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Cognitive ability and awareness in domestic animals and decisions about obligations to animals.

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ABSTRACT

Observation of behaviour, especially social behaviour, and experimental studies of learning and brain function give us information about the complexity of concepts that animals have. In order to learn to obtain a resource or carry out an action, domestic animals may: relate stimuli such as human words to the reward, perform sequences of actions including navigation or detours, discriminate among other individuals, copy the actions of other individuals, distinguish between individuals who do or do not have information, or communicate so as to cause humans or other animals to carry out actions. Some parrots, that are accustomed to humans but not domesticated, can use words to have specific meanings. In some cases, stimuli, individuals or actions are remembered for days, weeks or years. Events likely to occur in the future may be predicted and changes over time taken into account. Scientific evidence for the needs of animals depends, in part, on studies assessing motivational strength whose methodology depends on the cognitive ability of the animals.

Recognition and learning may be associated with changes in physiology, behaviour and positive or negative feelings. Learning and other complex behaviour can result in affect and affect can alter cognition. The demonstration of cognitive bias gives indications about affect and welfare but should be interpreted in the light of other information. All of the information mentioned so far helps to provide evidence about sentience and the level of awareness. The term sentience implies a range of abilities, not just the capacity to have some feelings. The reluctance of scientists to attribute complex abilities and feelings to non-humans has slowed the development of this area of science.

Most people consider that they have obligations to some animals. However, they might protect animals because they consider that an animal has an intrinsic value, or because of their concern for its welfare. In social species, there has been selection promoting moral systems that might result in behaviours such as attempts to avoid harm to others, collaboration and other altruistic behaviour. An evaluation of such behaviour may provide one of the criteria for decisions about whether or not to protect animals of a particular species. Other criteria may be: whether or not the animal is known as an individual, similarity to humans, level of awareness, extent of feelings, being large, being rare, being useful or having aesthetic quality for humans. Cognitive ability should also be considered when designing methods of enriching the environments of captive animals.

Keywords: cognition, awareness, self-awareness, feelings, emotions, cognitive bias, sentience, welfare, domestic animals.

Introduction: The Dangers of Occam's Razor

Why are animal welfare scientists studying cognition and awareness? Has this subject anything to do with veterinary, animal production or other biological teaching and research? It does have relevance because attitudes to animals are affected by people's evaluations of the animals' abilities. If they are considered to be stupid and unaware, they are more likely to be treated as objects than as individuals. A key question in relation to our use of farm companion, laboratory and other animals is how we should consider the moral and intellectual status of animals, for example sheep, cattle, horses, dogs, cats, chickens, parrots, rats, mice, fish and some invertebrates?

The scientific study of animal welfare is raising questions about scientific methods and concepts. For example, can we talk about awareness, mental aspects of needs, or feelings such as pain, fear and pleasure in non-human animals? If so, for what animals can we use such terms? Some parts of the scientific establishment, largely those who are not behavioural biologists and who are more human-oriented in their research aims, are scornful of any attempt to do so and animal welfare scientists may be academically disadvantaged if they attribute complex abilities to non-humans. With which concepts and arguments will knowledge progress best and how should concepts referring to awareness etc. be used? This question is considered by Broom (2003) and some of the arguments are explained in this paper.

The brains of humans and of those animals domesticated by humans are very complex and our information about brain function, while improving, is still limited. One approach to science when considering the functioning of biological systems is to apply Occam's razor or Lloyd Morgan's canon. These approaches require that simple explanations for phenomena should be considered first and more complex explanations used only if the simpler ones are not satisfactory. Where there are several explanations for brain systems, some simpler and some more complex, if the Occam's razor approach is used it may never be possible to justify a complex explanation. However, given the nature of the brain, it may be that the simple explanations are wrong and the complex explanations right. Future knowledge may be needed to be completely sure of this. In these circumstances, it could be misleading, and it could slow down progress in science, to insist on accepting the simple explanation. I consider that this has happened for many years and that the development of our understanding of brain-based phenomena has been harmed by such attitudes. Some of those who use animals for food production or sport deny complex brain functioning, including feelings, in animals perhaps because knowledge of this might prevent aspects of the usage. It may be that some scientists use the argument requiring that simple explanations must be used because the demonstration of high level abilities in the animal subjects of their own research could prevent them from conducting such studies or lead to public condemnation of their work. We should deal with complex explanations without arbitrary avoidance of terms associated with them but we should be rigorous in our investigations of the phenomena, defining terms carefully and using all necessary controls.

