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Measuring Animal Welfare: What Can Cognition Contribute?

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Abstract

Brydges NM, Braithwaite VA. Measuring Animal Welfare: What Can Cognition Contribute? ARBS Annu Rev Biomed Sci 2008;10:T91-T103. In this review, we explore a variety of techniques that are currently available to investigate the welfare of non-human animals (referred to from now on as animals) with a particular focus on studies of animal cognition. We consider some of the more traditional measures of animal welfare: biological function, physiology and inference, and discuss different ways in which we might assess welfare requirements. We then consider whether cognitive assays can help us determine what animals want or prefer, and whether it is possible to use cognition to discover the mental or affective state of an animal (*i.e.* positive or negative affective states). We defend that certain aspects of cognition will play a fruitful role in helping us to understand animal 'mental welfare' and, in this way, we make a case for how cognition can be usefully applied in a welfare context.

Keywords: animal welfare, measure, cognition

Table of Contents

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1. Introduction

1.1. Historical perspective

An animals' state as it responds to environmental challenges defines its welfare (Broom, 1996). Welfare is a multi-faceted concept, and there are many ways in which an animal can respond to a particular challenge. Traditionally, an animal was thought to be in a better state of welfare if it demonstrated good biological functioning within its environment: good general physical health, productivity and growth. Although biological functioning is an integral part of welfare, contemporary thinking has begun to expand this definition to take into consideration an animal's mental welfare (Désiré *et al*., 2002; Mendl & Paul, 2004; Boissy *et al*., 2007; Broom, 2007). A driving force behind this is a greater willingness to accept that animals have a 'mental life' and are capable of experiencing affective states[1], feelings[1] and emotions[1], and may even have a conscious capacity[1]. This shift in thinking is underpinned by scientific research; for example, experiments have shown some animals have the capacity for metacognition, that is they 'know what they know' and they can reflect on this knowledge to help them form decisions (Hampton, 2001). Another recent approach has explored the idea that animals experience feelings and emotions that affect cognitive or mental state – the way an animal categorizes or appraises a situation can be affected by its current mental state. For instance, animals housed in unpredictable and stressful situations tend to show a negative outlook when tested under a range of conditions in operant tasks (Harding *et al*., 2004).

The first Animal Welfare Legislation was introduced into the UK during the 18th and 19th centuries. In 1822 the first Parliamentary legislation for animal welfare in the world was passed in the UK: Richard Martin's Act to Prevent the Cruel and Improper Treatment of Cattle (DEFRA, 2008). This legislation protected cattle only. As time has progressed and scientific knowledge increased, more species have been added to revised legislation and are now protected. Present legislation in the UK protects vertebrates other than man and, somewhat curiously, one species of invertebrate (*Octopus vulgaris*) (Animals (Scientific Procedures) Act, 1986). Similar trends have been seen in other countries, for example Australia, where amphibians, birds, mammals, reptiles, fish and crustacean are now protected (Australian Animal Welfare Act, 2005). However, although present legislation in America covers "any warm blooded animal which is being used, or is intended for use for research, teaching, testing, experimentation, or exhibition purposes, or as a pet. This term excludes birds, rats of the genus *Rattus* and mice of the genus *Mus* bred for research, horses not used for research purposes..." (Animal Welfare Act 2004, United States Department of Agriculture, 2008).

