Scientific evaluation of animal emotions: Brief history and recent New Zealand contributions

Beausoleil, N.J., Stratton, R.B., Guesgen, M.J., Sutherland, M.A., Johnson, C.B.

Abstract
The idea of animals having emotions was once rejected as being anthropomorphic and unscientific. However, with society's changing views and advances in scientific knowledge and technology, the idea of animal emotions is becoming more accepted. Emotions are subjective internal experiences that can't be measured directly. Animal welfare scientists must infer emotions by measuring the behavioural, physiological and neurobiological components of emotional experience. In this paper, we describe innovative ways in which these indicators have been used by New Zealand scientists to facilitate a more holistic understanding of the emotions and welfare of animals.

Introduction

From a scientific perspective, emotion is defined as an innate response to an event or situation (internal or external) that comprises behavioural, physiological, subjective (the feeling) and cognitive (subsequent decision-making) components.[1] Emotions are the result of complex processing, by the nervous system, of sensory information gathered from within and outside the animal's body. The capture and processing of this sensory information are influenced by the biology of the animal species, as well as by individual factors such as the animal's genetic predispositions, life stage, sex, previous experience, learning and memory.[2] The emotion or emotions resulting from these processes of mental evaluation are thus uniquely personal to the individual, but can be broadly characterized by their valence (pleasant or unpleasant) and the degree of arousal generated.[3]

While the behavioural, physiological and, in some cases, cognitive components of an emotional response can be scientifically evaluated using observable indicators, the subjective component cannot. In humans, these subjective experiences can be accessed by asking people about their feelings, and aspects of self-reported experience can often be reliably associated with observable changes in behaviour and physiology.[4] In contrast, non-human animals are unable to self-report, and there is still debate as to whether animals actually experience the subjective component of emotion, despite the fact that they clearly demonstrate the other components of emotional responses (see History below).[5]

On the basis of shared ancestry, similar anatomy and behavioural and physiological responses to the same stimuli, as well as the proposed evolutionary benefits of emotion for humans and other animals alike, many scientists today argue that mammals, at least, are likely to have subjective emotional experiences. Here, the term 'animal' is restricted to those species and life stages generally considered to be capable of sentience, i.e. those animals with the capacity to experience the world as pleasant or unpleasant.[6] Most scientists agree that all vertebrate animals (those with a backbone) are sentient, as well as some invertebrates such as octopus, although the criteria for inclusion in the 'sentience club' are still the subject of much debate.

How does the concept of animal emotion relate to one current conception of animal welfare and the discipline of animal welfare science?

Animal welfare is considered to be a state within the animal itself, and this state reflects the integrated outcome of all the mental experiences, affective states, feelings or emotions the

animal has at a particular point in time.[7] In other words, an animal's welfare is a reflection of how it is experiencing the world. Thus, the scientific study of animal welfare is ultimately the study of animal emotions and their causes. While generic information about the animal's external environment (e.g. housing, diet, social environment) can be informative, evaluating indicators of the animal's emotional response to those factors or circumstances is a more direct reflection of its welfare status.[8]

As noted above, the subjective component of emotions (and thus animal welfare) can only be inferred by measuring the other components that can be observed. These are most often behavioural, but also include physiological and neurobiological indicators of specific emotions. In this paper, we describe innovative ways in which such indicators have been used by New Zealand (NZ) scientists to facilitate a more holistic understanding of the emotions and welfare of animals. Much of the research presented here has focussed on the welfare of farmed species of animals, which are critical to NZ's agricultural economy. However, many of the principles and techniques developed in NZ are equally applicable to exploring the emotions and welfare of companion, research and wild animals.

A very brief history of the scientific evaluation of animal emotion

The following is a brief synopsis of the history of scientific philosophies and approaches to animal emotion. Most 'ordinary' people intuitively believe that mammals, at least, have the capacity for some emotions, feelings or affective experiences; that is they have pleasant and unpleasant feelings about the world around them.[9] This might be because our intuitive starting point is something like: "This is how I experience the world, and this is the only way I can imagine that similar animals might be experiencing it." However, this concept has not always been scientifically accepted, nor is it universally accepted by scientists today.