Some of the more sophisticated concepts that animals may have are discussed below, with examples from experimental studies and some thoughts about consequences for our obligations to those animals that we use. Domestication was defined by Price (1984,

2002) as that process by which a population of animals becomes adapted to man and to the captive environment by some combination of genetic changes occurring over generations and environmentally induced developmental events recurring during each generation. By this definition the common farmed and companion animals, with the exception of those that have not been bred and modified in captivity, would be called domesticated. Many parrots and other birds kept in captivity, most turtles and tortoises, some farmed fur-bearing animals, and most aquarium fish species would not be included.

Learning

Learning is one of the ways in which animals are affected by their environment. A definition is: learning is a change in the brain, which results in behaviour being modified for longer than a few seconds, as a consequence of information from outside the brain (Broom and Johnson 1993). The term brain in this definition refers to an aggregation of nervous tissue in which some transfer and analysis of information and integration with motor output can occur, and is normally the most complex of such aggregations in the individual. What kinds and complexities of learning are possible for domestic animals and how does their ability compare with other species? Can they discriminate individuals, remember their social qualities and learn about food, feeding places, danger, risks associated with particular places and other important environmental variables?

Early attempts to compare learning ability used operants, actions such as lever-pressing carried by an individual with consequent effects on its environment controlled by an experimenter. Some of these operants depended upon motor abilities that were easy for some species but were very difficult or impossible for other species. Hence no unbiased comparison of learning ability was possible. A set of studies that largely overcame this problem were those of Kilgour (1987) using modified Hebb-Williams mazes for animals of different sizes. These mazes start with a decision point where there are two or more possible directions to take, one being towards a concealed target reached after two further turns. Such a maze still has some bias, as a comparison of learning ability, in that animals that often have to navigate around their surroundings would have had more experience of a sequence of decisions about which way to turn. This might favour animals such as rodents that use discrete pathways. However, individuals of all of the species tested have to do this to some extent and the locomotion required to respond in a maze is common to all. When the numbers of errors were measured, cows, sheep, goats and pigs performed less well than 5-year-old children but better than dogs, cats, rats, horses and several other mammals and birds. When speed of learning was compared in the same study, the sequence was very similar but dogs performed as well as the farm ungulates.

Our understanding of cognitive ability in humans and other animals is based on our own, or reported, observations of behaviour during the course of everyday life and on the results of experimental studies conducted with the purpose of improving that understanding. As pointed out by Jolly (1966), Humphrey (1976) and others, social interactions are amongst the most demanding intellectual challenges encountered so some conclusions about cognitive ability are deduced as a consequence of observing these. Learning in social situations has been described for many species of animals (Box and Gibson 1999). In the course of such studies, different responses to different individuals, actions indicating awareness of intentions and social strategies more complex than those described as active or passive were evident. These strategies are generally more complex than the active (or proactive)/passive (or reactive) dichotomy in strategy described by Koolhaas et al (1999). However, based on such evidence, it is not easy to write about the concepts that the animals are likely to have. Although there are many descriptions of the behaviour of social domestic animals, and of some of the cognitive functioning deduced to be associated with it, this information has not been directly used in presenting the case for high level cognitive functioning in these animals. Evidence from experimental studies seems to be more convincing to biological scientists. The ethologist studying social and other behaviour may accept without question that animals of a species have a certain level of cognitive ability whilst those experimenting on cognition may not accept their conclusions. Since there is, and will continue to be, much evidence about cognitive ability available as a result of observation of animals in free-moving situations, it is important that there should be refinements in precision of observation and the development of field experiments so that valid and convincing information about the ability can be obtained. Anecdotal or unsubstantiated information suggesting certain levels of cognitive ability should be further investigated.

Discrimination and recognition

Can social animals like cows, pigs and dogs recognise individuals of their own or of other species? The first step in attempting to answer this question is to attempt to establish whether or not they can discriminate between individuals. Recognition involves discrimination and then using the information to facilitate social interaction. Pigs (Mendl et al 2002, McLeman et al 2005) and dogs (Sommerville et al 1993) are amongst the species that have been shown to be able to discriminate amongst and respond to conspecifics and other animals using olfaction. Cattle have been trained to go towards one conspecific rather than another in order to get a food reward (Hagen and Broom 2003). In a series of studies with sheep, Kendrick and colleagues demonstrated behavioural discrimination of individual sheep and humans and identified neurones in the medial temporal and prefrontal lobes of the cerebral cortex that fired only when particular individuals were seen. These discriminations of pairs of photographs could still be shown and the specific cells could still be found one to two years after the training period (Kendrick and Baldwin 1987, Kendrick et al 1995, 2001). When a ewe recognises her lamb between two and twelve hours after birth, changes in the brain are associated with the behavioural process. Certain brain changes started after 2 hours and were consolidated over a 10 hour period. Production of brain-derived neurotrophic factor and its receptor trk-B, occurred at 4-5 hours after birth and there was mRNA expression in the olfactory and visual processing systems, temporal cortex, four other cortical regions, hippocampus and amygdala (Broad et al 2002).