Why are certain species protected whilst others are not? As Broom (2007) points out, history shows that we began by protecting species that most closely resemble ourselves, for example, non-human primates, but then as our understanding of behaviour and physiology grew and welfare increased in profile we began to include other mammals, then birds, and now there are debates about whether it is meaningful to provide welfare for fish (Huntingford *et al.*, 2006) and certain invertebrates (Sherwin, 2001). This appears to be a rather anthropocentric point of view, and does not provide us with a specific framework or set of criteria that we can use to determine which animals should be afforded welfare protection. We need to move towards a more animal directed viewpoint when considering which animals merit welfare protection. This will require considering the world from the animals' point of view, and

[1]We are aware that due to their inherently subjective nature, these terms are not always clearly scientifically defined. Here we use them simply to mean that animals experience more than reflexive reactions to stimuli, and that there is some higher level processing and experience occurring within the animal. We assume that consciousness is a higher level process than emotions and feelings, which are higher level processes than affective state. The issue and controversy over precise definitions of these words is beyond the scope of this review.

taking into account the different ways in which they detect and perceive the world around them. Many animals have different perceptual systems to our own, yet until recently this has been overlooked. Being aware, however, of what animals detect and what information they internalise and process is vital if we are to understand how they cope in the captive environment we provide for them. For example, some birds can perceive the flickering of fluorescent lights provided in their enclosures – flickering that is imperceptible to our own eyes, and broiler chickens have been found to react to changes in high and low frequency fluorescent lamps, (Boshouwers & Nicaise, 1992). Several animals see more than we do, for instance many birds and fish possess a fourth type of cone photo-pigment, the human eye has only three. When present this fourth cone allows animals to see and respond to UV light (Jacobs, 1992). Other animals have sensory modalities we have no experience of – for instance several species can use the Earth's magnetic field to help them find their way around; pigeons (Keeton *et al.*, 1974), salmon (Quinn, 1980) and sea turtles (Lohmann & Lohmann, 1996). Thus, when we design facilities that house the animals we maintain in captivity, we need to be aware of how the animal's senses will be affected as well as determining whether the captive environment affects the animal's mental welfare.

There are numerous practical and scientific reasons for investigating the mental experiences of animals, and the possibility that animals have awareness and feelings is a central component to the welfare we believe they deserve. If we assume that animals experience emotions, we feel morally bound to act in the interest of the animal's welfare and so strive to minimise animal suffering. This is reflected by the existence of several forms of legislation governing farming and animal research practices worldwide. For example, see the Australian Animal Welfare Act (2005 - Bill 58), The Federation of European Laboratory Animals Science Associations (FELASA), New Zealand Animal Welfare Act (1999), UK Animals (Scientific Procedures) Act (1986), UK Animal Welfare Act (2006) and a large number of groups that campaign to ensure good welfare for animals (for example, Advocates for Animals, Compassion in World Farming (CIWF), American Association for Laboratory Animal Science (AALAS), Australian and New Zealand Council for the Care of Animals in Research and Teaching (ANZCCART), Canadian Council on Animal Care, Fund for the Replacement of Animals in Medical Experiments (FRAME), Humane Slaughter Association (HSA) and Universities Federation for Animal Welfare (UFAW). If animal mental experiences are important components for welfare, then we should devise ways of understanding these processes so that we can be confident appropriate welfare standards are set. As the range of animals that we consider merit welfare protection continues to expand we need to develop suitable criteria that allow us to judge which animals should reasonably be covered by legislation and protected. Aspects associated with cognition, in particular feelings and awareness, could be helpful factors here.

Another reason for providing a sound scientific basis for animal welfare concerns consumers. It is clear that the consumer's perception of welfare can directly feedback into economic considerations; for example, if the public perceives farm animal welfare standards are poor for a particular product, then sales can be compromised (Broom, 2007). In this manner, the consumer can influence how we regard animal welfare. To ensure consumers understand the relevant issues, it is important that animal welfare research provides sound evidence about what contributes to good or poor welfare.

