Review

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Acknowledgements

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1 Executive summary

In this review on relational enrichment in ruminants and equines, we extensively explore the current literature, emphasizing species-specific relevance and the identification of knowledge gaps. Our overarching goal is to delineate best practices for social enrichment, which we term as relational enrichment. We address various critical aspects, including group housing, the importance of the young-dam relationship, inter-species enrichment, and the human-animal relationship. Throughout this review, we examine the literature concerning domestic herbivores, which are inherently social animals displaying intricate behaviours on farms. We explore how they form enduring social groups characterised by activities such as social facilitation and synchronisation, as well as their communication and individual recognition, all of which are influenced by the complexity of social organisation and group size.

We highlight current farm practices that facilitate relational enrichment, such as group housing and prolonged young-dam rearing systems. We describe the benefits of these practices on performance, behaviour, and cognitive development, emphasising the importance of careful management and further research to address existing knowledge gaps. It is essential to deepen our understanding of these gaps to comprehensively grasp the qualities of relational enrichment and its potential positive effects on animal welfare. The human element in promoting relational enrichment is crucial, with farmers' practices playing a pivotal role in fostering positive human-animal relationships. It is imperative to foster daily interactions to cultivate lasting positive contacts and build strong relationships. Additionally, the review emphasises crucial factors for attention during welfare inspections, including evaluating social interaction opportunities, duration of contact, and assessing environmental factors like facilities and surroundings, as well as the quality of the human-animal relationship. This synthesis offers a comprehensive overview of relational enrichment practices and outlines avenues for future research.

2 Foreword

European Union Reference Centres for Animal Welfare (EURCAWs) develop and disseminate knowledge and tools to assist the Competent Authorities (CAs) in performing better official controls and enforce EU animal welfare rules.

Domestic ruminants and equines are kept in a wide range of environments with varying complexity, from individual housing in barren pens to rearing in large groups in semi-natural environments. The richness of the environment has an impact on animal welfare. EURCAW *Ruminants & Equines* proposed to review the available knowledge on the richness of the environment for the species covered by the Centre. A first review (Botreau et al., 2023a) introduces the issue of richness of the environment in general: What does a rich environment mean? What are the various types of enrichment and what are the main consequences of a poor vs. rich environment? Specific reviews address the various types of enrichment: occupational, physical and cognitive enrichment (Botreau et al., 2023b); sensory and nutritional enrichment (Ginane and Rørvang, 2023); and the present review on relational enrichment (including the impact of the presence of conspecifics (social or maternal enrichment), humans or other species).

The goal is to understand the underlying mechanisms and how they impact the various animal species and age.

Directive 98/58/EC for the protection of farmed animals mentions ethological (behavioural) needs, but not positive emotions nor enrichment. Directive 2008/119/EC for the protection of calves further specifies that calves must have visual and tactile contacts and must be kept in groups from the age of 8 weeks. Directive 2010/63/EU on the protection of animals used for scientific purposes mentions enrichment in reference to the expression of behaviour and the reduction of negative emotions (stress). For the purpose of EURCAW *Ruminants & Equines*, the reviews on enrichment therefore mainly address enrichment to cover behavioural or sensory needs and make no distinction between animals used for farming or scientific purposes.

3 Definitions

Social enrichment has been defined as *"the provision of access to direct or indirect (visual, olfactory, auditory) contact with conspecifics (other individuals of the same species) or humans"* (Prado Mandel et al., 2016). As in Heinrich (2015), we consider that social behaviour can encompass any interaction between individuals that contributes to lasting relationships between them. The social qualification is often restricted to intraspecific interactions (i.e. same species) and relationships (Boivin et al., 2003). However, many properties of some intraspecific relationships can be found also in some human-animal relationship (Mellor et al., 2020).

Thus, the present review covers both intra and interspecific enrichment and is entitled "relational enrichment". We define "relational enrichment" as social contacts that provide putative functional benefits on development of safety, facilitation or learning in diverse situation and specific bonds with conspecifics or individuals of other species (including humans). The term "relational" emphasises the importance of the quality of the relationship, which determines the perception of the inter-individual contact and its enrichment properties. Subject to the quality of the relationship and individual engagement, social contacts can provide adequate stimulation, promoting positive emotions, increased interest for proximity and active involvement in behaviours such as allogrooming and play. Additionally, it may support individual development by promoting learning, enhancing behavioural flexibility, and coping strategies. Like Prado Mandel et al. (2016), we stress that social enrichment should not be confounded with other forms of environmental enrichment such as exploration of new environmental enrichment sources and exercise effects.

4 Scientific knowledge

4.1 The formation of relations between individuals

Domestic herbivores are social species. Their social behaviour has played a crucial role in their domestication, as their wild ancestors naturally lived in groups. Sociality, a trait found in all gregarious species, shapes the structure and behaviour of animals within a group, evolving as an adaptive response to environmental pressures. From a behavioural ecology standpoint, this trait develops when the benefits of associations with conspecifics outweigh the costs and directly contribute to the overall fitness of individuals within a group (Hawley, 1999; Krause and Ruxton, 2002).

Social living remains an important part of animal life also on farms. Most farm species live in long-lasting social groups, showing social facilitation of behaviour and synchronised activities (Broom and Fraser, 2015; Ramos et al., 2021). Most of them display complex social organisations and sophisticated interactions between individuals. Within the group, each individual depends to some extent on the others and poorly adapts to socially isolated living conditions (Miranda-de la Lama and Mattiello, 2010; Broom and Fraser, 2015). Communication and individual recognition are integral parts of social behaviour and are related to the complexity of social organisation and to the range of group sizes adopted by these species in free-ranging situations (Squires, 1975; Mendl and Held, 2001). The group structure is set and maintained by agonistic interactions and by affiliative behaviours among individuals (Miranda-de la Lama and Mattiello, 2010), with

preferential relationships (Bouissou, 1980). Herbivorous ungulates engage in affiliative and greeting behaviours that build this social qualification. Such interactions include nose-to-nose, body and genital sniffing, reciprocal or one-way grooming and other forms of friendly physical contact, and they seek to maintain proximity with familiar members of their group (Mellor, 2015). For example, a review on coping in domestic horses by Van Dierendonck and Spruijt (2012) concluded that social behaviours in horses such as allogrooming and play are likely mediated by rewarding endogenous opioids (as reported in many other mammalian species), and an inability to perform these behaviours could lead to chronic stress. Thus, both, allogrooming and play should be considered as ethological needs.