A further level of recognition, perhaps involving some similar mechanisms, is to distinguish individual state and respond to it physiologically and behaviourally. Elliker (2007) trained sheep to approach photographs of sheep with a calm expression rather than those of sheep with a startled expression, or vice versa. Elliker also found, using computer modified photographs, that it was the ear position that was the main feature used by the sheep to make this distinction, rather than eye features.

Needs, Welfare and Health

The welfare of an individual is its state as regards its attempts to cope with its environment (Broom 1986). In order that welfare can be good rather than poor, it is important to know the needs of the animal, hence most accounts of the welfare of a particular kind of animal start with a summary of its needs (see, for example, various EFSA Scientific Reports and Council of Europe Recommendations). A need is a requirement, which is part of the basic biology of an animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus (Broom and Johnson 1993, Broom 2008). These include needs for particular resources and needs to carry out actions whose function is to obtain an objective (Toates and Jensen 1991, Broom 1996a, 1997). Needs can be identified by studies of motivation and by assessing the extent of poor welfare in individuals whose needs are not satisfied and of good welfare when they are satisfied (Hughes and Duncan 1988a,b, Dawkins 1990, Broom and Fraser 2007). Unsatisfied needs are often, but not always, associated with bad feelings whilst satisfied needs may be associated with good feelings. When needs are not satisfied, welfare will be poorer than when they are satisfied. Sophisticated strength of preference studies depend upon the use of operant and other techniques that exploit the abilities of animals to learn to carry out new procedures (Matthews and Ladewig 1994, Fraser and Matthews 1997, Kirkden et al 2003).

The health of an animal is its state as regards its attempts to cope with pathology (Broom 2006 a,b). It is my view that the definition of health by the World Health Organisation is not useful because it is much too broad and vague. It includes much more than the normal meaning of the word and those who wrote it did not consider properly the use of other scientific terms such as welfare. Health is a very important part of welfare and evaluation of the extent and impact of any disease condition requires some knowledge of complex behavioural responses. The use of cognition to find out about welfare, stress, feelings and mental disorders in humans and other species is discussed in the proceedings of a Dahlem Conference (Broom 2001b).

Cognition and Awareness

Cognition was defined by (Shettleworth 1998) as the mechanisms by which animals acquire, process, store and act on information from the environment. However, this definition includes a high proportion of all brain function including just perceptions, some of which would not normally be considered as part of cognition. A narrower definition proposed here is: cognition is having a representation in the brain of an object, event or process in relation to others, where the representation can exist whether or not the object, event or process is directly detectable or actually occurring at the time. The representation of something absent is an abstraction.

When is an individual aware? The term does not have the same meaning as being conscious. An individual is conscious when it is capable of perceiving and responding to events in its sensory environment. An unconscious individual is unable to do this. It would be better if the word conscious were limited to this meaning. Aware implies a certain degree of input analysis. One definition of awareness is: a state in which complex brain analysis is used to process sensory stimuli or constructs based on memory (Sommerville and Broom 1998). These authors distinguish four levels of awareness as follows. Perceptual awareness: a perceived stimulus results in an automatic response which the individual may or may not be capable of modifying voluntarily. Cognitive awareness: brain processing of sensory inputs or of constructs based on memory results in a flexible response. Assessment awareness: the individual is able to assess and deduce the significance of a situation in relation to itself over a short time span. Executive awareness: the individual is able to assess, deduce, and plan in relation to long-term intention. For example, the individual would not only be sensible to stimuli but would have memory of events and mental images of non-current events that could be used when taking appropriate action, both to avoid the negative and to increase positive consequences. Snyder et al (2004) refer to awareness of concepts and equate consciousness with executive awareness. Mendl and Paul (2004, 2008) discuss basic awareness of sensations, feelings, emotions and memories.