For many years, philosophers and scientists have argued over the capacity of non-human animals for sentience.[10] Some have argued that emotion is the unique domain of our species and the hallmark of the only 'rational' animal. Notably, in the 17th century, Rene Descartes proposed that animals simply responded to inputs as machines would, because of automatic internal processing of these inputs in the absence of any conscious experience; animals used in the pursuit of scientific knowledge were treated accordingly. There was no perceived problem with this, because the animals did not perceive unpleasant experiences such as pain or fear, although their behavioural and physiological responses were similar to those of humans in similar situations.[11]

Later, such arguments were challenged. Philosopher Jeremy Bentham, (1823) famously crystallized the counter-argument to animal automata when he said "The question is not 'Can they reason?' nor 'Can they talk?' but 'Can they suffer?', and the prevailing scientific position on animal sentience and emotion appeared to shift.[12]

In the 19th century, the evolution and biological value of emotion, for both humans and other animals, was explored by Charles Darwin. Darwin and many others since have been interested in the ways in which experiencing pleasant and unpleasant feelings associated with particular events or situations could benefit the animal, in terms of its survival and/or reproductive success.[13] This field of scientific endeavour reflects an inherent acknowledgment of the experience of emotions by animals other than humans.[14]

In the 20th century came something of a backlash, with the development of a branch of psychology called Behaviourism. Many scientists studying animal behaviour in this field rejected the suggestion that behaviour (human or animal) reflected subjective mental experiences.[15] Ostensibly, these scientists restricted themselves to descriptions of observable behaviours and explorations of the proximate mechanisms underlying their expression. To illustrate, B.F. Skinner (1975) suggested that feelings were a distraction to the valid study of behaviour.[16]

As a result of this influential scientific movement, until relatively recently, animal behaviour scientists have been cautious in their use of language regarding behaviour and emotion. The fear of being labelled 'unscientific' and 'anthropomorphic' strongly limited the interpretation of measured behaviour in terms of the mental or emotional experiences of the animal actor.[17] However, from the mid-1970s, pioneering scientists in the field of animal behaviour, including Donald Griffin, Marion Dawkins and Ian Duncan, led the way for scientifically valid and rigorous exploration of subjective experiences in animals. In part, this has been facilitated by technical advances allowing us to correlate behavioural responses with measures of physiological and neurobiological responses (see below for examples).

Thus, animal sentience, emotion and welfare have become recognized and important scientific topics in their own right. Highlighting this, in 2015, NZ legally recognized animals as sentient beings, explicitly acknowledging that animals (as defined above) are capable of experiencing pleasant and unpleasant emotions and thus have welfare to be considered.[18] In recognition of this and other factors, NZ was ranked first in World Animal Protection's inaugural global Animal Protection Index.[19]

Innovative research from New Zealand scientists for scientifically exploring animal emotion and welfare

NZ scientists are globally recognized leaders in the fields of animal emotion and welfare science.[20] Below, we provide a number of case studies to illustrate recent innovative NZ research using scientific methods to explore animal emotion and welfare.

Scientific assessment of positive emotions and positive welfare states

Traditionally, evaluations of animal welfare have focussed on unpleasant emotions such as pain, fear, sickness, thirst and hunger, and there were good reasons for doing so. Firstly, it was felt that the greatest improvements to animal welfare could be made by addressing the causes of these (and other) unpleasant emotions, such as disease or malnutrition. Secondly, the science to support the existence of some of these emotions has been more readily available (e.g. pain) than that for positive emotions.[21] Finally, the understanding that some unpleasant feelings are necessary for the animal's survival (e.g. thirst to motivate drinking, fear to motivate avoidance of danger) made it easier to gain acceptance that animals do, in fact, experience such emotions.[22]

However, there is growing disciplinary focus on the importance of animals having positive or pleasurable experiences too. In other words, it is now recognized that good animal welfare or "a life worth living" cannot be achieved simply by preventing or alleviating unpleasant experiences. Recently, an established theoretical framework, the "Five Domains model", has been modified to incorporate positive experiences, in order to facilitate more holistic scientific evaluations of animal welfare. The model was originally developed by NZ scientists in 1994 in the context of research animal welfare and initially only considered the ways in which a limited number of unpleasant emotions could arise.[23] Subsequent iterations expanded the number of negative emotions evaluated but it wasn't until 2015, with the publication of the latest version, that positive emotions were incorporated.[24] A wide range of pleasurable experiences can now be systematically considered, including those relating to provision of a preferred or varied diet and appropriate physical surroundings, to opportunities to develop fitness and physical vitality, and importantly, pleasures associated with the animal's social environment, including feelings of engagement, affection, excitement, playfulness, and security.

