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Animal Cognition and Animal Welfare: A Review

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ABSTRACT

The cognitive abilities of farm animals, particularly dairy cattle, play a crucial role in their adaptation to and interaction with their surroundings, influencing their performance, welfare and the safety of handlers. Despite the growing recognition of the importance of cognitive capabilities in animal welfare assessment, there remains a limited understanding of the cognitive repertoire of farm animals. Animals can acquire, process, store and act upon information from their environment through a variety of cognitive processes, including perception, learning, memory and decision-making. In order to address the behavioural and cognitive needs of farm animals and eventually improve their welfare and performance, housing systems and management techniques must be tailored with an understanding of these cognitive mechanisms. The practice of removing calves from their mothers immediately after birth, although aimed at disease control and ease of management, raises concerns regarding calf welfare and cognitive development due to social isolation. By providing cognitive enrichment opportunities, such as social interaction and environmental stimulation, animals can develop coping mechanisms for stressful events and enhance their ability to adapt to environmental changes. Moreover, the interconnection between cognition and welfare is complex, with cognitive processes influencing and being influenced by welfare conditions. This bidirectional relationship underscores the importance of considering cognitive functioning in welfare assessment and management practices. It highlights the need for further research to advance our knowledge of farm animal cognition and its implications for welfare and performance.

Key words: Cognition, Environment, Farm animal, Management, Welfare.

Dairy cattle in commercial production systems must learn about their social and physical surroundings and be able to adjust as needed (Nawroth, 2022). Research has shown that dairy calves adapt quickly to new environments, whether they are introduced to mechanical feeders or are taught how to use an automated milking system (Jacobs and Siegford, 2012). Therefore, the productivity of the production system, the welfare of the animals and the safety of the handlers all depend on the cattle's ability to learn about and adapt to their physical and social settings. In spite of this, relatively little is still known about cattle's cognitive capacities (George and Bolt, 2021; Nawroth *et al.,* 2019). Due to this ignorance, commercial housing systems and management practices are probably only loosely tailored to the cognitive and behavioural repertoire of cattle. Providing cattle with cognitive exercises, such as opening gates to get food incentives, may enhance their welfare by giving them a feeling of control over their surroundings or a way to pass the time when bored (Mandel *et al.,* 2016). All of this emphasises the necessity of developing housing systems and management practices that are more in line with the behavioural and cognitive repertoire of cattle. In order to develop such future systems, it is critical to comprehend the range of cognitive abilities possessed by cattle.

One of psychology's fundamental pillars includes motivation, emotion and cognition (Burghardt, 1997). The initial five freedoms have given way to more animal-centered approaches that take into account the needs, emotions and individual uniqueness of farm animals. As a result, farm animal welfare has grown in importance for both society and food production. It's crucial to understand the cognitive abilities of livestock to accurately assess farming practices and prevent welfare issues (Shettleworth, 2010). This understanding is essential for various stakeholders, including legislators, cognitive ethologists and philosophers, to improve animal farming practices. In dairy farming, the common practice of removing calves from their mothers immediately after birth and raising them individually may reduce disease transmission but likely compromises calf welfare. Social isolation at birth can affect cognitive development (Meagher *et al.,* 2015). Providing cognitive enrichment can help animals cope with stress, adapt to environmental changes and improve learning abilities (Hovarth, 2015). The more we understand about this topic, the easier it will be to modify husbandry practices and enrichment materials to suit the needs and preferences of farm animals.

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Cognition

Cognition encompasses how animals are able to perceive, learn, remember and make decisions. They can also gather, interpret, store and act upon information from their surroundings (Shettleworth, 2001). It enables animals to adapt to their surroundings flexibly. Consciousness, on the other hand, involves an "interior vision" allowing animals to understand their internal states, like fear and pain (Duncan, 2006). Broom *et al.* (2009) propose four levels of consciousness, indicating that animals not only react to stimuli but also remember events and mental images to make decisions, avoid negative outcomes and seek positive ones (Table 1). Basic forms of consciousness are crucial for animal well-being (Dawkins, 2006).

Welfare and cognition are intricately and multi dimensionally related, forming a reciprocal relationship (Presented in Fig 1). In addition to being socioeconomic factors, cognitive talents are also influenced by welfare situations. Environments that are beneficial or harmful to welfare have an equal effect on cognitive functions. This relationship shows up as a dynamic and reciprocal interaction, emphasising how closely related cognitive function and general wellbeing are.

Consequently, there exists a reciprocal influence between cognition and welfare, wherein cognitive processes exert an impact on well-being while concurrently being shaped by welfare conditions. Furthermore, cognitive processes are integral components of emotional experiences, thereby implicating cognition in the broader context of welfare beyond its independent role.

