How assessing relationships between emotions and cognition can improve farm animal welfare

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Summary
The assessment of farm animal welfare requires a good understanding of the animals' affective experiences, including their emotions. Emotions are transient reactions to short-term triggering events and can accumulate to cause longer-lasting affective states, which represent good or bad welfare. Cognition refers to the mechanisms by which animals acquire, process, store and act on information from the environment. The objective of this paper is to highlight the two-way relationships between emotions and cognition that were originally identified in human psychology, and to describe in what ways these can be used to better access affective experiences in farm animals. The first section describes a recent experimental approach based on the cognitive processes that the animal uses to evaluate its environment. This approach offers an integrative and functional framework to assess the animal's emotions more effectively. The second section focuses on the influence of emotions on cognitive processes and describes recently developed methodologies based on that relationship, which may enable an assessment of long-term affective states in animals. The last section discusses the relevance of behavioural strategies to improve welfare in animals by taking their cognitive skills into account. Specific cognitive processes eliciting positive emotions will be emphasised. Research into affective states of animals is progressing rapidly and the ability to scientifically access animal feelings should contribute to the development of innovative farming practices based on the animals' sentience and their cognitive skills in order to truly improve their welfare.

Keywords
Affective state – Appraisal – Cognition – Cognitive bias – Emotion – Farm animal – Mood – Sentience – Welfare.

Introduction

Concern for animal welfare is increasing and this concern stems from the recognition that animals are sentient beings and are capable of affective experiences, such as being stressed or, by contrast, enjoying good welfare. Thus, the assessment of farm animal welfare requires a good understanding of the affective experiences of animals, including their emotions. However, emotions in animals are difficult to measure due to the absence of verbal communication. In addition, whilst assessing the emotions of an animal is necessary, it is not in itself sufficient to provide a complete understanding of the animal's welfare. An emotion is a transient reaction in response to a triggering event. Although emotions are transient, they accumulate to create longer-lasting affective states, such as moods, which reflect how the animal feels, not only when facing the triggering events but also in the periods between these events.

Over the last two decades, scientists have made significant progress in understanding how animals perceive their environment and in accessing the feelings prompted by this perception. Experimental methods have been developed to assess emotional experiences in various animal species and many of the emotions that animals can feel are now well documented. A large number of studies in human psychology show that emotions and cognition are intimately and bidirectionally linked, so that affective experiences can be

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approached without using verbal language by investigating the interactions between emotions and cognition. Cognition refers to the mechanisms by which animals acquire, process, store and act on information from the environment (1). Cognitive processes can therefore provide new insights into the scientific assessment of emotions in animals and their longer-lasting affective states such as moods (2).

The objective of this paper is to scientifically highlight the subjective experiences of an animal, i.e. both the emotions and the mental mechanisms which contribute to its welfare. The paper is structured in three sections. The first section summarises the authors' approach (which is based on appraisal theories originally developed in human psychology) to exploring the basic cognitive processes that animals use to evaluate their environment and which trigger their emotions. The second section reviews the increasing body of research, first in humans and then in animals, that suggests that emotions influence cognitive functions through the attention and judgement processes. The last section discusses the relevance of husbandry strategies based on the sentient and cognitive skills of animals that may improve their welfare. Husbandry practices that stimulate specific cognitive processes which, in turn, give rise to positive emotions, will be discussed in more detail as an innovative behavioural strategy for truly improving the quality of life for farm animals.

Cognition induces emotions: a method to access the emotional experience of animals

According to appraisal theories developed in cognitive psychology to probe human emotions, an emotion is triggered by simple evaluative processes based on a limited number of elementary characteristics, such as familiarity and predictability, which are used by individuals to evaluate the level of challenge set by their environmental situation (3). Based on this conceptual framework, the authors have developed an integrative and functional approach to assess emotions in animals according to their cognitive capacities. This approach has been used in sheep and involves studying whether the same basic evaluative processes as those identified in humans are undertaken by animals and whether they produce emotional experiences that can be recognised by behavioural and physiological changes (4). A necessary first step was to develop a detailed analysis of relevant behavioural expressions that can indicate emotions, such as the position of the head and ears (5). Similarly, non-invasive techniques (e.g. analysis of heart rate variability) were developed as indices of activation and involvement of the autonomic nervous system in mediating

physiological changes (6). Experimental designs were then developed to ascertain which elementary evaluative characteristics were relevant to animals. At the same time, cardiac and behavioural reactions were recorded and direct relationships between presumed appraisal and measurable emotional outcomes were established.