This latest version of the model provides scientists, animal carers, regulators and policy-makers with a systematic science-based way to consider opportunities for enriching the quality of animals' lives. The updated model is now being applied to numerous animal species

and contexts. Of particular note, it has been embraced as the conceptual basis of the World Association of Zoos and Aquariums Animal Welfare Strategy, demonstrating the global commitment of zoos to enriching the welfare of animals under their care, particularly by providing them with opportunities to have pleasurable experiences.[25]

As noted above, greater attention is being paid to identifying and evaluating positive emotions to facilitate enhancement of animal welfare. This is due, in part, to a growing body of neuro-scientific evidence to support the existence of some positive emotions in animals.[26] However, a remaining challenge is the lack of reliable and practical scientific indicators of pleasurable feelings. Recent NZ research aimed to identify behavioural and physiological indicators of positive emotions in horses.[27] One novel approach was to explore the horses' facial expressions during presentation of both pleasant and unpleasant events, in conjunction with a range of other behavioural and physiological measures.

A more general problem with emotion research in animals is the assumption that a particular animal finds a particular stimulus pleasant or unpleasant. It became evident during the first phase of this research that the stimulus we had presumed would be pleasurable for all horses was so for some but not for others. Our pioneering approach to this problem was to first test each individual horse's relative preferences among the various stimuli presented. We were then able to 'individualize' the putative positive stimulus and measure the behavioural and physiological responses of the horse to its own preferred stimulus.

Individual horse's preferences were found to differ. Compared to an unpleasant event (scented spray), horses demonstrated what might be termed a 'more relaxed' posture and facial expression with their more preferred stimuli. However, the behavioural and physiological responses to the unpleasant event were more marked and more uniform across the subjects in this study. Further work is required to validate these behavioural responses as reliable indicators of pleasurable emotions in horses.

Other approaches to assessing positive emotions in animals, that were not explored in this project, include indirect measurement of brain activity using images of blood flow or oxygen levels in different brain regions (however, see below); measurement of levels of hormones and brain chemicals associated with reward and positive emotions in humans; and tests which assess the longer-term 'emotional state' or cognitive bias of the animal, i.e. is it in a positive or negative 'frame of mind'?[28] Animals in positive emotional state interpret ambiguous situations as rewarding (optimistic bias) while those in negative states interpret them as aversive (pessimistic bias). Combining these and other methods will help validate behavioural measures of positive emotions that can be used in models of welfare assessment such as the Five Domains model discussed above.

Innovative behavioural techniques for exploring animal emotion and welfare

The traditional approach to scientifically evaluating animal behaviour is to quantify the frequency or duration of certain behaviours expressed by the animals.[29] However, NZ scientists have recently pioneered or applied innovative behavioural methods for understanding animal emotion. For example, Guesgen et al. have recently explored how sheep use their ears to express pain and have developed a 'lamb grimace scale' to characterize the facial expression sheep use to communicate pain to other sheep.[30] This information adds to the growing body of knowledge about facial expressions in animals and their value in social communication.

Guesgen *et al*. have also used innovative behavioural methods to explore the notion of empathy in non-human animals. Empathy has long been considered a uniquely human emotional state, however, there is growing scientific evidence that non-human mammals may also experience some form of empathy. International research has explored paradigms for studying animal empathy in rodents and primates however, this is the first foray into the capacity for empathy in farm animals.[31] Sheep are an appropriate species to study as they are

highly social prey animals, and thus may benefit from a shared understanding of the feelings or mental experiences of others.

Guesgen *et al.* hypothesized that expressing 'empathetic' behaviour would be more valuable among genetically related individuals, as it might increase survival and transmission of shared genes. Thus, we investigated whether the social context (presence of a related versus unrelated lamb) influenced the expression of caring or comfort behaviour of one lamb towards another in pain. In support of our hypothesis, twin lambs were found to offer more comfort-like behaviour to their sibling than were unrelated lambs.[32]

This work is also innovative in that it applied the Qualitative Behaviour Assessment (QBA) approach to this question. QBA applies statistical techniques to analyse untrained people's intuitive interpretations of animal behaviour.[33] The value of this approach is that it may facilitate a more holistic and contextualized interpretation of the animal's demeanour and behaviour in terms of its welfare state. Guesgen *et al.*'s results from both the QBA and the more traditional quantitative analysis of the same events provided some different though complementary support for the idea that sheep can express some form of empathy in certain situations.

Another creative behavioural approach is the use of play behaviour to understand animal emotion. Play is commonly observed in young animals and is believed to have both immediate and longer-term benefits.[34] Play is not easily defined but is generally agreed to be behaviour that is not "fully functional", that is initiated when there are no immediate threats to the animal's survival and whose expression is self-rewarding.[35] Importantly, the performance of play is reduced when animals are exposed to negative events or environmental challenges.[36] The corollary is that the presence of play behaviour may be used to indicate the absence of these sorts of negative emotions, and sometimes, the presence of positive ones.

