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Emotions and cognition: a new approach to animal welfare

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Abstract

The concept of quality of life in animals is closely associated with the concepts of animal sentience and animal welfare. It reflects a positive approach that inquires what animals like or prefer doing. The assessment of farm animal welfare requires a good understanding of the animals' affective experience, including their emotions. However, affective experience in animals is difficult to measure because of the absence of verbal communication. Recent studies in the field of cognitive psychology have shown that affective experience can be investigated without using verbal communication by examination of the interactions between emotions and cognition. On the one hand, appraisal theories provide a conceptual framework which suggests that emotions in humans are triggered by a cognitive process whereby the situation is evaluated on a limited number of elementary criteria such as familiarity and predictability. We have applied these appraisal theories to develop an experimental approach for studying the elementary criteria used by farm animals to evaluate their environment and the combinations of those criteria that trigger emotions. On the other hand, an increasing body of research, first in humans and then in other animals, suggests that emotions also influence cognitive processes by modifying attention, memory and judgement in a short- or long-term manner. Cognitive processes could therefore be manipulated and measured to provide new insights into how not only emotions but also more persistent affective states can be assessed in animals. Further work based on these cognitive approaches will offer new paradigms for improving our understanding of animal welfare, thus contributing to 'a life of high quality' in animals.

Keywords: *animal welfare, cognition, emotion, farm animals, quality of life*

Introduction

The concern for animal welfare stems from the recognition that animals are not only reactive to their environments but also sensitive. This implies that animals have emotional capacities, such that they will attempt to minimise negative emotions (eg fear, frustration) while seeking positive emotions (eg pleasure, joy) (Dawkins 1983; Duncan 1996). However, whereas it is claimed in the context of quality of life that animals are sentient creatures (ie they can feel their emotions), it is paradoxical that there is no strong scientific knowledge of what their emotional experiences are. In addition to emotions, which are by definition (Dantzer 1989) short-lived, the concept of welfare involves more persistent affective states that influence the way in which the individual perceives and reacts to its environment (Lazarus 1991). Nonetheless, as noted by Dawkins (2001) and Dantzer (2002), research on farm animal welfare has generally been limited to indicators of stress and has not linked these indicators to the existence of affective states. In the future, it will be essential to move beyond the simple description of animals' behaviours towards an understanding of their emotional states (Désiré *et al* 2002; Mendl & Paul 2004).

Although there is no single general definition, an emotion can be defined as an intense but short-lived affective response to an event associated with specific body changes (Dantzer 1989). An emotion is classically described by a subjective component, which is, strictly speaking, the emotional experience, and two expressive components, one motor and the other physiological (Dantzer 1989). The subjective component is generally inferred in humans by means of verbal self-reports. However, conceptual-psychological scales cannot be used in animals, and hence their subjective component can only be inferred from the behavioural and/or physiological components. There has been growing interest in the study of emotions in animals in the past few decades, resulting in the emergence of a new discipline referred to as 'affective neuroscience' (Panksepp 1998). However, despite the increasing number of studies, the exact nature of emotional experiences in animals remains poorly understood, and the existence of subjective

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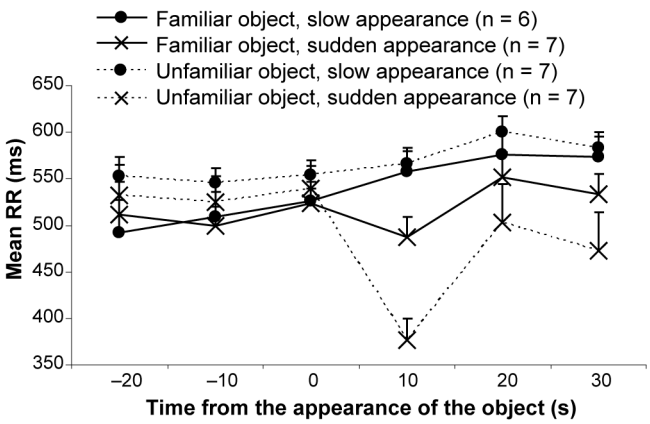
Figure 1



Cardiac activity (mean beat-to-beat interval [RR]) of lambs before and after the appearance of an object that is either familiar or unfamiliar and that is presented either slowly or suddenly (after Désiré *et al* 2006). Mean RR decreases after the sudden appearance of the object. This decrease is more marked when the object is also unfamiliar ($F_{time} = 10.64$, $P < 0.001$; $F_{time \times sudden} = 11.98$, $P < 0.001$; $F_{time \times unfamiliar} = 4.76$, $P < 0.01$; $F_{time \times sudden \times unfamiliar} = 3.11$, $P < 0.05$).

states common to both humans and other animals is not readily accepted in the scientific community.