As already reported in many species, it was shown that the sudden presentation of a familiar object produces a startle response and a brief cardiac acceleration (i.e. tachycardia), while the presentation of an unfamiliar object elicits behavioural orientation towards the object and a transitory increase in heart rate variability (7). These basic evaluative processes appear to be automatic, and may not require the animal to be aware that it is evaluating the situation. More interestingly, it was found that sheep are able to anticipate and that their emotional response to an event is affected by the predictability of the event (8) (Fig. 1). Likewise, they can develop expectations, and a discrepancy between their own expectations and the current situation itself induces behavioural agitation and cardiac acceleration (9). Similarly, sheep are able to control their environment in such a way that the emotional response to a given event depends on the extent to which the animal can act on it
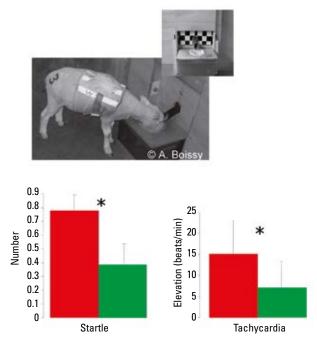

Fig. 1

Mean ± standard error of the mean (SEM) startle responses (arbitrary units) and tachycardia (beats/minute) in sheep when a white and blue squared panel drops down behind the trough (upper panel)

Lambs for which the appearance of the panel was preceded by a light signal (green bar) are compared with lambs that had no cue signalling the panel (red bar) (lower panel). The specific emotional response of sheep to sudden events (i.e. startle response and tachycardia) was affected by the predictability of that given event (after Greiveldinger *et al.*) (8)

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(10). Furthermore, as we would assume from the dynamic sequential organisation of appraisal in Scherer's model (3), the behavioural and cardiac responses associated with a single elementary evaluative characteristic can change when that original elementary characteristic is combined with other elementary characteristics. For instance, it has been shown in sheep that the combination of suddenness with either unfamiliarity or unpredictability has a synergistic effect on the animal's emotional response to suddenness. The specific responses to suddenness, both the startle response and tachycardia, are accentuated when the sudden event is also unfamiliar (11), while they are less marked when the animal can predict the appearance of the sudden event (8).

As the emotional responses of sheep involve cognitive processes, sheep not only have emotion-related responses, which could be considered to be reflexes, but they really do experience the emotions. Collectively, sheep may experience a wide range of emotions, including fear, rage, despair and boredom, via their sensitivity to suddenness, unfamiliarity, unpredictability, discrepancy from expectations and uncontrollability (12). These findings add scientific support to the argument that farm animals are sentient beings. Although this approach has not yet been completely applied to many farm animal species, it is now widely accepted that not only mammals but also poultry and even farmed fish can experience emotions (13, 14). These findings highlight the benefits of using frameworks and methods derived from cognitive sciences to assess animals' emotions. Therefore, the evaluative processes identified in humans for studying the emotional nature of a situation can also be used for animals. The study of emotional processing in animals should not only consider the behavioural and physiological components; in order to better access the emotional experience *per se*, such study should also take the cognitive component into account.

Emotions influence cognition: a complementary method to assess long-lasting affective states

While the integrative and functional approach presented in the previous section enables the measurement of short-term emotions in response to specific eliciting events, this section describes methodologies which may be applied to assess longer-lasting affective states. These states may be referred to as mood states, or the accumulated experience of shorter-term emotional episodes (15). Moods such as depression or agitation may indicate a chronic stress state and are thus important when considering animal welfare.