In most ungulates of livestock interest, except horses which live in harems throughout the year, the formation of mixed-sex groups mainly occurs during the breeding season, although it has been reported mixed groups of adult females with heifers and young bulls in cattle under natural conditions (Bouissou et al., 2001). During most of the year, adult males and females live in separate groups and occupy different areas. By contrast, the birthing season generally corresponds to greater isolation of the females, which move away from the main group to find quiet, solitary areas in which to give birth (Mattiello, 2001; Ramos et al., 2021). The relationship between the new-born and the dam is generally established in the first few hours (e.g. for cows (Jensen, 2018), sheep (Nowak et al., 1996)) or during the first days (e.g. for deer (White et al., 1972)) through suckling and grooming. The presence of the dam and other animals in the group plays an important role in the development of their social skills. The opportunity to express maternal-filial behaviours is fundamental to ensuring good welfare. In general, it involves species-specific patterns which are linked to positive emotional states that generate positive experiences with an important adaptive value. It potentially contributes to positive long-term effects, such as greater social competence within a group (Spinka, 2006). Studies on young-dam rearing systems has shown that the early relational enrichment with the presence of the dam promotes social skills (Flower and Weary 2001; Vaarst et al., 2001; Wagner et al., 2012; Santo et al., 2020), long-term social competence, locomotor play and cognitive abilities (Waiblinger et al., 2020; Broucek et al., 2020). These effects are most likely favoured by the transmission of information to the offspring by the dam through social facilitation and stimulus enhancement mechanisms (Rorvang and Nawroth, 2021).

Intraspecific social transmission is a crucial aspect of animal social life, influencing various non-social activities such as feeding, fear, exploration, and sexual behaviour (Nawroth et al., 2022; Neave et al., 2018; Rørvang et al., 2018). Social transmission encompasses mechanisms like local and social stimulus enhancement, social facilitation that alters the observer's motivation to mimic others, and social learning involving goal emulation and imitation (Rørvang et al., 2018). While the first two mechanisms are well-established, the latter requires further investigation in ruminants and equids.

Social partners and group life contribute to relational enrichment. They offer possible advantages like a secure base for environmental exploration and anti-predator protection. Additionally, it

might contribute to stress coping, emotional and cognitive improvement, and social transmission or learning in different situations, including feeding and social regulation (Veissier et al., 1998).

Affiliative behaviours play a crucial role in providing social support during challenging situations, eliciting calming and rewarding physiological responses (Rault, 2012). Nevertheless, even though domestic herbivores are inherently social animals, they must possess the ability to withdraw from the group when necessary or, at the very least, evade the attention of other group members (Mendl and Held, 2001).

At the core of group life are dominance relationships, which establish fundamental rules for navigating social conflicts and managing limited resources, while concurrently defining the dominance order within the group. These relationships are acquired through animals recognising each other and recalling past social interactions. Experimental studies have described that farm ungulate species can discriminate and recognise conspecifics, e.g. cattle (Hagen and Broom, 2003, Coulon et al., 2009), sheep (Kendrick et al., 1995, 1996), goats (Pitcher et al., 2017) and horses (Proops et al., 2009). Sheep have the ability to remember the faces of approximately 50 different individuals for over 2 years (Kendrick et al., 2001), while goats demonstrate cross-modal recognition of close social partners (Pitcher et al., 2017). Cattle are capable of discriminating between familiar conspecifics and retaining this information for at least 12 days (Hagen & Broom, 2003). Additionally, studies have shown that cows can recognize familiar traits of individuals from other species and identify other cows' faces by viewing pictures (Coulon et al., 2007, 2011).

The dominance order is specific to each group, and addition or removal of individuals might temporarily disrupt the group equilibrium, necessitating the establishment of a new order of dominance (Lindberg, 2001). To ensure the functionality of the dominance hierarchy, subordinate individuals must be afforded opportunities to avoid conflicts, such as providing sufficient space allowance (Lindberg, 2001). Group size also influences the dynamics of dominance hierarchy. In many species, such as goats (Andersen et al., 2011), sheep (Jørgensen et al., 2009), and camels (El Shoukary and Osman, 2020), an increase in group size correlates with a decrease in agonistic interactions. This trend may stem from reduced individual recognition in larger groups, leading animals to adopt less aggressive social behaviours and thereby decrease fights. However, this pattern appears inconsistent in cattle, where studies have reported increased or unchanged agonistic interactions with larger groups (Rind and Phillips, 1999; Telezhenko et al., 2012). A recent study on dairy cows (Krahn et al., 2024) found no alteration in agonistic interactions when group size changed from 50 to 10 animals (with same stocking density), emphasising that the directionality of agonistic interactions remained consistent regardless of group size. More research is needed to understand the species-specifics strategies considering the social dynamics within the group, in order to optimise group formation.

The impact of dominance and affiliative relationships extends to social transmission in farm herbivores (Neave et al., 2018). Group participation holds significance for both individuals and social learning. While individual learning involves trial and error, social learning offers a cost-effective means of information acquisition through interactions with group members, proving

particularly advantageous in unpredictable environments (Stenfelt et al., 2022). In domestic herbivores, inter-species affiliations vary depending on several mechanisms: bonding/attachment processes, animal experience of pleasant or unpleasant interactions, and sensitive periods to these social contacts, particularly in the presence of the mother in early life (Rault et al., 2020).

Bonding/attachment processes can occur in the absence of obvious reinforcement but just in the contiguity and conspicuousness between individuals and their attachment object (Nowak and Boivin, 2015). Bonding/attachment leads to a preferential relationship, proximity seeking, social support and reassurance in the case of stressful situations and possibly a base for exploration. The more an attachment object is animated and from the same species, the stronger is the bond, as demonstrated in sheep (Cairns and Jonson, 1965).