Classification of cognition

Shettleworth (2010) presented a taxonomy of cognitive abilities that entails a thorough division of cognitive mechanisms into physical and social cognition as the two main categories.

This classification encompasses the systematic delineation of cognitive capacities based on their functional domains, providing a structured framework for understanding the diverse aspects of cognitive processes. The classification was also given by Naworth *et al.* (2019) presented in Fig 2.

Physical cognition

The phrase "physical cognition" refers to an organism's understanding of items and their many spatial and causal relationships. For a majority of animal species, the primary challenge involves locating and acquiring sustenance, leading to the evolution of crucial cognitive skills within the foraging context (Naworth *et al.,* 2019). In this context, categorization denotes the ability to group objects based on shared attributes, facilitating higher cognitive processing through organization according to physical, associative, or relational similarities (Zentall *et al.,* 2002). Distinguishing food types based on specific characteristics

Table 1: Description of four states of consciousness.

Levels of consciousness	Description
Perceptive	Demonstrated when someone experiences perceived stimuli and automatically responds in a way that they may or may not be able to consciously change.
Cognitive	Cerebral processing of sensory stimuli, or memory-based creations, produces a flexible response.
Evaluation	Within a short period of time, an individual can appraise and determine the significance of a circumstance in regard to himself.
Executive	The individual can analyse, deduce and plan with regard to his long-term objective.

Source: Sommerville and Broom (1998).

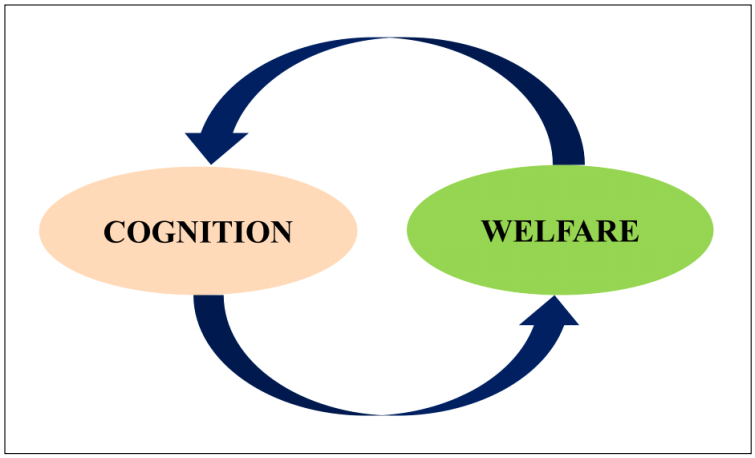


Fig 1: Cognition welfare reciprocal relationship.

can reduce cognitive demands in complex environments, aiding foraging efficiency and adaptation to new habitats and stressors.

Numerical ability, defined by Pepperberg (2006), involves discriminating between quantities regardless of size or shape, facilitated by mechanisms like "subitizing" or the "approximate number system". Evaluating food quantity or group size influences environmental predictability and adaptation to stressors, as evidenced by Uller and Lewis (2009) study with horses. According to Jaakkola (2014), object persistence is the knowledge that objects endure even when they are hidden from view, which is useful for scavenging and avoiding predators. In husbandry systems, object permanence development is crucial for anticipating future events. Reasoning, illustrated by Penn and Povinelli (2007), entails systematically eliminating alternatives to solve problems, relying on indirect evidence like absence of cues. Its role in enhancing husbandry environment predictability is noteworthy. Tool use, identified across various animal taxa (Vaesen, 2012), involves dynamic manipulation of objects or subjects for specific goals, such as foraging or self-defense. Increasing enrichment complexity, like offering chimpanzees arbitrary anthills, can benefit tool-using animals.

Social cognition

Conspecifics, individuals of the same species, pose unique cognitive challenges compared to inanimate objects. Memory and discrimination among conspecifics become more complex within social groups, requiring higher cognitive abilities for tasks like influencing others' behavior. Additionally, unpredictability from others' spontaneous actions adds further complexity. Deducing intentions and motives aids in predicting conspecific behavior, reducing uncertainty (Naworth *et al.*, 2019). Complex social interaction mechanisms include individual discrimination and identification between heterospecifics (different species) and conspecifics (same species). Discrimination

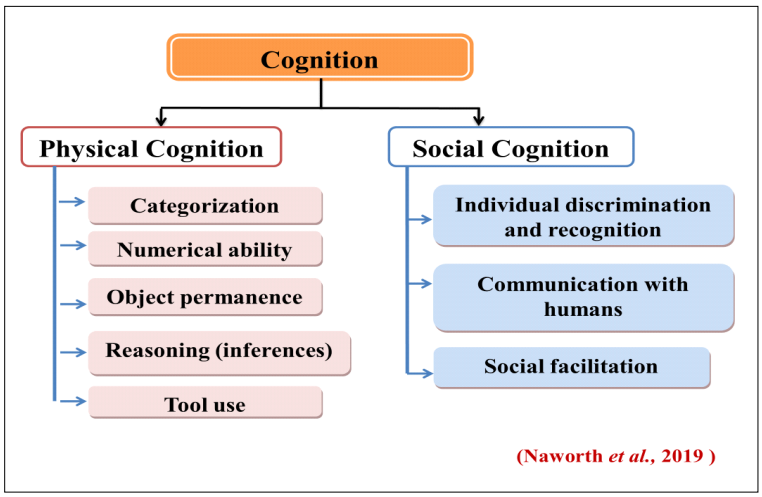


Fig 2: Classification of cognition.