Progress has been made in understanding how emotions influence cognitive processes and this has enabled the development of new methodologies to assess prolonged affective states. Here again, the concepts underlying these methodologies are based upon research into human psychology. In humans, affective states influence cognitive processing and alter the ways in which individuals perceive, evaluate and interpret information from their environment. These influences are called 'cognitive biases'. Depressed people show a biased attention towards negative stimuli (16) and have an increased expectation of negative outcomes (17), and anxious people tend to interpret new information as more threatening (18). In contrast, a positive mood may make creative problem-solving easier and enhance the recollection of remembered details (19).

Recently, there has been an increased focus on the investigation of affective states using cognitive approaches in animal welfare research (20). This was initiated through the development of a judgement bias test in rats (21), which has been adapted and used in a range of species, including starlings (22), dogs (23), sheep (24, 25) and pigs (26). One example of the methodology is the sheep test developed by the authors' two teams from INRA and CSIRO, which is based on a spatial location task (24, 25). Sheep are trained to associate one cue (a bucket at one side of a pen) with a reward (food), and another cue (the bucket at the opposite side of the pen) with a negative reinforcer (a dog or a noisy blower). Once trained to this go/no-go task, sheep are exposed to several ambiguous cues, i.e. the bucket located in various positions between the positive and negative trained cues, and the animal's response to the different cues is measured. The interpretation of ambiguous cues by the animal is considered to reflect whether it is in a positive or negative mood. An 'optimistic' judgement bias is suggested when the animal approaches buckets in ambiguous positions, i.e. it has an increased expectation of a reward, and a 'pessimistic' bias is shown when the animal does not approach ambiguously placed buckets, i.e. it has an increased expectation of the negative reinforcer. With this methodology, it has been demonstrated that negative past experiences, such as the removal of environmental enrichment (27), repeated exposure to unpredictable and aversive events (21, 28, 29), and the administration of a serotonin inhibitor to induce depression (30), elicit a 'pessimistic' bias. By contrast, animals treated with a benzodiazepine (diazepam), known for its anxiolytic properties (25), or with the opioid agonist morphine (31), or housed in an enriched environment (32) judge ambiguous cues more 'optimistically'.

While judgement bias shows promise as a method of assessing long-term affective states in animals, it requires significant training of these animals, which limits the use of such tests, and it is not suitable for very young animals. Other types of cognitive bias measures, such as attention

bias or threat perception (33), which reflect states such as anxiety through increased attention and vigilance in response to a threat, may be more suitable to develop into robust and practical tests as they may not require prior training. The authors suggest that, after further development and refinement, the application of cognitive bias methodologies to the assessment of affective states in farm animals may enable significant improvements in their welfare.

Improving welfare in animals by taking their cognitive abilities into account

Animals can perceive their environment as more or less comfortable and environmental comfort really matters to them. Major physical and physiological causes of poor welfare in modern farming systems include:

– inadequate nutrition resulting from a reduction in either the quality and/or quantity of food intake, leading to hunger and stereotypies (34)

– non-adapted housing conditions that impose behavioural restrictions on the animals, preventing the satisfaction of their highly motivated behaviours or so-called 'behavioural needs', leading to frustration (35)

– pain due to husbandry procedures after surgical procedures such as castration or dehorning, or due to disease processes (36)

– poor handling (37) and a constrained or badly managed social environment (38).

However, situations do not need to cause obvious physical harm to affect animal welfare. Previous repeated exposure to suddenness, novelty, unpredictability, discrepancy from expectations and uncontrollability can also have detrimental effects on the emotional responses of an animal. For instance, long-term exposure to aversive events that occur unpredictably and uncontrollably increases subsequent emotional stress in sheep (29, 39). Generic knowledge of cognition can thus improve our understanding of potentially negative aspects of the animals' living conditions. For instance, sudden noises or movements occur in all farm environments, and animals that are offered new foods, housed with unfamiliar animals or moved to a new barn can all experience fear (40). Likewise, unpredictability and uncontrollability may be distressing to animals. In this case, even positive events like food provision can also compromise welfare by causing stress when the animal either loses its ability to control food delivery or learns that it cannot exert any control over its food, as found in

lambs (10). In addition, taking the cognitive skills of farm animals into account should help our understanding of why chronic stress sometimes results in apathy or blunted emotion, whereas in other cases it leads to heightened emotional reactivity. Apathy would be likely to develop when the animal has no way of altering negative events, whereas hyper-reactivity would occur when it thinks that it can control such events (40).

