimental effects of isolation. Evidence suggests that socially reared calves are less fearful (Boe and Farevik, 2003) and more dominant when mixed in groups later in life (Veissier *et al.,* 1994) compared with calves that have been reared in isolation. Several factors play a role in social behavior development, such as age of first contact with conspecifics and level of contact.

For instance, calves allowed full social contact with another calf, either from birth or from 3 wk of age, established a stronger bond compared with calves raised with only visual or auditory contact with other calves (Duve and Jensen, 2011). Calves housed individually or with only limited contact were more fearful than pair-housed calves (Jensen and Larsen, 2014). Collectively, this evidence suggests that full social contact with peers from an early age is important for the calf.

Table.1 Effect of social housing on behavior of calves

Treatment	Animals	Parameter	Effect of socialization	Reference
Individual;complex (≤8 calves +night access to cows)	Bull calves	Intake of unfamiliar feed type	Complex housed calves had more intake of unfamiliar feed type	Costa *et al.*, 2014
Individual;pairs	Female calves	Vocalization after teat removal	Pair housed calves had less vocalization after teat removal	Vieira *et al.*, 2010
Individual;pairs	Female calves	Latency to feed in novel environment	Pair housed calves had less latency to approach feed	Vieira *et al.*, 2010
Individual;pairs	Female calves	Intake of feed after being moved to a new environment	Pair housed calves had more intake of feed	Vieira *et al.*, 2010
Individual;pairs	Female and bull calves	Social behavior	Pair housed calves performed more social behaviors	Duve *et al.*, 2012
Individual ;group	Heifers	Avoidance of unfamiliar calves	Group housed more interactive with unfamiliar calves	Jenson *et al.*, 1997
Individual ;group	Heifers	Fear in open field test	Group housed heifer less fearful in open field test	Jenson *et al.*, 1997
Individual;pair	Female and bull calves	Playing behavior	Both showed equal play behavior	Jenson *et al.*, 2015
Individual; group (4 calves)	Bull calves	Aggression at mixing	Group housed had more aggressiveness	Veissier *et al.*, 1994
Individual; group (4 calves)	Bull calves	Social rank	Group housed calves higher in social ranking	Veissier *et al.*, 1994

Group housing of dairy calves

One benefit of housing calves in groups includes reduced labor requirement per head (Broom and Leaver, 1978). One recent study reported that "reducing labor" and "saving time" were among the main reasons that farmers provided for group-housing dairy calves (Hotzel *et al.,* 2014). The development of automated feeding systems for calves has accelerated adoption of group housing of dairy calves, particularly for larger dairy farms (Kung *et al.,* 1997). There is also increased awareness of animal welfare by both dairy producers and the public, and one important welfare concern is the social isolation of calves (Boogaard *et al.,* 2010; Ventura *et al.,* 2013).

Social support and behavior of calves

Social buffering is the ability of social partners to decrease the effect of stressors during a challenge (Cohen and Wills,1985). Social buffering has been demonstrated in humans (Thorsteinsson *et al.,* 1998), rats (Kiyokawa *et al.,* 2014a), guinea pigs (Hennessy *et al.,* 2000), pigs (Reimert *et al.,* 2014), and other farm animals (Rault, 2012). For example, the work on rats has shown a decreased response to stressors in the presence of others (Hennessy *et al.,* 2000; Kiyokawa *et al.,* 2014a), especially familiar conspecifics (Kiyokawa *et al.,* 2014b). In cattle, the presence of conspecifics is known to reduce behavioral reactions to social separation (Boissy and Le Neindre, 1997; Piller *et al.,* 1999). For example, calves vocalize less in a novel arena when in companionship with familiar calves compared with when they are placed with unfamiliar calves (Farevik *et al.,* 2006). There is also some evidence of social buffering in calves in response to a nonsocial stressor; individually housed calves show a stronger vocal response to weaning from milk compared with paired calves (Vieira *et al.,* 2010). Efficacy of social buffering may be influenced by several factors, including the strength of affiliation between the individuals. As (Bolt *et al.,* 2017) found that calves paired at day 28 exhibited lower number of vocalization as compared to calves paired at day 28.