Bonding can occur with familiar conspecifics and with individuals from other species, e.g. bonding between sheep or goats, between sheep and donkeys or between cattle or dogs, in particular when these species are mixed for anti-predator management, and of course between animals and humans (Scott, 1992; Kendricks et al, 1998; Anderson et al., 2012; Nowak and Boivin, 2015).

As for intraspecific social relationships (e.g. with humans), the process referred to as socialisation may also play a role through animals learning how to behave and communicate toward others (Scott, 1992; Jardat & Lansade, 2022). Farm ungulates such as horses and goats are able to use referential communication (perceiving human signals or sending signals to humans) and to engage in social learning with humans (e.g., local enhancement, demonstration, and social referencing) (Nawroth, 2017; Jardat and Lansade, 2022).

Responses of sheep, cattle, goats, and equids to other individuals are affected by the animals' experience, especially the way they are handled, and the frequency and type of contacts. This has been deeply explored in the human-animal relationship (Hemsworth and Coleman, 2011; Napolitano et al., 2020; Jardat and Lansade, 2022).

Farm ungulates have good memories (e.g. sheep can remember other individual sheep for a period up to two years, (Kendrick et al., 2001) and are able to durably remember emotional experiences. The maternal-filial bond has been described to persist for years under more natural conditions in cattle (Reinhardt and Reinhardt, 1981), and sheep keep a close relationship with their offspring even after weaning (Hinch, 2017). This has also been described to happen towards human caretakers. They discriminate among humans and can generalize and anticipate future interactions with them (Fell and Shutt, 1989; Rushen et al., 1999; Destrez et al., 2013). Such effects are particularly evident in young animals or at weaning (Rault et al., 2020). However, further contact can modulate such an effect. Interestingly, humans can provide reassurance to isolated animals when they have been familiarised to humans (Rault et al., 2011; Coulon et al., 2015). The presence of the dam has an important effect on the human-animal relationship depending on her behaviour toward the human in the presence of the young (horses: Henry et al., 2005). Calm interactions between the mother and humans can have a lasting impact on how the young approach humans. Additionally, genetics influence how different breeds and individual animals respond to people, with this trait being moderately heritable in herbivores. (Haskell, 2014;

Grandin, 2019; Rankins and Wickens, 2020). However, strong genotype × environment interactions can be observed. Sheep, for example, can have different perceptions of human gentling depending on their genetic background (Caroprese et al., 2012; Tamioso et al., 2018).

4.2 Enriching properties of relations between individuals

Here, we delineate the characteristics of social interactions that have led us to state their enriching nature. Animals actively seek out such relations. These established relationships equip them to face further challenges.

First, when it comes to social interactions, enrichment should offer animals the chance to actively engage with the social resource, fostering the development of meaningful relationships. Providing a social companion might enhance stimulation for a socially deprived individual but it doesn't inherently guarantee relational enrichment beyond fulfilling the social behavioural needs. The extent of enrichment is contingent upon individuals' motivation to engage in such interactions. Through interactions, animals can establish relationships that yield benefits as delineated in this review.

Second, animals are willing to exert effort to obtain social companionship. For example, cows are motivated to reunite with their calves (Wenker et al., 2020) even if they had contact just during day time (Jensen et al., 2024) and calves displayed a drive to be near other calves (Ede et al., 2022; Holm et al., 2002). Yet, the literature concerning motivation and the willingness to invest effort for social contact remains limited in ungulates.

Third, during periods of stress, the presence of close social partners can reduce stress experienced in challenging situations, an effect called 'social buffering' (Young et al., 2014). Social buffering has been observed in cattle during disbudding (Bučková et al., 2022), re-grouping (Mounier et al., 2006; Foris et al., 2021), and weaning (Bolt et al., 2016), in sheep during fear test with a group (González et al., 2013) and tail-docking (Guesgen et al., 2014), in horses, during exposition to a sound stressor (Janicka et al., 2023) or to fear tests (Ricci-Bonot et al., 2021). Deer while grouped with other males presented lower cortisol concentrations (Bartoš et al., 2023). In addition, in sheep, the group impacts on grazing behaviour (Boissy and Dumont, 2002): groups of familiar sheep have longer grazing sequences, reduced frequency of vocalisation and vigilant behaviours compared to groups of unfamiliar sheep.

Fourth, social contact contributes to positive emotional states in animals through affiliative interactions, such as allogrooming, as evidenced in studies with cattle (reviewed by Keeling et al., 2021), horses (Sigurjónsdóttir et al., 2003), and other ungulates (Hodgson et al., 2024). Besides, young animals have opportunities to engage in social play behaviour. Play behaviour is linked to positive emotional states and is regarded as an indicator of positive welfare (Held and Špinka, 2011). Play also fosters the development of motor and social skills crucial for their behavioural development and coping abilities.

Fifth, social interactions introduce a heightened level of complexity to animals' environments and rich environments are known to increase the resilience of animals. However, research on how

social contact enhances behavioural flexibility and coping strategies in farm animals remains relatively scarce. There is evidence suggesting that social housing benefits dairy cattle. Studies have indicated that social housing improves cognitive flexibility in dairy cattle, as demonstrated by findings from reversal learning experiments (Gaillard et al., 2014; Meagher et al., 2015). Additionally, calves raised in social groups exhibit reduced neophobia towards food (Costa et al., 2014, 2016) and display increased social interactions with peers (De Paula Vieira et al., 2012), hinting at potential effects between early-life social experiences on individual traits, such as fearfulness. Research on horses has shown that positive emotional states enhance cognitive flexibility, with fearless horses performing better in instrumental learning tasks (Fortin et al., 2018). Furthermore, few studies on long-term effects, particularly in dairy cattle reared in young-dam systems, suggest that early social housing prepares animals better for adulthood by enhancing coping abilities when introduced to lactating groups (Wagner et al., 2012; Field et al., 2023). At 2.5 years old, cows that had permanent access to their mothers showed increased exploration during fear tests, lower heart rate after its completion but higher levels of cortisol, resembling a reactive coping style, usually described as individuals that are more resilient with changes in their social or physical environment (Wagner et al., 2015).