Although research on affective and cognitive components in farm animals is currently at a strategic stage, these approaches may contribute to the development of innovative livestock management practices. Such practices would focus on the animals' sentience and cognitive skills in order to reduce stress by ensuring a better match between the needs or expectations of the animals and the characteristics of their environment.

While the concept of welfare is based on a balance between negative and positive experiences (41, 42, 43, 44), current research in animal welfare is mainly focused on identifying and preventing negative emotions and bad welfare. However, preventing negative welfare for animals is not the same as providing them with opportunities to experience positive emotions and good welfare (45). Therefore, in addition to assessing negative experiences, it is also necessary to consider both positive expectations (what an animal 'likes') and resources that an animal is motivated to obtain (what an animal 'wants'). The authors' integrative framework based on the cognitive skills of animals is particularly useful in developing behavioural strategies in animal husbandry for enhancing positive experiences.

At least three specific evaluative processes can be outlined for eliciting positive emotions (45). First, positive emotions can be enhanced by signalling a reward in advance. When anticipating food rewards, rats (46), mink (47), poultry (48) and pigs (49) show increased locomotor activity and frequent behavioural transitions, reflecting a positive emotion. Secondly, a positive emotion can also be elicited when receiving a greater reward than expected. For instance, sheep have been reported to express transient hyperactivity when their food reward is bigger than usual (9). Thirdly, a positive experience is also induced when an animal is able to cope with or control a wanted event. For instance, after having learned that a particular sound signals that they can work for food by pressing a button, a transient cardiac reaction, revealing a positive emotion, is observed in pigs when they hear this signal (50). Interestingly, unlike conventionally housed pigs, pigs reared for several weeks under such a model show modifications in the reward-sensitive brain opioid receptors, indicating frequently occurring positive experiences (51).

In conclusion, such 'cognitive' enrichment, based on the evaluative abilities of farm animals and their proactive

behaviour, could provide promising behavioural strategies to induce positive emotions and related longer-lasting affective states. More speculatively, such behavioural strategies based on cognitive enrichment might be useful in alleviating stress or production diseases and their detrimental effects. For instance, rats submitted to prolonged stress did not develop anhedonia – a major symptom of depression – if at the same time they received repeated food reward announcements, suggesting that an emotionally positive experience can counteract the adverse effects of a simultaneous stressful experience (52). As for the putative impacts of cognitive enrichment on health, further interdisciplinary research on farm animals is necessary to fully understand how basic evaluative processes and ongoing affective coping influence the immune system and therefore an animal's potential susceptibility to infections (45).

Conclusion

While it may now be generally accepted that farm animals are sentient beings, it is still a common misconception that they are passive. Farm animals evidently have the capacity to play an active role in enhancing their own welfare as long as the farming environment is favourable. Welfare outcomes are influenced by the way in which the animal perceives the events which confront it, as well as by whether it perceives it has the ability to manipulate or control those events, and to what degree. In addition, welfare outcomes depend on the animal's past emotional experiences as well as its current situation, as those previous experiences bias its perception of the present situation.

In summary, this paper describes how studying cognitive functions in farm animals and the emotion-induced alterations in such functions can help us to better access both animals' emotions and their longer-lasting affective states. Animal management procedures designed to create cognitive challenges incorporating positive anticipation and contrast, and the control of rewards, are promising and may provide practical approaches for making animals more resilient and empowered under sustainable farming systems. These changes to the animals' experiential environment could easily be introduced into farming systems because they are safe, simple and inexpensive, with the potential to have strong impacts on animal welfare and, more speculatively, on animal health.