One of the key factors explaining the phylogenetic success of emotions is that they would favour adaptive cognition and action. From an evolutionary perspective, emotions refer to processes, which are likely to have evolved from basic mechanisms that gave the animals the ability to avoid harm/punishment or to seek valuable resources/rewards (Panksepp 1994). Animals should thus be capable of assigning affective values to their environment. Studies of stress have shown that it is the animal's representation of an event rather than the event itself that determines its reaction. For example, it is not so much the absence of food as the perception of deprivation that induces stress (Mason 1971). Thus, cognitive processes, ie information processing and mental representation, have to be taken into account in order to better assess the emotional experiences of the animal. According to Lazarus (1991), an emotional state requires a primary appraisal of the emotional stimulus which is responsible for action planning and execution, after which the consequences of this action are evaluated through a secondary appraisal. Since the pioneering work of Magda Arnold (Arnold 1960), appraisal theories have been developed in human psychology to access emotions: an emotion arises from the cognitive process engaged by the individual to evaluate the emotion-eliciting event (for reviews, see Scherer 1999; Kappas 2006). According to Scherer (1987), this evaluation is based upon a limited number of elementary criteria, some rapid and others more subtle, including the intrinsic characteristics of the event (its suddenness, familiarity, predictability and pleasantness), the consequences of the event relative to the individual's expectations, the coping potential of the individual, and then the relevance of the response to social norms (ie how the response fits social norms). Scherer (1987) postulates that the kind of emotion results from the characteristics of the combination of these elementary criteria used to evaluate the emotion-eliciting event. Such an approach provides a conceptual and pragmatic framework that may be at least partially applied to animals since it is based upon elementary cognitive processes that can be manipulated by the experimenter. Furthermore, there is increasing evidence that causal links between emotions and cognition occur in both directions, with not only cognitive processes determining felt emotions but also emotional manipulations more or less persistently influencing cognitive processes (Paul *et al* 2005). Therefore, cognitive science can be useful for research on emotions in farm animals and thus provide a better approach to studying animal welfare.

This paper provides a brief review of the interactions between emotions and cognition in farm animals. In the first part we will examine cognitive processes involved in the elicitation and differentiation of emotions. In the second part of the paper we will address how emotions may in turn affect cognitive processes, in particular exploring how emotions may act as a more or less persistent filter influencing how animals perceive events or situations to which they are exposed.

(1) Cognition in emotions, or how to gain access to the emotional experience of animals

Having defined a conceptual framework derived from research in cognitive psychology, we have developed our own approach to studying emotions in farm animals (sheep, goats, pigs and quail) that is based on the animals' cognitive capacities. In concrete terms, this approach consists in studying whether elementary evaluation criteria such as those identified in humans (suddenness, familiarity, etc) are perceived by animals and whether they produce emotional states that can be recognised by behavioural and physiological changes (Désiré *et al* 2002). A necessary prior step was to develop a detailed analysis of relevant behaviours (positions of the head, ears, etc). Similarly, non-invasive techniques (eg analysis of heart rate variability) had to be developed in order to measure the autonomic nervous system activation mediating physiological changes (sheep: Després *et al* 2003; quail: Valance *et al* 2007b).

Experimental situations designed to activate one or several likely evaluation criteria in the animals were developed in order to ascertain which elementary evaluative criteria are relevant to animals, such as suddenness or unfamiliarity of the situation. At the same time, cardiac and behavioural reactions were recorded, and direct relationships between presumed appraisal and measurable emotional outcomes were established. For instance, it was shown that the sudden presentation of an object produces a startle response and a brief cardiac acceleration (ie tachycardia), while the presentation of an unfamiliar object elicits behavioural orientation toward the object and a transitory increase in heart rate variability in sheep, goats or quail (respectively, Désiré *et al* 2004; Roussel *et al* 2005; Valance *et al* 2007a).