Individual differences in social behaviour and personality, considering their previous experience also plays an important role when we consider enriching properties of social contacts. How individual personalities affect the development of social interactions have been scarcely studied in farm animals compared to wild animals' literature (Lee et al., 2022). Individual horses form relationships based on similar personality traits and hierarchical rank (Briard et al., 2015). Additionally, shy and bold sheep exhibit different grazing behaviours in groups, exploring areas differently (Michelena et al., 2009), supporting the notion that individuals within a social group may adopt diverse behavioural strategies and exhibit greater behavioural flexibility, which can be advantageous for navigating their environment (Taborsky and Oliveira, 2012). In goats, physiological and behavioural responses of kids to a person depend on the bold or timid reaction of their pen-mates or adults, particularly their mother (Lyon et al., 1988). To be in a social context is therefore enriching for behavioural flexibility and development. Substantial gaps remain in understanding the mechanisms on how relational enrichment supports behavioural flexibility and coping strategies in these species, and more studies are needed to understand its long-term effects on their welfare.

5 Minimising welfare problems / promoting best practices

The relational enrichments presented in this section are summarised in Table 1.

5.1 Group housing

Group housing is a feasible way to provide relational enrichment and has been shown to reduce faecal glucocorticoids – a sign of stress – and to improve handling in horses (Yarnell et al., 2015).

Feral horses have been found to groom and spend more time in close proximity with individuals familiar to them, regardless of genetic relatedness or hierarchical rank (Mendonça et al., 2021, Bouskila et al., 2015; Cameron et al., 2009; Heitor and Vicente, 2010). However, this is in contrast

to studies where horses of similar hierarchical rank (Briard et al., 2015) as well as those with kinship (Heitor et al., 2006; Sigurjónsdóttir et al., 2003) display more affiliative behaviours toward one another. It has also been shown that weaned horses, particularly females, show motivation to engage socially with their dam even after five months of separation, suggesting a long-term effect of relational bonds and potential welfare effects for fillies weaned artificially before nine months of age (Lansade et al., 2022). Aside from the purely social aspect of horse-horse interactions, further benefits may include a reduction in fear, particularly when a horse experiencing a novel situation is grouped with one that is habituated to that particular experience (Rørvang and Christensen, 2018). The reverse scenario is also feasible, where fear can spread within the group (Pérez-Manrique and Gomila, 2022) and between rider and horse (Jardat et al., 2023). In the latter instance, horses were able to discern human odors produced in various emotional contexts. Furthermore, in group housing, social behaviours can be promoted by providing additional enrichments. For instance, in group-housed horses, the provision of automatic brushes can promote additional relational enrichment by increasing instances of allogrooming among conspecifics (Lansade et al., 2022, see also Ginane and Rørvang, 2023).

Four or five animals is the lower limit for the number of sheep to constitute a socially stable group (Rault et al., 2011). In smaller groups, behaviour may be altered and feed intake may be reduced (Penning et al., 1993). The formation of subgroups of grazing sheep is partly determined by the availability of feed. Sheep remain in a single group or form a small number of large groups when feed is not limited; in contrast, the flock may split into a number of smaller and widely distributed subgroups when feed is scarce (Fisher and Matthews, 2001). Feeding behaviour in sheep also depends on their social motivation. A sheep will leave its group to reach a preferred feeding site located further away only if it is followed by several other familiar peers (Dumont and Boissy, 2000). Whereas wild adult male goats are spatially segregated from the nursery group and the bucks approach the female group during the breeding season. In captivity, the bucks should be separated from the female groups outside the breeding season to avoid harassment of females (Fournier and Festa-Bianchet, 1995; Miranda-de la Lama and Mattiello, 2010).

Isolation from conspecifics should be avoided in ruminants and equids because it elicits a stress response and has detrimental effects on health (Proudfoot and Habing, 2015). Both sheep and goats exhibit adverse behavioural and physiological reactions to social isolation, such as decreased feeding, increased standing, and elevated cortisol levels (Patt et al., 2013). In pregnant and preparturient goats, social isolation can induce stress and other negative effects on both the dam and the offspring (Ekesbo and Gunnarsson, 2018; Søndergaard et al., 2011). If isolation becomes necessary, goats should still be allowed to maintain olfactory, vocal, and visual contact with the rest of the herd (Miranda-de la Lama and Mattiello, 2010; Ekesbo and Gunnarsson, 2018).

When given the option between social isolation and social contact, horses exhibit a strong preference for social interaction, irrespective of the extent of tactile engagement possible. Individual housing of young horses leads to stress-related behaviours and stereotypies (Visser et al., 2008) and complicates training and handling procedures (Søndergaard & Ladewig, 2004).

Brief periods of isolation are also detrimental to cows, as evidenced by increased heart rate, hypothalamic-pituitary-adrenocortical axis activity, and heightened vocalization (Boissy and Le Neindre, 1997; Rushen et al., 1999). Individual housing should therefore be avoided. Transportation is a stressful experience for horses, particularly when they are transported alone. Traveling with a social companion mitigates stress, reducing both behavioural and physiological fear-related responses. When horses cannot travel with a companion, providing a mirror during transportation can be useful in creating the illusion of companionship (Kay and Hall, 2009), though a live companion is preferable. The use of mirrors can also be helpful in reducing the response to isolation in heifers. However, the positioning of the mirror should be directly in front of the animal, as the reflected side-view might be perceived as an unfamiliar, threatening animal, and is less effective at reducing isolation stress (Piller et al., 1999). Due to the social nature of camelids, both spatial and visual isolation can result in increased stress, as observed in alpacas (Pollard and Littlejohn, 1995).