Are domestic animals aware of objects or other resources? At one time it was thought that a chicken would lose any concept of an object if it were out of sight. However, studies by Vallortigara and colleagues showed that, not only could young domestic chicks go to objects hidden behind screens but that when two or three objects were hidden behind screens, the chicks went to the screen with the larger number of objects (Rugani et al 2009). Other experimental studies show that domestic animals can use a visual or auditory symbol for objects. Langbein et al (2004) were able to train goats to respond by carrying out an operant in order to get water when they saw one particular picture rather than others. A second example is familiar to those who have trained dogs but has been studied in one female dog in a carefully controlled way by Rossi and Ades (2008). When a dog was given commands that required her to respond to one of several objects, such as a ball, a stick, a bottle, a key or a toy bear, and to carry out one of several actions, such as point to it or fetch it, she was successful. Similarly, Kaminski et al (2009) found that dogs shown replicas or photographs could use this information and fetch the objects that were thus iconically portrayed. When Rossi and Ades' dog was provided with a keyboard that had symbols on it that indicated water, food, stroke me, I go out, I get a toy, or I urinate, she could indicate what she detected or what she wanted to do next. A further example is of pigs studied by Held et al (2000). They were put in a room and allowed to find hidden food. On the next day they were returned to the room and they went immediately to the place where they had found food. These studies show that the animals, in one or more of these examples, had a concept of an object in the absence of that object, had a concept of a symbol or of a location, and had a concept that pressing the symbol or going to a particular place was linked in a causal way to obtaining the resource.

Copying the actions of others requires a significant level of cognitive ability. However, when experiments are carried out to assess this, the nature of the action to be copied in relation to motor ability will result in some actions being easy for an animal and some being difficult so this has to be taken into account when evaluating the information given about awareness. In some studies, the objective of an action may be copied but not the detail of the movement, for example manipulatory actions by pigs (Held pers.comm.). Some birds have very good ability to copy the vocalisations of others. Perhaps the most impressive demonstrations of the awareness and cognitive ability of animals of the species kept as pets, farm animals or working animals, are those of an African grey parrot (*Psittacus erithacus,* Pepperberg 2000), a species that is not domesticated. The parrot learned to name each object correctly. He also said the correct words for seven colours, five different shapes and quantities from one to six. Words for seven colours, five different shapes and quantities from one to six were correctly used. Requests to be given particular objects or to be able to carry out certain actions were also made by the parrot. Humans find ability to use words in context particularly impressive but many animals cannot impress in this way because they cannot make the appropriate sounds and we cannot recognise any other kinds of "words" that they produce.

In some cases, animals have to learn that immediately detectable information about the location of a resource has to be modified in a specific way in order that the resource can be obtained. One example is that animals of several species have been able to learn how to make a detour around a fence in order to get to a resource. This has been shown for chickens (Regolin et al 1995), for dogs Pongrácz et al (2001) and for other species, including tortoises (*Testudo*) provided that they have watched another tortoise do it (Huber pers comm.). A second example is that an individual capable of assessment awareness may be able to learn about what it sees in a mirror in relation to itself and then to use the information at a later time. Human infants can use mirrors in the course of shape discrimination (Itakura and Imamizu 1994) and, at an appropriate age, will discover the contingency between visual and proprioceptive feedback from their own body movements (Lewis and Brooks-Guy 1979). Povinelli et al (1996) allowed children to see a television image of themselves, very similar to a mirror image, and found that when a sticker was put on their head, no 2-year-olds reached for the sticker, 25% of three-year-olds reached for it and 75% of 4-year-olds reached for it. Tests with chimpanzees, an elephant, dolphins and magpies that had had previous experience of mirrors, using marks on the body visible in a mirror, led to the individuals touching or apparently looking at the marks (Gallup 1982, Reiss and Marino 2001, Plotnik et al 2006, Prior et al 2008). Broom et al (2009) found that 4-6-week-old pigs responded to a mirror initially as if to another pig but later appeared to look at the image as they moved. They made a movement and then stopped still, apparently looking at their image and its surroundings, oriented either with nose towards the mirror or with the head parallel to it. After 5 hours spent with a mirror, the pigs were shown a familiar food bowl, visible in the mirror but hidden behind a solid barrier. Seven out of eight pigs found the food bowl in a mean of 23s by going away from the mirror and around the barrier. Naïve pigs shown the same, looked behind the mirror. To use information from a mirror and find a food bowl, each pig must have observed features of its surroundings, remembered these and its own actions, deduced relationships among observed and remembered features and acted accordingly.

One level of awareness is to be self-referent and to discriminate labels of self from labels of non-self, a distinction made by (Hauber and Sherman 2001) who described the ability as different from being self-aware. Bekoff and Sherman (2004) said that self-awareness is the cognitive process that enables an individual to discriminate between its own body or possessions and those of others. However, this is a description of a consequence rather than a definition. An individual could be self-aware in the absence of any cue from others. The inclusion of possessions in this description of self-awareness by Bekoff and Sherman is of particular interest. It means that a dog that defends its own bone, but does not defend the bone of another dog, could be called self-aware. Similarly, according to the Bekoff and Sherman statement, a bird that defends its territory but not an adjacent area could also be called self-aware. Most people would say that neither of these capabilities involves self-awareness. The definition proposed here is: self-awareness is the cognitive process in an individual when it identifies and has a concept of its body or possessions as being its own so that it can discriminate these from non-self stimuli.