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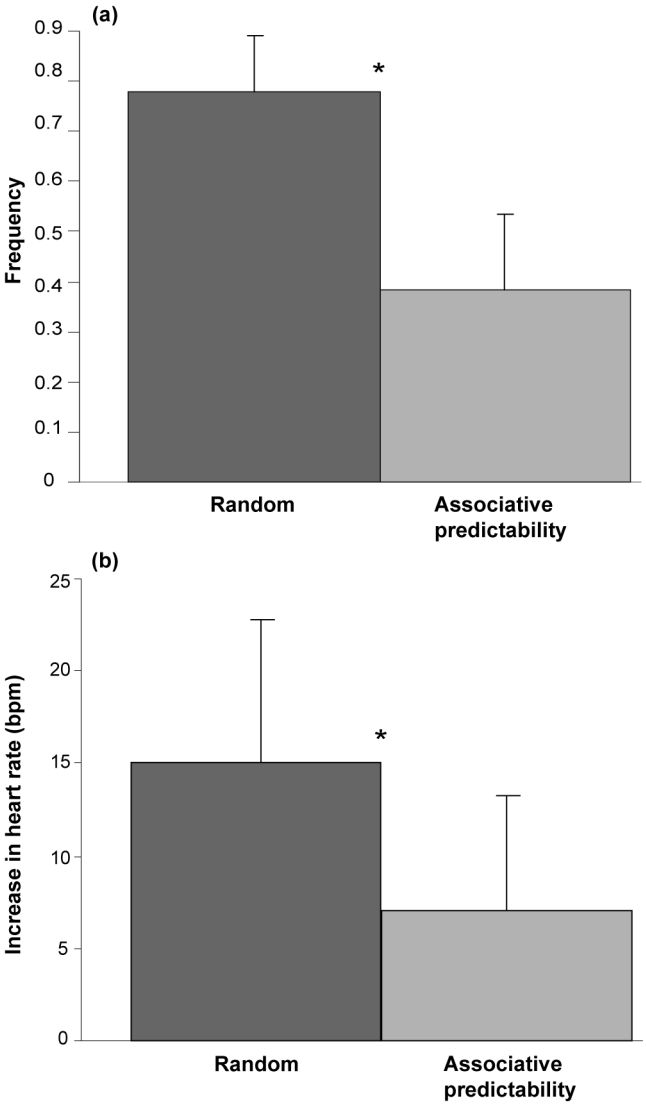
Furthermore, as would be assumed from the dynamic sequential organisation of appraisal in Scherer's model (1987), the combination of different criteria enhances behavioural and cardiac responses that are specific to a criterion. It has been shown in sheep that the combination of suddenness with either unfamiliarity or unpredictability has a synergistic effect on the animal's emotional responses. The heart rate acceleration specific to suddenness is accentuated when the sudden event is also unfamiliar (Désiré *et al* 2006; see Figure 1), while both startle response and tachycardia in reaction to suddenness are less marked when the animal can predict the sudden event (Greiveldinger *et al* 2007, p 170, this issue; see Figure 2). Similarly, sheep are able to develop expectations, and the discrepancy between their expectations and the actual situation itself induces behavioural agitation and heart rate acceleration. These preliminary results confirm the benefits of using theories and techniques from cognitive science to study animals' emotions; the evaluative criteria identified in humans for studying the emotional nature of a situation can also be used for animals. Therefore, emotional processing in animals must now be regarded as comprising not only behavioural, physiological and subjective components but also a cognitive component.

Using an approach that has been developed progressively over a period of several years, we have investigated the potential role played by conspecifics in the elicitation of emotions. Farm animals are frequently exposed to changes in their social environment. For instance, sanitary processes often require isolation, and sorting animals into new groups generally entails breaking relationships with familiar conspecifics as well as encountering unfamiliar ones. It is known that encountering unfamiliar animals or simple isolation are causes of marked stress reactions in the majority of domestic species that are known to be gregarious (Boissy *et al* 2001a). Thus, we have conducted comparative studies between mammals (sheep, goats, pigs) and birds (quail) on the emotional effects of brief or long-lasting modifications of the social environment (Veissier *et al* 2001; Boissy *et al* 2001b; Arnould *et al* 2002; Roussel *et al* 2006; Valance *et al* 2006; Coutellier *et al* 2007; see Figure 3). These investigations are expected to lead to species-specific assessments of the emotional consequences of disturbances in the social environment. This research should help to establish livestock management practices that will ensure a better match between the animals' needs or expectations and their environment.