Most young farmed ungulates, such as sheep, goats, horses, and beef cattle, are typically raised in groups or with their dam during infancy, allowing them access to conspecifics of similar age or their mother. Group-living provides opportunities for these young animals to learn from their dam or other individuals about various cues related to feeding, dominance, emotionality, spatial cognition, and social behaviour. However, dairy cattle calves are an exception to this practice. They are often separated from the dam shortly after birth and may be kept in individual pens until they reach 8 weeks of age, as allowed by European legislation (Council Directive 2008/119/EC, 2008). Consequently, this results in social isolation and deprives the calves of important stimuli necessary for the development of their social skills.

Compared to group housing (composed by an average of eight to ten individuals), individual housing has a negative impact on young calves, making them hyper-reactive (Veissier et al., 1997), afraid of novelty (Meagher et al., 2015), and less socially skilled and flexible in their behaviour (Gaillard et al., 2014), with lower cognitive abilities (Whalin et al., 2018).

Despite this, individual housing is still a common practice in Europe on the grounds that it is better for calf health, especially for the prevention of diarrhoea (Cho and Yoon, 2014), bovine respiratory disease (Griffin et al., 2010), and to avoid cross-sucking (Lidfors and Isberg, 2003) and aggression when competing for food (von Keyserlingk et al., 2004). However, given the detrimental effects on calves' welfare when socially isolated, group housing is a growing practice in young calves.

Social housing may improve welfare since it encourages feed intake by social transmission mechanisms (Vieira et al., 2010), higher weight gain and growth (Jensen et al., 2015; Pempek et al., 2016; Cobb et al., 2014), higher sociality, stronger bonds with other calves (Bolt et al., 2017; Duve et al., 2011), higher social competence, higher activity levels (Veissier et al., 1994; Boe et al., 2003; Duve et al., 2012; Jensen et al., 1999; Tapki, 2007), more play behaviour (Duve et al., 2011; Pempek et al., 2016), decreased fear and stress responsiveness (Vieira et al., 2010; Rault, 2012), increased cognition and learning (Babu et al., 2004; Gaillard et al., 2014), and higher

optimism (Buckova et al., 2019). Rearing young ungulates in groups rather than in social isolation mitigates against later aggressiveness towards humans (Price and Wallach, 1990).

Furthermore, because they have more space, group-housed calves can express play behaviour, which has been associated with positive emotions (Jensen et al., 1998; Boissy et al., 2007). Regarding health, studies have found contradictory results, varying from higher risks for enteric and respiratory diseases (Bertoni et al., 2021; Gulliksen et al., 2009), to no differences among housing systems (Mahendran et al., 2021) or improved health in socially housed calves (Babu et al., 2009; Hanekamp et al., 1994; Hänninen et al., 2003). Factors related to farm management, such as hygiene, ventilation, colostrum feeding, health monitoring, and diet quality, have an important role in the successful implementation of social housing in groups varying in size and stability (mixed or stable groups) (Costa et al., 2016; Pedersen et al., 2009; Svensson et al., 2003). Hence, while group housing may yield positive outcomes for performance, behaviour, and cognitive development, inadequate management could potentially lead to adverse health effects.

Pair housing has been increasing in popularity in North America, and has been described as a compromise between individual housing and group housing. Pair housing seems to provide some benefits of social contact (although limited) particularly for animals deprived of full social interaction when individually housed. The practical aspect of easier handling and health management has been highlighted as a benefit (Mikus et al., 2020; Vieira et al., 2012; Jensen and Larsen, 2014; Gaillard et al., 2014; Buckova et al., 2019; Bolt et al., 2017). Studies suggest that pair housing does not adversely affect health and performance (Jensen and Larsen, 2014; Bolt et al., 2017; Buckova et al., 2021) or reduce feed intake and growth compared to individual housing (Vieira et al., 2010; Jensen and Larsen, 2014; Costa et al., 2015; Jensen et al., 2015; Pempek et al., 2016; Whalin et al., 2018; Chua et al., 2002; Hanninen et al., 2005; Liu et al., 2019). Overall, pair housing should be preferred over individual housing as it improves welfare without negatively impacting important calf rearing variables. However, it's important to note that pair housing does not provide the opportunity for group living.

5.2 Young-dam relationship

Young-dam rearing systems for dairy cattle, also known as cow-calf-contact (CCC) rearing, provide prolonged physical contact between the dam and offspring (her own or foster young) and allow the expression of behaviours such as licking, sniffing, suckling/nursing, and playing (Sirovnik et al., 2020). These systems vary considerably in terms of the type and duration of physical contact allowed between dams and offspring (Johnsen et al., 2016), but generally, young-dam contact is allowed throughout the milk feeding period, after which weaning and separation occur (Sirovnik et al., 2020). At early ages, young animals learn how to navigate their social environment. Therefore, allowing the formation and maintenance of social bonds between cattle and calves, and between goats and kids in commercial dairy herds, has a positive appeal for promoting welfare. In several species, the young-dam relationship also influences development of human-animal relationships (in dairy cattle, Krohn et al., 2003; in beef cattle, Boivin et al., 2009; in sheep Boivin et al., 2001).

As social learning is important in herbivores, it is particularly important to have tame adults or to tame adults in the presence of the young during the development of the relationship, as an important management tool. For example, taming the dam in the presence of the foal can durably improve the young-human relationship (Henry et al., 2005). Nonetheless, raising dairy calves and kids with access to their mothers presents challenges, such as adapting housing conditions, requiring increased care in system management and health, and addressing separation and weaning processes. More research is needed to have a better understanding of the trade-offs that this rearing system presents (de Oliveira et al., 2020) before specific recommendations are finalised (Meagher et al., 2019).

Considering prolonged maternal care in the current dairy systems is receiving increasing interest from different stakeholders (Ventura et al., 2013; Vaarst et al., 2020; Sirovica et al., 2021) because early dam-young separation has been one of the main criticisms targeted at the dairy industry amongst societal demands for higher welfare levels (Eriksson et al., 2022).

Prolonged contact between dams and offspring has been proposed to have beneficial effects on health and welfare of cattle (Flower et al., 2003; Johnsen et al., 2016) and social abilities in dairy goats (Toinon et al., 2022). Furthermore, cow-calf contact systems do not appear to be a risk factor for Johne's disease (Johnsen et al., 2016; Beaver et al., 2019). However, there are still some inconsistencies when it relates to health, caused mainly by variations in disease prevalence at the farm level and in the management of immunity transfer via the colostrum (Meagher et al., 2019).