It is widely accepted that an animal's physical state can affect its behaviour. For example, rats subjected to nutritional deprivation early in life not only exhibit a lower body weight but also have a slower development of exploratory behaviour and an elevation of spontaneous activity compared to control rats reared on a balanced diet (Frañková & Barnes, 1968), and more recently it has been shown that levels of aggression in pigs (*Sus scrofa*) are correlated with nutritional status (D'Eath & Lawrence, 2004). By contrast, we know less about how mental state affects animal behaviour, yet this may have considerable bearing on experimental results – animals with a compromised mental state may generate abnormal data and lead to the unnecessary use of animals in an effort to replicate/further investigate inconclusive results. This is a particularly important point to consider when experiments are being conducted in different laboratories where environmental conditions may differ and affect the outcome of scientific trials. Testing protocols are regularly standardised between laboratories in an effort to obtain similar results, but one study using mice found that there were significant laboratory by genotype interactions on the results for specific behavioural tests (Wahlsten *et al.*, 2003). One potential reason for these unexpected differences may be variable levels of husbandry, handling and care that impact on

the emotional state of the animals being tested. Thus where comparisons are to be made for assays taken in different laboratories, we should perhaps not only standardize testing protocols but also consider the welfare and husbandry methods too.

2. Measuring Welfare

2.1. Biological function

Measures of biological function include factors such as growth rate, productivity and immune function. Growth rate can be measured by *e.g.* taking the weight or length of an animal at various time points and doing simple calculations (*e.g.* Owens *et al.*, 1993; Brown *et al.*, 2005), productivity can be measured *e.g.* as the number of eggs produced over time (*e.g.* Gavora *et al.*, 1980), and good general physical health can be assessed by *e.g.* immune function and lack of disease (*e.g.* Mustafa *et al.*, 2000). Although desirable for economic reasons and as measures of physical welfare, measures of biological function do not necessarily indicate good mental welfare for the animals. For example, a year long study of White Leghorn Hens reared in caged, organic and organic plus rearing systems demonstrated that although caged hens produced more eggs, the quality of these eggs was poorer and caged hens showed little interest in or fear of observers and had high tonic immobility (Castellini *et al.*, 2006).

Measuring welfare through biological function is relatively straightforward, but assessing mental welfare faces inherently greater challenges. At present there exists no simple, direct way to access the subjective, mental experiences of animals, hence not only are we unsure if they are experiencing good or poor mental welfare, but we cannot tell *what* they are experiencing at all. Animals, unlike most human adults, cannot speak and so cannot tell us directly what they are perceiving or feeling. Neither, however, can human infants, so in these cases we devise validated methods to assess subjective experiences.

If we can devise tests that determine human infant subjective experiences, can we use similar approaches to devise valid and reliable tests for animals, and could these be used to measure animal mental welfare? A number of methodologies have been proposed to measure animal mental welfare, and are discussed in the first half of this review. We believe the most promising avenue of research is to use cognitive assays to investigate the problem, and we explore this approach in the second half of the review. We will look at how cognitive assays can contribute to determining what animals want or prefer, whether it is possible to use cognition to discover the mental or affective state of an animal (*i.e.* positive or a negative affective states), and discuss the utility of cognitive assays in aiding decisions over which animals warrant welfare protection.

2.2. Physiological measures

Animals may respond physiologically to a particular perturbation, and the magnitude of the response is typically thought to reflect the severity of the perturbation. Such responses can be primary, including changes in levels of catecholamines and corticosteroids and secondary, including changes in respiration, cardiovascular function, immune function, hydromineral balance and metabolism (Barton, 2002). A primary response includes, for example, the release of hormones such as cortisol that are produced via the hypothalmic-pituitary-adrenal (HPA) or (hypothalmic-pituitary-interrenal – HPI - in fish) axis in response to stressful situations. Higher levels of such 'stress hormones' are usually accepted as indicating increased stress. Commonly used examples of a secondary response are heart rate or gill beat frequency, again with higher levels reflecting greater physiological stress. Other biochemical measures are sometimes taken; for example, levels of circulating macrophages can be used to measure immune response (Mustafa *et al.*, 2008). Such assays have been used over many decades to investigate chronic and acute effects of a wide variety of perturbations in numerous species (*e.g.* see Barton, 2002 for a review in fish; Möstl, 2002 for a review on hormones; Salak-Johnson & McGlone, 2007 for a review on immunity in swine and cattle). For example, handling and transport (*e.g.* Frisch & Anderson, 2000; von Borell, 2001; Barton, 2002; Balcombe *et al.*, 2004; Portz *et al.*, 2006), restraint (*e.g.* Frick *et al.*, 2008), prenatal stress (*e.g.* Otten *et al.*, 2001), castration, tooth resection and tail docking (Prunier *et al.*, 2005) and enrichment (Moncek *et al.*, 2004). However, such measures are not always correlated