Table 2: An explanation of the various cognitive tests that are applied in the production of animals and their suitability.

Types of cognitive tests systems	Applicability in livestock	Livestock system
Learning and retention by animals	Reallocating favoured spots for relaxation, cautiously investigating the lodging and avoiding regions that are typically inhabited by dominant or unknown animals.	Birds, horses, pigs and sheep.
Test of image recognition	Reduced impact of social distancing, decline in stereotypes and reduction in aggression.	Cattle, horses, sheep, rabbits and pigs
Recognition of stock people by domestic animals	Reduced apprehension of stock people by animals, improved ease of handling and reduced adverse interference with production.	Cattle, horses, pigs and birds
Preference of environments	Animals are impacted by the reduction of stressful environmental conditions.	Cattle, pigs, goats, birds and sheep
Preference for types of objects and food	Draw the animal's focus to the food and the equipment, encourage the animal to display its natural behaviour and lessen the boredom of the lodging.	Birds, pigs and cattle

distinguishes identities using inherent cues, while recognition recalls specific characteristics (Tibbetts and Dale, 2007). Cross-modal recognition, vital in humans, reduces aggression and injuries among conspecifics and alle*via*tes stress during management practices. Hagen and Broom (2003) found cattle rapidly learn to discriminate socially familiar conspecifics, with responses influenced by stimulus identity. Facial information is crucial in social communication, as shown by Coulon *et al.* (2010), who found cattle prefer familiar faces.

Communication with humans is vital for domestic animals to gather information. Animals understand human cues, like pointing gestures and communicate by alternating gaze, serving as referential and intentional communication (Savalli *et al.,* 2014). Livestock's communicative abilities impact management practices, improving handling routines. Social learning, involving observational conditioning and imitation, influences behavior based on others' actions, particularly in high-cost learning situations (Naworth *et al.,* 2019). Understanding others' perceptual states, or "Theory of Mind," aids in predicting interactions where conspecifics compete for resources and handlers manage practices.

Types of cognitive tests

Using behavioural indications, it is possible to indirectly evaluate an animal's cognitive capacity. Numerous tests, such as those measuring motivation, preference, memory and learning, have been applied mostly to animals. The objective is to enhance the animals' living conditions while concurrently augmenting their productive indices (Fernandes *et al.,* 2020). Evaluating the mental experiences of animals poses a challenge, but a meticulous approach involving the application of diverse cognitive tests, as delineated in (Table 2), can facilitate this endeavor.

Tests assessing animal learning and memory have unveiled insights into their decision-making processes. Pigs' auditory perception was examined by Imfeld-mueller *et al.* (2011), who looked at the animals' capacity to distinguish between sounds and link them to either good or unfavourable circumstances. Tests of image recognition are essential for assessing an animal's cognitive capacity since they provide information about its awareness and comprehension. Mirrors have aided animals in recognizing familiar images, advancing our comprehension of their cognitive processes (Broom *et al.,* 2009; Jones, 2013). Recognizing stock people is crucial for animals as it influences their interactions and farm success. Negative interactions during milking impact milk yields, highlighting the importance of positive handling (Oliveira *et al.,* 2014). Positive interactions increase cows' proximity to humans, necessitating interventions like stockmanship training. Preference tests allow animals to choose resources, offering insights into their welfare and emotional states (Kirkden and Pajor, 2006). These tests gauge animals' cognitive abilities and welfare, focusing on their motivation and preferences (Molento, 2005; Panksepp, 2006).

Implication of cognition capacities in farm animals

A comprehensive examination of diverse physiological and socio-cognitive capacities in distinct farm animals (Table 3), along with their associated implications, is provided by Nawroth *et al.* (2019).

Numerous elements, including as development, breed, personality, mood, motivation, food, gut microbiota and environment, can affect an animal's behaviour and cognitive ability. During prenatal and neonatal stages, rapid brain development occurs, impacted by factors like prenatal stress, which can affect cognition throughout life (Weinstock, 2008; Imfeld-Mueller *et al.,* 2011; Conrad and Johnson, 2015). Breed differences contribute to variations in temperament and cognitive task performance (Sih *et al.,* 2004). Animal personality, involving consistent behavioral patterns, interacts with cognitive processes and varies between proactive and reactive types (Sih and Del, 2012; Dall *et al.,* 2004). Mood affects cognitive performance, with

Table 3: Physio-cognition and socio-cognition capacities and their implications.