A recent study tested different levels of maternal contact on calves' health, namely a) no contact (NO) with their calf, in which calves were removed directly after birth and the calf was housed in a calf barn, b) partial contact (PC) with their calf, in which calves were housed in a pen adjacent to the cow area allowing physical contact on the initiative of the dam but no suckling, and c) full contact (FC) with their calf including suckling, in which calves were housed together with the dams in a free-stall barn (Wenker et al., 2022). FC calves had more health issues with a tendency for higher antibiotic usage than PC calves, despite their higher growth rate and differential faecal microbiota. The authors attributed these differences to particular circumstances related to farm management, such as postnatal housing conditions (e.g. cleanliness of maternity pens, inadequate barn climate including temperature, humidity, and wind speed). The experiment was conducted at a dairy farm with no previous experience with prolonged young-dam contact. The authors highlighted the importance of management, monitoring, and staff motivation for transitioning with new practices when implementing new systems.

The literature on young-dam rearing for dairy goats is scarcer than that on dairy cows. Prior to the weaning process, young goats raised in groups without their mothers exhibit reduced solitary rest time and less mutual grooming, yet engage in play-fighting, racing, stepping on one another, and maintaining physical contact to a greater extent compared to those raised solely under maternal care (Toinon et al., 2022). However, these disparities ceased post-weaning, suggesting that the presence of adult goats and the experience of maternal care may contribute to a decrease

in playful aggression and an increase in mutual grooming among kids raised with their dams (Toinon et al., 2022). Nevertheless, it is not yet clear if goats raised full time with the dam present greater stress coping. In fact, one study found that goat kids in a young-dam rearing system, which were separated during the daytime from their mothers, demonstrated the strongest stress response in behavioural tests (social isolation and novel object tests), while kids raised in groups without their dam seemed to have adapted well to their living conditions, showing the lowest stress reactivity. The ones that were raised full time with the dam presented a variety of stress responses in different variables compared to the other kids, which the authors found difficult to interpret, but an intermediate level of stress reactivity (Winblad von Walter et al., 2021).

At the current stage, there is a breadth of work required to fully understand the fundamental costs and benefits of alternative rearing systems in which social contact is a premise and how the re-introduction of maternal care into the dairy systems can be done successfully. The relatively limited work available must be viewed with caution given the tremendous challenges associated with interpreting the literature.

5.3 Enrichment with other (non-human) species

Interspecific relational enrichment has been developed, for instance, to safeguard flocks of sheep from predators (Anderson et al., 2012; Tischaefer, 2020; Dwyer, 2022; Matthews et al., 2020). Placing dogs, heifers, donkeys, alpacas, or other animals, particularly at an early age in the flock of sheep, reduces the prevalence of predation. This can be considered as relational enrichment if such mixing provides a feeling of safety/security resulting from the protection against predators.

Mixing species for other purposes has scarcely been studied, with some questioning results regarding the improvement of animal welfare. For instance, in an experimental study investigating relationships between cattle and broiler chickens in a co-grazing system, the main inter-species behaviours that occurred were cattle displacing chickens and chickens approaching cattle (Schanz et al., 2022). In this study, intra-species comfort and social behaviours did not differ between single- or multi-species groups, and the expected positive effect of multi-species group on fearfulness in chickens was not observed through individual behavioural tests.

When testing different housing conditions by mixing goats and horses, Wiśniewska et al. (2022) suggested that adding a small group of goats in a paddock with an individually housed horse provided a "distraction" by decreasing the level of activity for the horse compared to individually housed horses without goats. However, when lambs were penned during the first three months of age with cattle, they maintained proximity with the other species suggesting a beneficial effect for them if no cattle physically bully the sheep (Anderson et al., 2012). Overall, mixing groups of different species could have a potential positive effect on animal welfare but this needs further investigation. Inter-species play, predominantly observed among wild animals like cetaceans or primates and less frequently among ungulates, has been poorly documented in the scientific literature (Brooks and Burghardt, 2023). Regarding individually housed animals, although not well described in the literature, other species could be used as stable companions if group housing

with conspecifics is not possible. Further studies are needed to avoid any relational or disease issues between different farm species.

5.4 Human-animal relationship

Many surveys on human-animal interaction have been conducted in commercial farms on the basis of the voluntary participation of farmers (e.g., in sheep: Napolitano et al., 2011; Stubsjoen et al., 2022; goat: Muri et al., 2013; dairy cattle: Waiblinger et al., 2002; de Boyer des Roches et al., 2016; beef cattle: Windschnurer et al., 2009; Destrez et al., 2018; calves: Lensink et al., 2001; buffalo: Napolitano et al., 2019; alpaca and llama: Windschnurer et al., 2020; Menchetti et al., 2021). The information is collected from observations on-farm or from questionnaires about attitudes and practices. The interactions vary a lot between farms. Farmers reported benefits from providing their animals with neutral or positive contacts such as talking, touching, or bringing food rewards when approaching animals. These behaviours result in reduced avoidance distance or an increased approach towards humans by the animals and an increased acceptance to be touched by humans, suggesting a positive perception of those contacts. On-farm evidence is still rare for the link between positive human-animal interactions and improved production or health. For example, positive behaviour of stockpersons during milking is associated with better udder health in dairy cows (Ivemeyer et al., 2011) and higher milk production in buffalos (Napolitano et al., 2019). However, it is difficult to distinguish the direct effect of positive human contact from other related practices such as better monitoring of the animals by the farmers.