with the severity of a perturbation (Barreto & Volpato, 2004), and there can also be confounds with individual and diurnal variations in baseline levels (Ruis *et al.*, 1997; Schrader & Ladewig, 1999).

Although physiological measures remain useful in their own right, in terms of utility in measuring mental welfare, they are of limited suitability. A physiological response does not reveal whether an animal is psychologically affected or not. We can imagine different scenarios where similar physiological reactions are evoked. For example, heart rate can be elevated in both aggressive and sexual situations in the same animal; however, we do not assume that the animal is in the same mental state in both these situations (see Dawkins, 2001). Yet we might conclude this if we based our decision on physiological data alone.

Using physiology as a sole measure of welfare is also problematic because if a particular perturbation does not affect the physiological measure we have chosen, we assume that perturbation is unlikely to be a welfare issue for the animal we are monitoring. Alternatively, an animal may respond physiologically to a perturbation, forcing the conclusion that it is a welfare issue, yet stress reactions can be adaptive mechanisms that allow animals to cope and maintain homeostasis (Barton, 2002) and may even be beneficial (see Davis, 2006, for a review). We therefore need a more holistic approach to animal welfare measures than physiology alone. Many studies acknowledge these short-comings, and measures of behaviour are now often incorporated alongside physiology (*e.g.* McKeegan *et al.*, 2007; Verga *et al.*, 2007; Johonson *et al.*, 2008).

2.3. Inference

It has been suggested that quality of life can be equated to welfare (Wojciechowska *et al.*, 2005; Mullan & Main, 2007). Validated measures exist to assess the welfare of human subjects that cannot communicate directly their subjective experiences. These measures consist of extensively validated questionnaires completed by someone who knows the individual well, for example a parent or carer. They work on the principle of inference, whereby the parent or carer infers the subjective experiences of the subject. For example, the non-communicating children's pain checklist is used to assess pain in children aged 3-18 with severe cognitive impairments (Breau *et al.*, 2002) and the Gustave Roussy Child Pain Scale (Douleur Enfant Gustave Roussy, DEGR^{R}Scale) is completed by nurses to assess pain and anxiety in child cancer patients (Gauvain-Piquard *et al.*, 1999). Similar questionnaires have been developed to measure the subjective experiences of dogs with chronic osteoarthritis (Glasgow University Veterinary School Questionnaire - GUVQuest - Wiseman-Orr *et al.*, 2004, 2006), and these appear to have good validity. These questionnaires, however, require that the individual filling in the questionnaire knows a particular human or animal very well (for example, the owner must have owned the dog for at least one year before it became ill in the case of GUVQuest). Attempts are now being made to develop similar questionnaires to assess the subjective experiences of groups of cattle. While this approach appears to work well in certain circumstances, it will have limited applicability to animals that do not share a close coexistence with humans. An example of this is in fish, a taxonomic group so different to us that it may be difficult for us to infer any of their experiences in a meaningful manner.