Studies recently conducted at AgResearch in New Zealand have used play behaviour to assess the effects of management practices (e.g. space allowance, flooring) and routine husbandry procedures (e.g. disbudding) on the emotional state and welfare of dairy calves. Our results are consistent with ideas about the relationship between play and emotional state in that play behaviour was reduced when calves were experiencing pain, when they were housed on uncomfortable surfaces and when they were kept at high density.[37] In addition, the biological mechanisms underlying the expression of play behaviour have been explored, and preliminary results support an association between opioids (natural pain-killers) and play behaviour in calves.[38] Thus, measurement of play behaviour may provide another tool for assessing the well-being of animals in our care.

Use of brain recordings to understand unpleasant emotion in animals

In humans, negative emotions such as pain, fear and breathlessness can be studied by asking people how unpleasant they feel. However, in animals, who are unable to verbally express these unpleasant feelings, quantifiable indices of these sorts of emotions are required. Behavioural indicators have been validated for some negative emotions such as pain and fear, but can be confounded by species, contextual and individual differences in expression and require the animal to consciously experience the unpleasant event.[39]

A complementary approach is to measure changes in the electrical activity of the brain, using an electroencephalogram, in response to application of a stimulus believed to generate unpleasant emotion. Changes in brain electrical activity reflect integration and interpretation of information arriving from the sensory systems, and in humans, such changes correlate well with self-reports of unpleasant emotions.[40] Thus, by measuring such changes, we can infer the existence and magnitude of some of the emotions experienced by animals.

Electrical brain activity is difficult to measure in awake, behaving animals but can be accurately measured in lightly anaesthetized animals. This 'minimal anaesthesia model'

(MAM) has been validated for a range of mammalian species for measurement of the brain's response to noxious (i.e. damaging or painful) stimuli.[41] For example, at Massey University, the responses of horses, deer, pigs, cattle and sheep to painful husbandry procedures such as castration, antler or horn removal and tail docking, and the ameliorating effects of pain-relieving drugs for these procedures have been evaluated using the MAM.[42] In addition, the model has been used to investigate the age-related development of pain perception in lambs and piglets, and the effects of early pain on later pain sensitivity in sheep (unpublished data).

Recently, our group at Massey University has measured brain electrical responses to painful stimuli in birds, with interesting results. Although chicken brains respond similarly to anaesthetic drugs as do mammals, their brains do not respond in the same way to painful events – these investigations are ongoing. In addition, we are currently investigating the responses of mammals to stimuli expected to generate another unpleasant emotion, breathlessness. The MAM represents an ethical way to study experiences that would be unpleasant for awake animals, thus informing our understanding of negative emotions in animals and allowing us to work towards minimizing such experiences without compromising the welfare of our subject animals.

Where to next in the study of animal emotion?

The fields of applied ethology and animal welfare science are now firmly established, and a great deal has been learned about the private lives of the animals under our care. So what is the future of scientific exploration of animal emotion and welfare?

As technology continues to advance, explorations of animal emotions and welfare are likely to focus on the mental substrates and processes underlying the generation of the subjective component of emotion. Already brain imaging techniques routinely used on humans are being applied to studies of animal emotion (e.g. functional MRI to study dog cognition).[43] Ultimately, such tools will help validate the use of more practical behavioural and physiological parameters for indicating emotion in animals.

Such techniques may also help refine our understanding of the biological substrates of sentience and consciousness in animals. Such understanding is critically important, as legal protection of animal welfare depends on the definition of 'animal' which, in turn, depends on the biological criteria for recognizing sentience and the resulting 'cut-off' point along the continuum of animal taxa. Taking a further step back, we should ask whether phylogeny (evolutionary relatedness of different animal species) is even a valid criterion for determining the capacity for sentience or whether we need to consider other criteria that do not map onto phylogenetic classifications, such as the environmental or social complexity of the species.[44] The development of sentience during the lifetime of an individual animal is also worthy of exploration. Massey and Auckland University scientists have already undertaken some fascinating work in this area.[45]

On a more pragmatic note, further research is required to validate non-invasive indicators of positive emotions in animals. In terms of welfare assessment and enhancement, how can we provide animals under our care with opportunities for positive experiences, how can we assess the value of various putatively positive experiences for individual animals, and when and how can positive experiences compensate for, or offset, some unavoidable negative experiences associated with life in captivity?

Conclusions

Most animal scientists implicitly acknowledge that at least vertebrate animals experience at least some emotions, and thus have welfare to protect. For the last 50 years, NZ scientists have been at the forefront of systematic investigations of animal emotion and welfare, and have made major contributions to safeguarding and improving the welfare of animals.[46] These

scientific contributions, as well as our ground-breaking legislative recognition of the capacity of animals to have emotional lives and to have their welfare protected, make NZ a world leader in animal welfare.

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