When positive rewards such as feeding or gentling are given experimentally, especially at an early age, they make animal moving and handling easier. Gentling is associated with relaxed physiological states and postures (e.g., dairy cattle: Schmied et al., 2010; sheep: Coulon et al., 2013; Tamioso et al., 2018). Animals are more likely to follow a stockperson who provides positive interactions (e.g., sheep: Tosi and Hemsworth, 2002; Dwyer, 2022). These results confirm the potential for enrichment through contact experiences that elicit positive affective states. Positive experiences also increase tolerance during veterinary procedures (dairy cattle: Schmied et al., 2010) or at slaughter (beef cattle: reduced cortisol release at slaughter, Probst et al., 2012). Furthermore, they improve production. Lensink et al. (2000) showed that additional gentling improved veal calves' response to humans and to handling, and meat quality (by reducing stress during transport to slaughter). Early human contact can have long-term beneficial effects. Early gentling associated with artificial feeding in the first day of life affects animals' approach towards humans durably (in goats: Boivin and Braastad, 1995; in dairy calves: Krohn et al., 2001). Artificially reared goats are easier to approach and handle throughout their lives, and later they are more accepting of the milking machine and retain less milk than mother-reared goats (Lyons et al., 1988). Gentling lambs at weaning reduces stress, increases weight gains, and decreases reactions to human handling (Freitas-de-Melo and Ungerfeld, 2016). All of these findings suggest an enhanced resilience in animals resulting from human contacts and its enriching properties.

Despite very limited scientific studies, some counter effects can be reported. Mialon et al. (2023) observed that artificially reared lambs that developed a high affinity towards humans could also have lower growth rates, suggesting a strong dependency on humans. Farmers should also earn

"respect" from the animal towards humans, meaning that young animals should not be allowed to interact roughly or play with their human partners. Otherwise, they can become dangerous towards humans when they become adults, particularly through imprinting processes (Sambraus, 1975).

Promoting relational enrichment through the human factor requires a review of farmers' practices in terms of their daily interactions with their animals and by questioning them about their strategy to improve their human-animal relationship. Such a strategy can be labelled as "relational practices" (Beaujouan et al., 2021). Considering the scientific state of the art reported in the above sections, such strategies should include several factors involved in the interactions and follow the whole life of the animals. Selecting animals with a favourable genetic background to perceive and interact positively with humans is a first important step. Then it is necessary to provide appropriate quality and quantity of human contact during sensitive periods such as early age or weaning periods. Such contact needs to build reassurance in the human presence with calm and predictable human behaviour. Humans should be encouraged to provide consistent positive stimulations (see Ginane and Rørvang, 2023). Moreover, managing the intraspecific social environment, particularly the presence and behaviour of tamed mothers or adults, is highly recommended for obtaining benefits from social transmission to young animals. Specific training sessions have been developed for stockpeople, in particular with cognitive behavioural approaches to modify behavioural attitudes towards the animals (Acharya et al., 2022).

Table 1: Summary of relational enrichments found in the scientific literature and their relevance for ruminants and equines. ✓ = tested and relevant, ? = not tested but probably relevant (expertise), ■ = not tested and uncertain

	Social contact	Welfare outcome	Comment	Cattle	Buffaloes	Bisons	Goats	Sheep	Horses	Donkeys	Camelids	Deer
Enrichment with conspecifics of the same species	Group housing for adults	Social affiliative behaviours, social learning, growth, play behaviours, decreased stress and fear…		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Group housing for young		Possible negative impact on health if not well managed	✓	?	?	✓	✓	✓	?	?	?
	Young raised with their dam			✓	?	?	✓	✓	✓	?	?	?
	Companion during transport	Reduced stress		?	?	?	?	?	✓	?	?	?
	Visual, olfactory and vocal contact when isolation is necessary	Reduced stress		?	?	?	✓	?		?	?	?
Enrichment with other non-human species	Guards animals (e.g. heifers, donkeys, llamas)	Reduced predation, possible feeling of social security		■	■	■	■	✓	■	■	■	■
Human-animal relationship	Regular and predictable neutral or positive contacts with animals (e.g. talking, feeding, stroking)	Reduced avoidance distance and increased approach towards humans, reassurance, positive emotions	Strong individual variability	✓	✓	?	✓	✓	✓	✓	✓	?

6 Key factors to focus on during welfare inspections

Best practices considering relational enrichment should focus on following the biological needs, providing environments in which animals can express their social behaviours. Farmed ruminants and equines are social animals that have evolved in groups. Therefore, their social needs should be fulfilled to achieve a high level of welfare, meaning that to promote an adequate balance between physical environments, mental stimulation and social interactions,, animals should be exposed to a complexity of social stimuli, including conspecifics and humans.

Welfare inspections regarding relational enrichment should focus on the opportunities that animals possess to express their social behaviours within the environment in which they are kept, and on the aspects of these interactions (i.e. considering the extent of time during which they can have social/physical contact with one another). The inspection of the environment (facilities/housing type, fences, space, etc.) is important when animals are kept in groups. The animals should be managed in a way to avoid undesired behaviours (e.g. aggression between animals). To this aim, animals should be kept in stable groups with sufficient access to resources (e.g. food, water) to minimise the risk of competition. In an ideal scenario aimed at enhancing relational enrichment, animals would thrive with greater control over the formation of their social structure through processes such as fission and fusion. However, financial constraints often make this impractical.

The human-animal relationship at the farm is also an important aspect that can be both measured in interviews (extent of interaction with humans, although not always feasible) or by standardised simple behavioural tests such as approach tests (Rault et al., 2020). Approach tests can be performed rather easily with cattle, goats, horses, whatever their age, and indoors or outdoors. Nevertheless, caution is needed in the presence of males during the breeding period or of young with protective mothers. These measures are crucial for assessing the extent of the human-animal relationship at the farm level; however, time constraints may present difficulties in this regard.

7 Gaps in knowledge and further studies needed

We have identified several knowledge gaps that are crucial to address in order to achieve a comprehensive understanding of relational enrichment:

- ***Understanding social needs***: Ruminants are social animals, and social interactions are integral to their welfare. Therefore, it would be beneficial to conduct further research to gain a deeper understanding of their precise social needs within the context of our current production systems. This includes exploring optimal group sizes and social structures that can be accommodated in housing systems. Future research endeavours could focus on designing housing systems that promote an optimal social environment aligned with the specific needs of the animals, considering, for example, memory capacity related to group sizes and opportunities to interact or withdraw from social contact.
- ***Social motivation***: The inner drive for individuals to socialise is a fundamental aspect of social behaviour and underlies important aspects in group dynamics, shaping opportunities for social support, access to resources, and social learning. More research into understanding

factors that influence social motivation (such as early experiences, social composition of the group) is encouraged to promote effective strategies of relational enrichment that support positive social experiences and overall well-being.