Physio-cognition capacities	Implications
Categorization	Adaptation to new stressors (obtained and handled food)
Numerical ability	Perception of environment predictability (group number) and stressor adaptation (group cohesiveness)
Object permanence	Perceived environment's predictability (housing)
Reasoning/Inferences	Perceived housing environment predictability; Cognitive enrichment complexity
Tool use	The intricacy of cognitive enhancement
Socio-cognition capacities	**Implications**
Discrimination and recognition of conspecifics	Reduction of aggressive behaviour and group cohesion
Discrimination and recognition of humans	Handler recognition and differentiation → Stockmanship (a fear response to known and unknown humans)
Communication with humans (Human → Animal)	Handling and transportation-related management and stockmanship
Social learning (vertical)	Transfer of information from parents to provide access to resources and preventive measures
Social learning (horizontal)	Peer-to-peer information exchange → Group structure and resource availability
Social learning (from humans)	Human information transfer → Environment adaptation

emotions influencing short-term variability and moods affecting longer-term states (Mendl *et al.,* 2010; Nettle and Bateson, 2012; Moors *et al.,* 2013). Motivation, influenced by rewards and prior experiences, is essential for task completion (Watanabe *et al.,* 2001). Diet impacts cognitive function, with feed restriction affecting learning and memory (Ferreira *et al.,* 2006). The gut microbiome influences cognitive function through bidirectional communication with the brain (Mayer, 2011; Galland, 2014). Environmental factors, such as housing conditions, enrichment and stress, also affect cognitive processes and welfare (Mendl, 2010; Newberry, 1995; Manteuffel *et al.,* 2009).

Impact of animal cognition

Post-weaning and mixing of animals often lead to aggressive behaviors as they establish new social hierarchies. Traditional methods to reduce aggression, like odor-masking agents or regrouping, offer only temporary relief. In contrast, cognitive enrichment promotes positive interactions among animals, mitigating aggression and promoting welfare (Puppe *et al.,* 2007). Animal cognition itself serves as enrichment, offering cognitive challenges. Purposeful methods involve goal-directed learning with rewards or punishments to reduce boredom and abnormal behavior (Puppe *et al.,* 2007). Engaging in cognitive tasks can evoke positive emotions, contributing to improved welfare. Successful navigation of challenges enhances welfare by promoting exploratory behaviors and access to resources (Manteuffel *et al.,* 2009; Franks, 2018).

Cognitive enrichment

Cognitive enrichment is crucial for improving animal welfare by broadening behavioral repertoire and reducing abnormal behaviors. Traditional forms of enrichment often lose effectiveness over time, emphasizing the need for tasks that engage animals cognitively. Positive operant training methods, like automated feeders, offer cognitive challenges but can be resource-intensive. As an alternative, baseline cognitive enrichment can be achieved by encouraging social interactions between animals (Baymann *et al.,* 2007). Studies have shown that social housing positively influences cognitive behavior in calves, enhancing learning efficiency and adaptability to tasks compared to individually housed ones (De Paula Vieira *et al.,* 2012; Meagher *et al.,* 2015; Gaillard *et al.,* 2014; Komal, 2019; Arya, 2021). Early social contact, including maternal interaction, is critical for learning skill development in dairy calves. Severing the maternal bond at birth may hinder behavioral development and adaptive abilities essential for navigating commercial housing systems (de Paula Vieira *et al.,* 2012; Meagher *et al.,* 2015). Farm animals use social facilitation and stimulus amplification as social learning mechanisms (Rørvang and Nawroth, 2021).

CONCLUSION

In conclusion, animal cognitive abilities facilitate the acquisition of new skills, such as using unfamiliar devices and navigating novel environments. Social cognition in cattle enables them to effectively utilize visual cues for locating food and prioritize numerical discrimination over volume. Furthermore, their physical cognition allows for the discrimination of familiar conspecifics and human handlers. Animals can also learn from mirror images, thereby enhancing their welfare. The attitudes of stockpersons significantly influence animal behavior and performance. Additionally, prenatal stress and maternal emotional reactivity impact the cognitive abilities of offspring. Dietary factors, such as the provision of hay, can influence behavioral flexibility in dairy calves. Providing cognitive enrichment leads to positive affective states in livestock, thereby improving their well-being. Group housing and fostering a positive social environment are crucial for promoting better social interactions among animals, offering potential benefits for optimizing performance and welfare in modern calf management practices.

Conflict of interest

Authors have declared that no competing interests exist.

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