Socialization and cognitive behavior of calves

Social isolation early in life can impair cognition in rodents and other species (Jones *et al.,* 1991; Fone and Porkess, 2008). Socially isolated rodents showed deficits in reversal learning (Jones *et al.,* 1991), a method often used to assess behavioral flexibility in animals (Fone and Porkess, 2008). The study was conducted to examine reversal learning in pair-housed and individually housed calves. They found that individually housed calves reached the criteria after 15 training sessions and pair housed calves after 12 sessions ($Z = 21.10$, $p = 0.27$). When the training stimuli were reversed, calves in both treatments performed poorly. The median number of sessions needed to reach this criterion was 19.5 for the individually housed calves versus 13.0 for the paired calves ($Z = 20.94$, $p = 0.34$) (Gaillard *et al.,* 2014). Daros *et al.,* 2014 studied the influence of separation from dam on the responses of dairy calves in a discrimination task between red and white colours and they found that the go responses to the screen was 72 ± 3.6% before separation but declined to 62±3.6% after separation from the dam.

A follow up study reported that during discrimination phase, there was no difference between group (8.9 ± 0.9 training sessions) and individually housed (10.6 ± 0.6 sessions) treatments in learning speed ($t_{13} = 1.49$, $p = 0.16$). But in the reversal phase, seven of the eight group calves were able to reach the learning criterion taking 10.3 ± 2.4 sessions

whereas only one out of seven calves reached the criterion in the individual treatment (Fisher-exact test; p = 0.01) .Group and calves paired at 6 day of life did not differ in learning the reversal task (7 of 9 vs. 9 of 12 calves; p =0.882).These group termed as early social group. Further 16 of 21 calves of early social groups successfully reached the criterion than did individual i.e. 9 of 12 calves (p=0.882). Late Pair i.e at 6 week of life had intermediate success (7 of 12 calves), not differing from Early Social calves, but tending to be higher than that for Individual calves (p = 0.099) (Meagher *et al.,* 2015).

In the latter study, it was concluded that the majority of individually housed calves did not learn the reversal task even when provided twice as many sessions as required by the average socially housed calf. Similar results have been reported in rodents, and these studies indicate that the cognitive deficit is associated with decreased brain development and plasticity (e.g., Schrijver and Wurbel, 2001; Fowler *et al.,* 2002; Lipkind *et al.,* 2002). In rodents, it is well established that the prefrontal cortex is responsible for behavioral control, decision-making, and inhibition of behavior (Dalley *et al.,* 2004). These controls are essential for success in reversal learning.

Costa *et al.,* (2014) found that dam reared calves, when tested at 10 weeks of age, tasted novel feed sooner after introduction of the food and ate more of it, compared to calves individually reared. Calves weaned for less than 2 weeks were faster in changing a learned route in a maze compared to those which were weaned for longer (Veissier *et al.,* 1989).

So from above review it was concluded that calves housed with social companions from an early age, either in a complex social environment (either with the presence of their dam and other cows and calves) or simply pair-housed, performed better in reversal learning than did individually reared calves indicating impaired behavioral flexibility in socially deficit calves.

Calves coping with novelty in social life

Farm animals, including dairy cattle, are more often exposed to novel events, such as changes in diet, changes in pen location, regrouping with new social partners, and new milking procedures.

Calves reared in groups were more social confident and show less fear than calves reared individually or in isolation (Bøe and Faerevik., 2003). Individually reared calves show greater reactivity to environmental novelty compared with socially reared animals. Veissier *et al.,* 1997 showed that isolation of calves promoted reactiveness to startling stimuli and development of self-directed oral behaviors. Calves housed individually for the first 3 month of life were more reactive to environmental and social novelty than group-housed animals when tested at 90 d of age (Jensen *et al.,* 1997).