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Améliorer le bien-être des animaux d'élevage grâce à une évaluation correcte des liens entre émotions et cognition

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Résumé
L'une des conditions nécessaires à l'évaluation du bien-être des animaux d'élevage est de bien appréhender les expériences affectives des animaux, émotions incluses. Les émotions sont des réactions ponctuelles à des événements déclenchants de courte durée, mais leur accumulation peut entraîner des états affectifs durables, qui constituent un état positif ou négatif de bien-être. La cognition désigne les mécanismes grâce auxquels les animaux sont capables d'acquérir, de traiter et d'enregistrer les informations émanant de leur environnement, et d'agir en conséquence. Après avoir fait ressortir les relations réciproques que la psychologie a identifiées chez l'être humain entre les émotions et la cognition, les auteurs proposent quelques pistes permettant d'utiliser cette connaissance pour accéder aux expériences affectives des animaux d'élevage. La première partie de l'article décrit une méthode expérimentale mise au point récemment, basée sur les processus cognitifs mis en œuvre par l'animal pour évaluer son environnement. Cette méthode offre un cadre cohérent et fonctionnel pour évaluer les émotions des animaux de manière plus efficace. La deuxième partie, axée sur l'influence des émotions sur les processus cognitifs, décrit des méthodologies récentes basées sur cette relation, qui permettront peut-être d'évaluer les états affectifs de longue durée chez les animaux. La dernière partie examine la pertinence des stratégies comportementales qui tentent d'améliorer le bien-être des animaux en

tenant compte de leurs compétences cognitives. Il s'agit de mettre l'accent sur certains processus cognitifs spécifiques qui suscitent des émotions positives. La recherche sur les états affectifs des animaux connaît des avancées rapides ; la capacité d'évaluer scientifiquement les sentiments éprouvés par les animaux devrait contribuer à développer des pratiques d'élevage innovantes basées sur le ressenti sensoriel des animaux et sur leurs compétences cognitives, afin de véritablement améliorer leur bien-être.

Mots-clés

Animal d'élevage – Bien-être – Cognition – Émotions – États affectifs – Évaluation – Humeur – Penchant cognitif – Sensibilité.

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Mejorar el bienestar de los animales de granja mediante la evaluación del vínculo entre emociones y cognición

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Resumen

Para evaluar el bienestar de los animales de granja es necesario aprehender cabalmente su universo afectivo, lo que incluye sus emociones, entendiendo por ello reacciones transitorias inducidas por un acontecimiento inmediato que pueden acumularse hasta dar origen a estados afectivos más duraderos: estos son los que constituyen un estado de bienestar o malestar. La cognición remite a los mecanismos por los que los animales adquieren, procesan y almacenan información procedente de su entorno y actúan en consecuencia. Los autores aspiran a poner de relieve las relaciones de ida y vuelta que existen entre el universo emocional y el cognitivo, que en un principio fueron descritas en el psiquismo humano, y exponer el modo en que cabe utilizarlas para aprehender mejor las vivencias afectivas de los animales de granja. En la primera parte del artículo describen un reciente método experimental basado en los procesos cognitivos de los que se sirve el animal para evaluar su entorno. Este método ofrece un sistema integrador y funcional para aprehender con más eficacia las emociones del animal. En la segunda parte abordan la influencia de las emociones sobre los procesos cognitivos y describen métodos recientes, basados en esa relación, con los que es posible evaluar los estados afectivos duraderos de los animales. En la última parte estudian la pertinencia de las estrategias conductuales para mejorar el bienestar de los animales, que pasan por tener en cuenta sus aptitudes cognitivas y por hacer hincapié en procesos cognitivos específicos que generen emociones positivas. La investigación sobre los estados afectivos de los animales avanza rápidamente, y la capacidad de acceder científicamente al mundo afectivo animal debería ser de ayuda para definir prácticas agropecuarias innovadoras, basadas en la sensibilidad y las aptitudes cognitivas de los animales, con el fin de mejorar realmente su nivel de bienestar.

Palabras clave

Animales de granja – Bienestar – Cognición – Emoción – Estado afectivo – Estado de humor – Sensibilidad – Sesgo cognitivo – Valoración.

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