In addition, a neurobiological approach was undertaken in these animal species to identify the brain structures involved in generating these emotions. Certain cortical regions, especially the prefrontal areas, play an essential role in the mental representation of emotions and, hence, of states of well-being (Rolls 2005). These findings, obtained primarily in primates, are difficult to apply to species of agricultural interest, especially given the lack of homology in structures, although the functional neuroanatomy of some of these structures is now being studied in sheep (eg Keller *et al* 2005). In any event, it is clear that subcortical structures, including the hypothalamus and the amygdala

Figure 2



(a) Frequency of elicitation of startle response and **(b)** increase in heart rate (mean ± standard error) after the occurrence of a sudden event in lambs. Lambs were given food deliveries that were either followed or not followed by a sudden event (a white and blue panel dropping down behind the trough). The frequency of startle response and the heart rate of lambs given food deliveries followed by a sudden event occurring at random were compared with these measures in lambs for which the sudden event was preceded by a light signal (associative predictability) (after Greiveldinger *et al* 2007, p 170, this issue). Specific emotional responses to suddenness (ie startle response and tachycardia) are reduced when the lambs can predict the sudden event. *$P < 0.05$.

nuclei, are essential in mediating emotions such as anger and fear (Panksepp 1998; 2005). We have thus begun a comparative approach on sheep and quail (Figure 4) focussing on the paraventricular nucleus of the hypothalamus and its homologue in birds. Functional neuroimaging techniques, which can be used in conscious animals with satisfactory spatial resolution, may lead to new developments in the study of the neurobiological substrates of emotion in farm animals. For instance, the mapping of the

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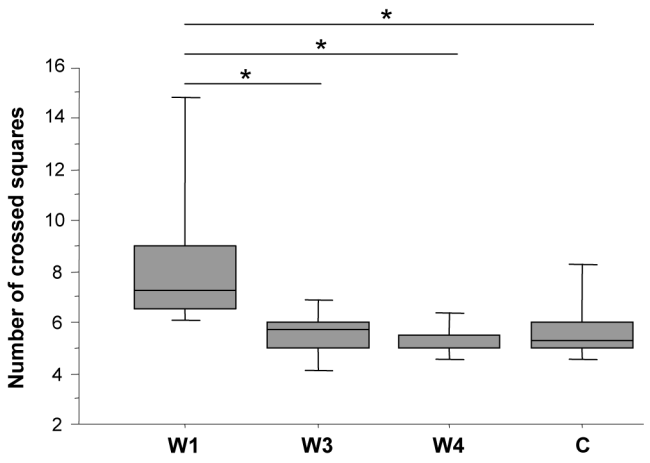
Figure 3



Locomotor activity (measured in terms of number of floor-grid squares crossed) in 46-day-old piglets exposed to a sudden event. The piglets were previously weaned at 1 week, 3 weeks and 4 weeks (W1, W3 and W4, respectively) or else maintained with their dams (C) (after Colson *et al* 2006). Early-weaned piglets (W1) showed the strongest reactions to suddenness. For all four groups, n = 6. *$P < 0.05$.

separation distress system in animal brains has striking anatomical correspondences to human sadness systems highlighted by positron emission tomography (PET) imaging (Damasio *et al* 2000; Panksepp 2003).

(2) Emotions in cognition, or how to understand the establishment of long-lasting affective states

While cognitive processes are at the origin of emotions, emotions can in turn influence cognitive processes. A significant body of work in human psychology has shown how emotional responses can bias the processing of information coming from the environment. This bias involves changes in attention, in memory, and even in judgements of the situation. For instance, anxiety induces attentional shift towards potential threatening information (Bradley *et al* 1997). Furthermore, emotionally charged events are more readily remembered than are neutral ones (Reisberg & Heuer 1995). Likewise, moderately strong emotions improve memory performance, while extreme emotions have a deleterious effect on memory (Mendl *et al* 2001). Finally, judgement processes may be affected by current emotions: participants exposed to strongly negative events tend to negatively interpret all subsequent ambiguous events (Wright & Bower 1992). Such emotional modulations of cognitive processes can be interpreted as having adaptive value by helping a fearful or anxious individual to pay attention to, to memorise and to make judgements on threatening circumstances. The few similarly focussed studies on animals show that such effects are not restricted to humans (Paul *et al* 2005). In rodents, the startle response induced by exposure to a sudden event tends to occur faster and with greater amplitude under negative emotional states (Lang *et al* 1998). Heifers subjected to a strong stressor are unable to abandon a previously learned behaviour that is no longer rewarded (ie extinction procedure), a pattern that prevents them from acquiring a new, more appropriate behaviour (Lensink *et al* 2006). In contrast, a more moderate stressor facilitates learning. Thus, rats that have received a catecholamine injection mimicking the physiological component of a moderately strong emotion are more attentive and display improved memory performance (Sandi *et al* 1997). Similar phenomena have been described in fish (Gibbs & Summers 2000).