Vieira *et al.,* 2012 reported that during the social novelty test with unfamiliar calf, calves housed individually spent less time running (51.8 vs. 96.4 ± 11.6 s/test), found a longer latency to socially interact (111.1 vs. 20.4 ± 21.7 s/test), and spent more time involved in social interactions (130.7 vs. 79.7 ± 19.0 s/test) than did pair-housed calves. As compared to pair housed calves, individually housed calves were also more reactive to the presence of an unfamiliar calf as indicated by increased rates of defecation (2.3 vs. 0.7 ± 0.5 events/test) and kicking (2.2 vs. 0.7 ± 0.4 events/test). Further Gaillard *et al.,* 2014 observed that housing treatment did not influence time spent exploring the object in the first session (t=20.18, d.f.= 11, p>0.10),

which averaged 55.4±22.2 s for individual calves and 50.9±12.2 s for pair calves. But latter on pair-housed calves significantly reduced their time spent exploring with repeated testing ($F_{1,69}$ =4.74, p =0.033) whereas individually-housed calves showed no significant decline in time spent exploring the object over repeated sessions ($F_{1,55}$ = 0.08, p>0.10). So Individually reared calves are more fearful and less willing to originate social interactions whereas group reared calves are more confident around conspecifics and show less fear response to humans (Bøe and Faerevik, 2003).

Buchli *et al.,* 2016 showed that during confrontation phase, calves reared without cow-contact procced towards the unfamiliar cow more often than calves reared with cow-contact ($F_{1,27}$ = 12.22, P = 0.002). Calves reared without cow-contact less often showed a response to threatening behavior of cows compared with calves reared with cow-contact ($F_{1,26}$ = 14.77, P < 0.001) as they were in regular contact with adult cows and experience broad range of interactions with dam and other adult, including agonistic behaviors like threats and displacements (Waiblinger *et al.,* 2013). Whereas calves reared without cow contacts were less cautious approaching the cow.

Moreover, calves reared with cow-contact showed submissive behavior more often than calves reared without cow-contact ($F_{1,26}$ = 16.94, P <0.001) in response to threatening behavior of the cow. Similarly, Wagner *et al.,* (2012) found that dam-reared heifers were more submissive during integration into the cow herd compared with heifers reared without dam-contact. They learned to know social signals of conspecifics and to react in adaptive way as submissive behavior reduce the risk of being attacked.

In contrast, early social contact reduces behavioral and physiological reactivity to environmental novelty. Calves provided social contact showed decreased responses to restraint, increased play during the milk feeding phase, and increased competitive success after weaning (Duve *et al.,* 2012), as well as lower adrenocortical reactivity to stress (Creel and Albright,1988; Raussi *et al.,* 2003).

Abdelfattah *et al.,* 2018 observed that calves housed in groups of 3 at 3rd day(GH3) showed more play behavior than calves housed in groups of 3 at 7th (GH7)and 14th day(GH14)($F2_{,189}$ = 6.39, P = 0.03). Play behavior peaked at 3rd week and reduced by 6th week (P < 0.001), supporting earlier work of Jensen *et al.,* 1998; Jensen and Kyhn, 2000 and Duve and Jensen, 2011.Calves raised in pairs or in small groups of calves showed lower heart rates when placed in a pen with an unfamiliar calf (Jensen *et al.,* 1997) and were less fearful and more willing to approach unfamiliar calves when mixed after weaning (Vieira *et al.,* 2012a).

Socially reared calves were also less neophobic toward a new food item than calves reared individually (Costa *et al.,* 2014). Horvath *et al.,* 2017 reported that during novel object session, enriched calves found reward faster than control calves (6.11 vs 20.6s; SE=4.06; P=0.001) whereas control calves spent longer in the middle of maze where the novel object was located (2.08 vs 13.4s; SE=5.33; P=0.04).

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