Most discussions of awareness refer to the social context and to whether animals are able to infer the mental states of others (Gallup 1998). Shettleworth (2009) says that to have a "theory of mind" means understanding that other individuals have minds. However, I find the term 'mind' imprecise and the distinction between mind and brain unnecessary (Broom 2003).

Where one individual is aware that another individual has information, it may be possible for us to know this if the first copies what the second does. Held et al (2000) described an experiment in which a pig watched another pig that could see a food location. The observer pig then did what the other pig had done to get food. A somewhat more complex ability was shown by Miklósi et al (2000) whose dogs demonstrated awareness of another individual having capacity to obtain a resource. The dog saw a toy being hidden in an area that it could not reach. When a human helper arrived, the dog signalled to the helper where the toy was. These dogs must have had a concept of the position of the object, have remembered this while no human was present, have had a concept of a human having ability to get the object, and had the ability to link this to the concept that a signal could make a human get the object for the dog. Similar abilities are demonstrated by a dog that responds to a human indicating which object to take. Dogs can do this by using human gaze direction but apes are not good at responding to a human in this way (Reid 2009). On the other hand, whilst apes could track an object hidden in a container when the container was moved, dogs could do this only if the container was moved in a simple way and not if the paths of two similar containers crossed their own path (Rooijakkers et al 2009).

In a further pig study, Held et al (2002) described the feeding strategy of a pig that watched an informed but subordinate individual and robbed it when it found food. Subordinate individuals who observed food being hidden by a person, although they went to the food if able to do so, refrained from going to it if a dominant pig was present. These pigs had a concept of the dominant pig taking the food from them if they went to it and hence delayed their action until there was a good chance that they could retain the food. Actions of animals that use others to obtain objectives are described by Byrne (1997) as Machiavellian. Another example from pig research by Curtis (1983) is of young pigs that have learned to raise or lower environmental temperature by putting the nose in a hole where a light beam is broken. Many of the pigs were able to control the heaters by nudging other pigs to make them turn them on or off.

Future work on domestic animal cognition could utilise methodology that in primates and corvids has demonstrated: prospective thinking, in which several sites are visited without duplication; semantic future thinking, where the individual is shown to envisage the future without the self being involved in it; and episodic future thinking, involving personal projection in which the self is part of the future scenario (Raby and Clayton 2009).

The evidence that socially living fish can assess the actions of others is clear (Huntingford et al 2006). Memory in fish is described in many papers and books (Laming 1981, Huntingford et al 2006). Fish often live in hazardous environments and have to be able to evaluate the risks associated with carrying out certain activities, going to certain places and consuming certain foods (Yue et al 2004). Awareness in fish is discussed by Chandroo et al (2004) and Broom (2007). We know that fish must have some mental representations of their environment because of their ability to navigate and recognise social companions and form mental maps (Reese et al 1989, Rodriguez 1994, Swaney et al 2001, Odling-Smee and Braithwaite 2003). Fish can avoid, for some months or years, places where they had aversive experiences (Beukema 1970, Czanyi and Doka 1993). The evidence for cognitive awareness in fish is clear from these studies.

Affect, Emotions, Feelings and Suffering

Following the question of whether or not animals can suffer, posed by Bentham (1789), the importance of feelings, in particular in relation to animal welfare, has been emphasised by Duncan (1993), Dawkins (1993) and Panksepp (1998). The biological basis for feelings and the evolution of feelings have been discussed by these authors and by Cabanac (1979) and Broom (1998, 2001a). A feeling has been defined as: a brain construct, involving at least perceptual awareness, which is associated with a life regulating system, is recognisable by the individual when it recurs and may change behaviour or act as a reinforcer in learning (Broom 1998). In relation to this definition, emotions were considered to be similar but physiologically describable. Suffering is: one or more bad feelings continuing for more than a short period. (Broom and Fraser 2007). Another relevant term is 'affect'. Paul et al (2005) state that affect involves: behavioural and physiological responses (and in conscious beings, feelings) that can vary both in terms of valence (pleasantness/unpleasantness) and also intensity (arousing/activating qualities). However, in widespread usage, an affect is an experiential state involving feelings so affect would be limited to animals that can have a sufficient level of awareness to have feelings.