The evidence that emotion has immediate repercussions on cognitive processes suggests that it would be worthwhile to develop a new research theme. This research would entail exploring how emotions may accumulate to modify an animal's cognitive functions in a long-lasting manner and, as a result, establish in the animal a state of well-being, or a lack thereof. In laboratory animals, research is already suggesting considerable, long-lasting modulation of evaluation capacities by emotional experiences. For example, rats or mice that are subjected to repeated unpredictable events, which are known to induce a repetition of negative emotions, are less ready to respond to an ambiguous stimulus (the characteristics of which are intermediate between those of a stimulus signalling the delivery of a positive event [ie a reward] and those of another stimulus signalling the delivery of a punishment), indicating reduced capacities for judgement and decision-making — that is, a cognitive bias (Pardon *et al* 2000; Harding *et al* 2004). Likewise, rats housed under social stress or isolation exhibit a lower frequency of behavioural agitation between the presentation of a conditioned stimulus predicting sucrose reward and the arrival of that reward, suggesting a reduced anticipatory behaviour resulting from judgement difficulties (von Frijtag *et al* 2000). Evidence of such systematic biases in the way in which an animal evaluates its environment could therefore be used as another variety of indicators of a persistent state of discomfort. Furthermore, it has been shown that an animal that is able to control its environment through a learned behaviour seems less disturbed by new constraints than an animal in an unpredictable and uncontrollable environment (Dantzer 1989). Evidence of elementary evaluation criteria used by animals in an ongoing manner and driven by specific features of the environment should help us to understand why chronic stress sometimes results in apathy or blunted emotion while in other cases it results in heightened emotional reactivity. Apathy would develop when the animal has no way to alter negative events ('learned helplessness'), whereas hyper-reactivity would occur when the animal is under the impression that it is able to control such events. Developing similar approaches in farm animals could help to develop new indicators of persistent emotional states (ie good or bad welfare), such as an enhanced expectation of positive events (Spruijt *et al* 2001).