- ***Individual variation in the context of social relationships***: Individual behavioural differences are present in all ungulate species. A better understanding of individual preferences, taking into account animal personalities and genetic predispositions, might help in tailoring better group compositions and enrichments that meet individual needs.
- ***Young-dam rearing systems***: The social experiences early in an animal's life profoundly shape their behavioural development. Further research is needed to better understand how dairy systems allowing contact between mothers and young can be practically implemented. For instance, in alternative systems where calves have partial contact with their mothers during the day, it is crucial to determine the optimal duration for keeping them together, the most beneficial times of day for interaction, and the necessary adjustments in farm management to maintain herd health. Moreover, exploring alternative foster systems aimed at enhancing the social environment of group-housed calves, including cows not suitable for machine milking but better suited for nursing calves. These experiments should investigate the potential benefits of long-term opportunities for social learning and facilitation.
- ***Relational enrichment in camelids***: Studies on camelids, specifically focusing on their behavioural patterns and social dynamics, are currently scarce, leading to a significant lack of knowledge in this area. To enhance their welfare, it is crucial to gain a deeper understanding of how group size and composition influence vigilance and group cohesion, indirectly promoting relational enrichment and a sense of herd security. Future research should prioritise behavioural studies, particularly in captive settings like zoos, to explore social and relational enrichments and their implications for camelids, especially within the context of Europe.
- ***Interspecific interactions***: Whilst many studies have focused on intraspecific enrichment, the beneficial effect of positive interspecific interactions has remained largely unexplored (Rault et al., 2020). One reason is that studies focus more on the reduction of stress induced by human presence and handling rather than considering the potential for enrichment through interspecific relationships. Studies are not so numerous for each species even if general trends can be observed. Most of these studies have explored the human-animal relationship rather than relationships with other species. The strong individual variability among animals has not been explored to understand their perception of what is really positive. The question of how such enrichment can have a durable impact is particularly important for producing synergy rather than conflict within the whole relational network of the animal across its life.
- ***Long-term effects of relational enrichment***: While numerous studies have explored the advantages of relational enrichment, most have focused on short-term effects. There is a notable knowledge gap when it comes to understanding the enduring benefits of such enrichment, considering factors like persistence of positive social interactions. Enrichment is supposed to impact on the animals' further resilience, i.e. adaptation to further challenges in life. Further research is necessary to explore deeper the effects of relational enrichment on exploratory behaviour, cognitive performance, and stress coping mechanisms.

8 Conclusions

In conclusion, this review highlights the essential social requirements of farmed ungulates and emphasizes the importance of tailoring relational enrichment strategies to the specific needs of each species. For enrichment to be genuinely relational, animals must actively engage with social resources, fostering the development of meaningful relationships, which cannot be achieved by merely providing social companions. We have extensively reviewed current approaches implemented in farm settings, shedding light on their potential advantages and challenges. Furthermore, we discussed the benefits of relational enrichment, particularly its interaction with individual motivation, positive emotions, stress buffering, resilience, personality, and behavioral plasticity. We also highlighted the limitations in fundamental research and with certain species, noting the associated challenges and opportunities that hold significant potential for enhancing animal welfare. We encourage future research to expand the understanding of foundational concepts of social behaviour and how individuals engage in such relationships, considering the long-term effects of complex social environments. Additionally, it is imperative to better understand how the implementation of relational enrichment and complex social environments can be achieved at the farm level, ensuring their full integration into farm management practices for optimal outcomes.

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EURCAW *Ruminants & Equines* is the third European Union Reference Centre for Animal Welfare. It focuses on ruminant and equine welfare and legislation, and covers the entire life cycle from birth to the end of life. EURCAW *Ruminants & Equines*' main objective is a harmonised compliance with EU legislation regarding welfare in EU Member States. This includes:

- Directive 98/58/EC concerning the protection of animals kept on farms;
- Regulations 1/2005/EC and 1099/2009/EC concerning their protection during transport and slaughter;
- Directive 2010/63/EU concerning the protection of animals used for scientific purposes;
- Directive 2008/119/EC laying down minimum standards for the protection of calves.

EURCAW *Ruminants & Equines* supports:

- Inspectors of Competent Authorities (CAs);
- Ruminant and equine welfare policy workers;
- Bodies supporting CAs with scientific expertise, training, and communication.

Website and contact

EURCAW *Ruminants & Equines*' website offers relevant and actual information to support enforcement of ruminant and equine welfare legislation.

We offer a 'Questions to EURCAW' service for official inspectors, policy workers, and other personnel providing advice or support for official controls of ruminant and equine welfare in the EU. For more information go to https://www.eurcaw-ruminants-equines.eu/questions-to-eurcaw/.

Activities of EURCAW *Ruminants & Equines*

- Coordinated Assistance
  Providing support, networking and Questions to EURCAW;
- Welfare indicators, Assessment & Best Practice
  Identifying animal welfare indicators, including animal based, management based and resource-based indicators, that can be used to verify compliance with the EU legislation;
- Scientific and technical studies
  Preparing Scientific Reviews of knowledge on welfare topics and identify research needs;
- Training
  Developing training materials and training standards for official inspectors;
- Communication and Dissemination
  Increasing awareness of our outputs via the website, twitter, and newsletter;

Partners

EURCAW *Ruminants & Equines* receives funding from DG SANTE of the European Commission and represents a collaboration between the following six partner institutions:

- Swedish University of Agricultural Sciences, Sweden
- Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise "G. Caporale", Italy
- French National Institute for Agriculture, Food, and Environment, France
- University of Natural Resources and Life Sciences, Vienna, Austria
- University College Dublin, Ireland
- Ellinikos Georgikos Organismos-Dimitra/Veterinary Research Institute, Greece