Cabanac (1979) suggested that many behavioural or physiological responses that involve a return to homeostasis are associated with pleasure: for example if an animal has become cold and is able to be in a warm place, as in the case of Japanese macaques bathing in a natural hot pool in cold weather. Similarly, food and water after deprivation may lead to pleasure and it may be either high or low arousal. Most of the studies that suggest this, describe behavioural responses that are assumed to indicate pleasure. Physiological changes associated with pleasure include certain vagal nerve activations and increases in oxytocin concentrations. Oxytocin is involved in nursing behaviour in lactating female mammals. Human mothers describe nursing as pleasurable and oxytocin is elevated at this time. However, oxytocin concentration is also elevated in several other circumstances that seem likely to involve pleasure (Carter 2001). Several behavioural studies have included arguments that they should be interpreted as indicating that individuals feel pleasure. For example, Widowski and Duncan (2000) argue that dust-bathing in hens is motivated by pleasure.

Pain, fear and other negative feelings are extensively discussed in animal welfare research (Broom and Johnson 2000). Experimental studies in domestic animals that indicate the occurrence of feelings have been described more and more often in recent years. For example, Desiré et al (2002, 2006) studied sheep disturbed by the sudden appearance of a coloured scarf. They recorded several behavioural responses, heart-rate changes and modification of vagal tone, the rate of firing in the vagal nerve. If the timing and nature of the appearance of the scarf was predictable there was less effect and the effect was greater according to how sudden, how unfamiliar and how large the stimulus was. The authors stated that it was simplest to conclude that sheep feel fear. Arguments for the occurrence of pain and malaise in domestic animals and descriptions of methods for their alleviation have been presented by many authors (e.g. Stafford et al 2003, Gregory 2004, Stilwell et al 2008).

Are animals aware of their own learning or achievement? In a study by Hagen and Broom (2004), the emotional responses of young cattle were monitored during a period when they were learning a task. Heifers were put into a small pen with a gate through which a food bowl could be seen 20m. away. If the heifer put her nose into a hole in the wall and broke a light beam, the gate opened. When the heifers learned how to open the gate, they showed behavioural excitement in the form of jumping and bucking and an elevated heart-rate response at the moment of learning. Matched control heifers that received the same reward after the same time in the pen did not show this response and neither did heifers that had previously learned the task and immediately opened the gate on entering the test pen. Similar results were obtained by Broom and Barone (in prep) in a study on sheep learning. It may be that the animals were aware of their own success in solving a problem so the phenomenon was called the eureka effect.

What can we deduce from “cognitive bias”?

Many studies show how activity in particular regions of the brains of mammals, for example the amygdala, prefrontal and orbitofrontal cortex, anterior cingulate, insula, nucleus accumbens, ventral tegmental area and periaqueductal grey, is associated with emotion and feelings (Panksepp 1998, Rolls 2005, Murray 2007). These authors also report the cognitive components of emotion.. The effects of emotional states on cognition are described in humans and, recently, in some other species (Call and Carpenter 2001, Paul et al 2005, Mendl et al 2009) and may have adaptive value (Mineka et al 1998).. When an animal has to evaluate a situation, there will often be some degree of ambiguity in the information available. In some circumstances the same sensory input could indicate that there is a likely consequence that could be positive or negative. As Mendl et al (2009) put it, should an individual interpret a rustle in the grass as danger or food? This depends on the overall set of information available. In a series of studies, Mendl and collaborators have investigated the possibility that an animal's interpretation of an ambiguous situation may be altered by its emotional state, those in negative states being the more likely to respond as if the negative outcome will occur. The influence of affect on a range of cognitive processes including attention, memory and judgement has been called cognitive bias (Mendl et al 2009).

Harding et al (2004) presented rats with one tone followed by positive consequences and another followed by negative consequences and then tested them with an intermediate tone. Rats which had been living in a relatively rich environment were more likely to respond to an ambiguous tone as positive. Similarly, Burman et al (2008) found that rats from a better environment treated an ambiguous food bowl position as positive. Casey et al (2008) found that rescue shelter dogs with a higher separation anxiety score were more likely to react to an ambiguous position as negative. Studies using such a paradigm, with some results indicating cognitive bias and some that do not, are reviewed by Mendl et al (2009).

Do the cognitive bias studies reveal affect accurately? Do they indicate how good or how poor welfare is? Key information needed in order to answer this is whether or not any non-affect factor could lead to cognitive bias. It may not be possible to know all of such possible factors. The existence of cognitive bias may well give information about the emotional state of the animals and about their welfare but in order to understand cognitive bias there is a need to consider the strategies adopted by individuals in life as a whole and in the test situation. What are the possible strategies, which of these are shown, and what will be the consequences of showing one or other strategy? Once this is ascertained, the probability that the supposed optimistic or pessimistic response will be shown can be calculated and compared with the data obtained.

Would cognitive bias generally be adaptive? It may be good for people to look for positive aspects of any situation and advantageous to be optimistic. However, an “accurate evaluation strategy”, or even a “look hard for the negative as it may be too risky not to do so strategy” may also be effective. These strategies may also be associated with good welfare in the individuals that use them. Hence the link between an optimistic evaluation and good welfare, or between a pessimistic evaluation and poor welfare, may not always be close.