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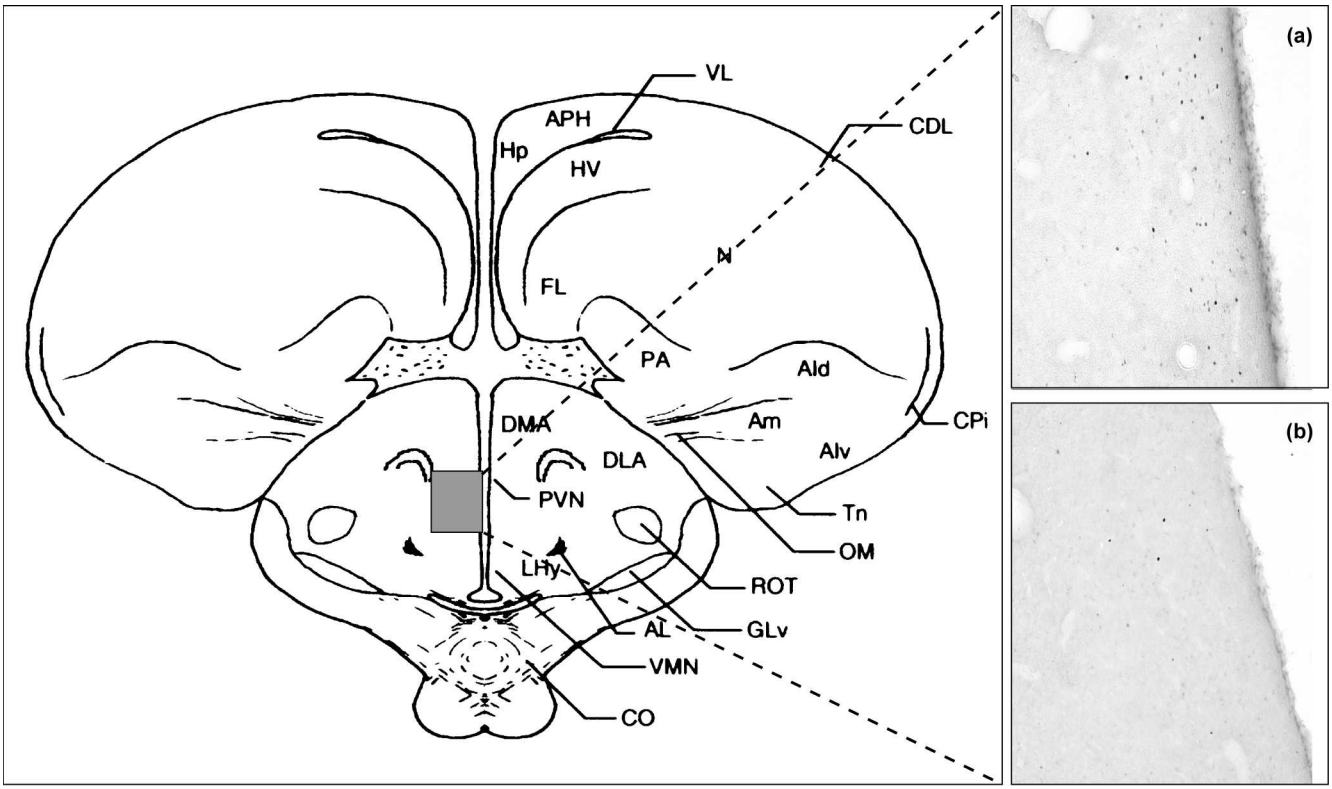
Figure 4



Measurement of the neuronal activation by immunohistochemistry (Fos protein) in the paraventricular nucleus (PVN) of the hypothalamus in **(a)** quails previously exposed to an unfamiliar environment and **(b)** control quails (after Richard *et al* 2003). Quails that had been exposed to an unfamiliar environment just before being sacrificed showed high levels of expression of Fos protein (black dots) in the PVN, in comparison with the low levels of Fos protein recorded in quails that had not had such exposure. These results have important implications for the role of the PVN in emotional responses in birds.

Conclusion

It was not our purpose here to discuss the links between cognition and consciousness (Mendl & Paul 2004) but rather to stress the usefulness of cognitive science for research on emotions and welfare in animals, with the aim of improving farm animals' quality of life. The study of complex interactions between emotions and cognition offers a new direction for the study of affective states in animals. We are looking to develop an integrative, multidisciplinary (behaviour, psychology, physiology, and neurobiology) approach to the issue of farm animal welfare. This approach will describe how the emotional systems in the brain operate and the minimum cognitive capacity required. Identifying evaluative criteria defined within the framework derived from appraisal theories developed in cognitive psychology to study emotions will make it possible to conduct a comparative study, both between-species (among farm animal species with various levels of cognitive capacity) and within-species (among individuals with varying degrees of cognitive capacity depending on age, sex, and breed), with the goal of establishing a precise set of breeding and rearing conditions to promote animal welfare according to the animals' cognitive capacities. Once these elementary evaluative criteria have been identified, the study of how they may be combined will facilitate the identification of both the emotional repertoire (ie negative and positive emotions) of farm animals and the characteristics of their environment that produce comfort *versus* discomfort. Indeed, there is an emerging view that good welfare requires not only the absence of suffering but also the presence of positive emotions such as pleasure (for a review, see Boissy *et al* 2007). The presence of pleasure contributes greatly to 'a life of high quality' in animals. In addition to studying the role of cognition in the generation of emotions, studies on the effects of emotions on the modulation of cognition should be promoted in order to provide deeper insight into the relationships between emotions and more persistent affective states defining welfare. More specifically, the analysis of cognitive predispositions and/or cognitive biases induced by repeated emotional experiences will allow a better understanding of how long-lasting affective disorders that are causes of persistent maladaptive states are established. Taken together, these approaches demonstrate how cognitive assessments can be used in animals to probe emotions as short-term affective experiences and welfare as persistent affective experiences.

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