2.4. Simple vs. a multi-faceted approach

Animal welfare can be measured in numerous ways, but recently it was suggested that complex approaches should be avoided and replaced with a simpler approach that simply asks whether an animal is healthy and does it have what it wants (Dawkins, 2004). Dawkins (2004) argues that animal welfare can effectively be reduced to these two questions. While the simplicity and effectiveness of this approach is appealing, it is not a panacea for all welfare issues. For example, this approach does not help us identify what it is that specific animals want in the first place? Without this knowledge, we cannot know whether an animal has what it needs. Furthermore, while Dawkins' approach is likely to be a good one to adopt for many of the captive animals we currently farm or use as part of research programs, it is not so helpful in terms of establishing which animals merit welfare considerations. This is a current concern because new research is forcing us to think about which animals should be included in terms of welfare and protection. There is mounting evidence that various species of fish (Braithwaite & Boulcott,

2007), and even crustacea (Barr *et al*., 2008) may have the capacity for suffering and so should be given welfare considerations as we do for birds and mammals.

How can we determine which taxonomic groups should be offered welfare considerations in the first place? In contrast to the approach proposed by Dawkins (2004), others suggest a more complex multi-faceted approach should be used to compare a variety of factors and that these more specific comparisons could be used to help us define which animals should be given welfare protection. For instance, Broom (2007) suggests the following factors should be taken into account: (1) complexity of life and behaviour, (2) learning ability, (3) indications of pain and distress, (4) the biological basis of suffering and other feelings such as fear and anxiety, (5) indications of awareness based on observations and experimental work, (6) functioning of the brain and nervous system. While this can certainly be considered a more holistic approach, to the simple 'Is the animal healthy and does it have what it wants', can we realistically compare different taxa and different species across this broad range of criteria to generate a meaningful conclusion about welfare needs?

We suggest that the six proposed categories may generate more confusion than clarity. For example, it is hard to define complexity of life and behaviour because different species can have different lifestyles and behaviours, each as complex as the other, so how can we reliably quantify complexity and behaviour? Learning ability initially appears to be a more promising angle - it is something that can be readily measured and quantified. A measure of how quickly an animal learns to solve a simple maze, for example, could be used as a common measure across species. Even here, though, we need to show caution, because learning and memory abilities vary across species and even between different populations within a species (Brydges *et al*., 2008). Such differences are often the result of different environments or ecologies selecting for different learning and memory abilities. For instance, an animal living in a very changeable environment will need to specialize in fast learning with little reliance on memory because the rate of change it experiences will limit the value of remembering information for long periods of time. In contrast, an animal from a more stable or homogeneous environment could take more time to learn new information and here a longer memory would be more valuable (*e.g*. Mackney & Hughes, 1995). So learning ability can be fine-tuned to an animal's environment and life history. Thus, an abstract comparison of something like maze learning ability will not reliably inform us about an animal's welfare requirements.

Although it may be relatively straightforward to interpret certain signs of pain and distress in some species, there are serious limitations in using these criteria to assess welfare status or affective state. An animal may limp if it has an injured leg, or howl if it is left alone. These are both indications of pain or distress, but they say nothing of the underlying mechanism. Limping may be a purely physical reaction, with no psychological involvement. However, there may be substantial psychological distress accompanying the physical symptoms – for any particular behaviour the possible connection between the two is not clear. Furthermore, there are problems of interpretation in species we are less familiar with – we may not be able to adequately recognise signs of pain of and distress in animals such as crustaceans or fish for example. Similarly, measures of fear, anxiety and any other emotion face similar problems.

Turning to the final category proposed by Broom (2007), it may be assumed that complexity of a brain and its associated nervous system may correlate with intelligence, or ability to experience emotion. For example, Rose (2002, 2007) considers that fish are incapable of experiencing the emotional component of pain because they lack a neo-cortex. However, there are many examples of different brain structures performing similar roles in different species. A high level of functional analysis occurs in the cerebral cortex of mammals, the striatum in birds and a variety of other brain regions in cephalopods and fish (Broom, 2007). For example in bony fish, the lateral and medial telencephalic pallia are known to be the functional equivalent to the mammalian hippocampus and amygdala, respectively. This has been shown through careful ablation studies in goldfish that clearly demonstrate the pallial regions of the fish telencephalon perform similar functions to the hippocampus and amygdala of mammals (Salas *et al.*, 2006). Therefore, the lack of neocortex in fish does not allow us to conclude that fish are incapable of experiencing the emotional component of pain. Determining that animals have the appropriate neuroanatomy to have particular experiences is an important starting point, but alone it cannot tell us about the mental experiences of animals.