It may well be, as assumed in cognitive bias studies, that a depressed individual will interpret ambiguous signals in a negative way. However, an individual that is feeling bad, and whose welfare is poor, might still have some probability of selecting the positive option because of a degree of randomness in action, or might do so as a strategy in an attempt to achieve the positive by selecting a cue associated with the positive. An expected level of positive selections might be calculated. If a positive bias is present, does it always mean that the welfare is good? There could be a link between the condition of the animal and the actual test used. The condition of the animal, and how that condition is engendered, may be related to positive and negative emotions. Suppose that the smell of cut hay engenders a positive affect in an individual. If this individual smells it and then evaluates all slightly ambiguous situations as positive, does this mean that its welfare is good? The test may be giving information about immediate past experience rather than about welfare in the longer term. It would seem essential, in interpreting the results of cognitive bias tests to take account of those of other tests. Data on cognitive bias are a useful addition to our repertoire of scientific studies of welfare. However, if there is additional information the welfare evaluation will be more reliable.

Sentience and decisions about acceptable animal usage

Many decisions about which human actions are moral and which are not, vary little across human societies and have parallels in societies of other animals (Broom 2003, 2006c). There has been a change, however, in what are considered to be the subjects of moral action. There is now concern about all people, not just those from the individual's own small community, and also about many kinds of animals. We are more likely to treat as deserving of moral consideration those identified as "us" than those considered to be "them". At one time, categories of "us" may well have included principally or only individuals readily recognised as close relatives. It is likely that the category expanded later to the wider range of individuals included if "all of those who know who I am" is the category. Later, and still wider, is the group who "might have access to the same information that I have", or "All sentient beings who share characteristics with me". As Midgley (1994) has pointed out, animals such as dogs have long been viewed as deserving moral consideration and Broom (2003) explains that, for many people, the latter three categories would include non-humans.

Many people want certain animals to be protected solely because they are considered to have some intrinsic value (see discussion by Rollin 1981,1989). A further group of people, who may not hold such a view of intrinsic value, are concerned that the welfare of animals should not be poor, perhaps because they are suffering. With the former view, the animal's sudden and painless death would be a matter for great concern but with the latter view it would not. A commoner position may be to have both an idea of the intrinsic value of animals and a concern about their welfare. Fraser (2008) distinguishes preference value from moral value. Whilst there will be aesthetic components to the values people consider that animals have, it is mainly the moral value that is the issue considered here. What are the criteria for valuing animals and for being concerned about their welfare?

Most people have the view that each of us has obligations to others. An obligation is a duty to act, or to refrain from acting, in a way that potentially affects another individual. In my view, this is the best approach to all moral issues and is better than claiming rights or freedoms. A right is a legal entitlement which can be defended using the laws of the country or a privilege which is justifiable on moral, perhaps religious, grounds whilst a freedom is a possibility for action conferred by one individual upon another. All of these issues have been discussed further elsewhere (Broom 2003, 2006c).

In deciding which animals should be killed, and for which animals we have concern about welfare, many people take account of the cognitive and emotional functioning of the animal. The words “sentient beings” are used in some important legal documents, for example the Treaty of Amsterdam that is the basis for the European Union as it now functions. The statement in this Treaty is (European Communities, 1997, page 110) “Desiring to ensure improved protection and respect for the welfare of animals as sentient beings, have agreed….” .

Those who write about sentience take account of the extent to which individuals are aware of the world in which they live, their ability to perceive and respond to external stimuli, and their ability to have feelings of some kind (DeGrazia 1996). The normal meaning of sentience is wider than just the possibility of having feelings. The range of qualities that are included amongst those of sentient individuals is summarised by Broom (2006c) as follows. A sentient being is one that has some ability: to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risk, to have some feelings and to have some degree of awareness.

Animals are more likely to be considered sentient if they can learn much, learn fast and make few errors once they have learned (Broom 2007). The evidence for cognitive awareness in fish is clear from the studies quoted above. Whilst we cannot know whether the feelings of fish are like our feelings, the criteria for sentience are fulfilled by at least those species of fish studied in this experimental work.

People have long appreciated that various domestic and other animals are sentient in the sense of the word as explained above. The animals have often been thought of as an example to follow or a friend who would help, rather than just as a resource object. However, a rabbit is viewed differently according to whether it is a family pet, a laboratory animal, an animal kept for meat production, or a wild animal that eats your crops. This is not scientifically sound as the biological functioning of the rabbit varies little with human usage. Each individual rabbit, once past a certain level of development, has its own perceptions of the world around it, an ability to feel pain, a degree of cognitive function, an array of coping mechanisms and a consequence for its welfare when there is an environmental impact on it. Should we not consider the welfare of the individual rabbit first and our usage of it second (Broom 2003)?

Experimental and observational studies of cognition and feelings in animals provide evidence that certain levels of ability and of functioning exist in some members of a species but they do not indicate that all members of the species are the same. There may be a substantial range in cognitive ability and emotional responsiveness within a species. However, if any member of a species has an ability, this should be taken into account when designing housing and husbandry systems for the species. Some of the ways in which cognitive ability can be considered when trying to improve the welfare of farm animals are discussed by Manteuffel et al 2009.

Many people consider that sentience is a criterion for deciding which animals should be legally protected by laws such as those concerning experimental animals in laboratories. Similarly, the use of anaesthetics and analgesics when serious sensitive tissue damage occurs may be decided according to whether or not the animal is sentient. The concept of welfare, however, applies to all animals so it is possible to assess the welfare of animals that are not sentient. Research on cognitive abilities of invertebrates has shown that those of cephalopods, decapod crustacea, insects, spiders and some gastropod molluscs is greater than many biologists might have expected (Sherwin 2001, Reznikova 2003, Cross and Jackson 2005, Broom 2007).

A prejudice exists to the effect that small animals are less likely to be sentient than large animals. However, it is not generally the case that the smaller members of any particular taxonomic group of animals have less behavioural complexity or cognitive ability than the larger members. When comparing across animal groups, hummingbirds and mice seem to live at a much faster pace than larger, slower-moving animals such as humans. Much decision-making, often involving sophisticated brain-processing, has to occur faster in such small animals than in large ones. When standing and watching hummingbirds feeding from a patch of flowers, I have sometimes been suddenly approached by one of them that hovered in front of me, looking at me for less than a second and then flew off extremely rapidly to resume feeding or take part in a social interaction. The human might well be perceived to be too slow to be of any consequence in a busy life.

Within the category of sentient animals, more sophisticated brain processing will provide better opportunities for coping with some problems. For example, there seem to be means of dealing with pain which humans have but fish do not. As a consequence, a certain degree of pain may cause worse welfare in fish than in humans. This argument would also be valid for other causes of poor welfare. The same type of human action may therefore be more cruel if inflicted on a simpler animal than on a human or other more complex animal. It also seems likely that more complex brains allow more possibilities for pleasure, which contributes greatly to good welfare. However, humans can suffer because of expectations of future pain. These expectations may be possible in some other animals. The possibilities of reduced adverse effect because of improved coping ability, increased potential for feeling pleasure, and the adverse effects of being able to dread future events, can all affect the risks of occurrence of poor or good welfare. Higher cognitive ability may mean less likelihood of poor welfare in adverse conditions and all of these possibilities should be taken into account when deciding what is acceptable animal usage. Accurate use of direct measures of animal welfare is the best way in which to decide such matters.

Conclusions

1. We should describe observations, experiment, analyse and write in precise ways but we should not be afraid to use complex concepts in explaining our results.
2. We should argue against those who criticise the use of complex concepts if a major part of their argument is that there must be parsimony.
3. Concepts used in cognition, awareness and animal welfare research should be properly defined in scientific writing rather than just being referred to in descriptive but imprecise ways.
4. Domestic animals have some ability for recognition, cognition, risk assessment, cognitive awareness, assessment awareness, emotions and feelings and hence are sentient. The key issues to investigate are the levels of sophistication reached in each of these aspects of functioning by members of a species and how species vary?

5. Recent studies have shown parrots, dogs, pigs, cattle and other animals kept as companions or on farms, to be capable of more complex cognitive and emotional responses than previously thought to be possible. An ability in individuals of a species does not necessarily mean that all members of the species have the ability but the level of complexity of functioning of the animal should be taken into account when designing housing and husbandry systems for the species. Careful studies of animal welfare are required for this.
6. Cognitive bias is a potentially valuable indicator of affect and of welfare. However, it has not yet been demonstrated that either the affect, or the welfare, will be reliably indicated by cognitive bias studies alone. A combination of studies is needed to increase the accuracy with which cognitive bias reveals feelings or allows assessment of welfare.
7. High levels of cognitive ability may often help animals to cope with their environment. Hence a given level of a problem, such as pain, may be less in more complex animals than in simpler animals. There is a possibility that animals may have fear of possible future adversity. The relationships between negative feelings, such as fear and pain, and the role of cognition in the coping abilities of the animal should be investigated further and considered when evaluating the risk of poor welfare. Cognitive ability should also be considered when designing methods of enriching the environments of captive animals.

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