Where does this leave us in terms of deciding which animals warrant mental welfare considerations? We have suggested the basic approach is too simple, yet the more complex, multi-faceted approach also seems littered with pitfalls. The second half of the review focuses on new cognitive approaches that may give insight into which animals are likely to be sentient (*i.e*. to experience emotions), and hence capable of mental suffering.

3. Cognitive Assays - Defining the Cognitive Approach

Cognition is the ability to internalise, process and act upon external information. It can range from a simple form of stimulus-response, where exposure to a certain stimulus triggers a specific response, to much more complex situations where multiple pieces of information are integrated, appraised and finally an action is decided. Most people accept that basic, lower level cognitive processes occur in most animals, after all even jellyfish can learn simple associations, but there is greater uncertainty over the occurrence of 'higher' mental processes in animals, for example the presence of levels of awareness, emotion and sentience, even the possibility of consciousness.

The ability for emotion and awareness are central to the pro-welfare argument - if animals were merely automata there would be no need to provide mental welfare and protection because concepts of fear and suffering, pain or pleasure would be meaningless. Thus we must determine if the animals we do regard to warrant welfare consideration have a sufficient level of cognitive capacity to provide them with awareness and emotion. Tests of cognition have been used to look at questions of welfare in a number of ways, mainly by trying to assess an animal's affective state (defined as the animal being in a positive or negative mental state). Theoretically, animals should be capable of assigning affective states to situations as such an ability would aid survival evolutionarily, through enhancing an animal's ability to seek reward and avoid harm (Young, 1959).

Cognitive tests involve observing what choices the animal makes about its environment, and results from these tests have been widely used as the basis for husbandry recommendations (Forbes *et al.*, 1997). The potential utility of investigating the cognitive components of affective state to determine what an animal may be experiencing has recently been highlighted (Paul *et al.*, 2005). They can be divided into several types of assay:

3.1. Learning ability

Animals can learn to avoid unpleasant stimuli, demonstrating that certain reactions are more than simply reflexive. For example, rainbow trout will learn to avoid a plunging net after conditioning to a light cue, and retain this for 7 days (Yue *et al.*, 2004), and rats can learn to avoid pressing a bar when it is associated with an electric shock (*e.g*. Geller, 1967), but as we discussed earlier, using learning ability as a criterion for welfare protection is problematic. Firstly, the underlying motivations of avoidance learning are unclear (Duncan, 2002) and so may not correspond to negative affective states (Braithwate & Boulcott, 2007). Secondly, there are problems with interpreting the results of learning ability: animals that learn *e.g*. the fastest are not necessarily more worthy of protection (or more sentient, or feel more emotion) than those that learn more slowly. Given the numerous reasons why learning rate may vary between individuals and between species, it cannot be reliably used to assess welfare, affective state, or emotion.

3.2. Preference tests

Preference tests involve giving animals a choice between two or more resources. Animals are presumed to 'prefer' the resource that they choose or spend the greatest time near/interacting with. These tests have been used for decades to investigate animal preferences, for example taste preferences in farm and companion animals (*e.g*. pigs: Kennedy & Baldwin, 1972; dogs: Ferrell, 1984), although the emphasis has not necessarily been on welfare. Over the last 30 years, this assay has increasingly been used to investigate questions of mental animal welfare. For example, in 2000, Danbury *et al.* trained lame and sound broiler chickens to discriminate between normal feed and feed laced with a painkiller called carprofen. When the two feeds were offered simultaneously, lame birds ate significantly more carprofen-laced feed than sound birds, and consumption of laced feed increased as lameness

severity increased. This suggests that lameness causes broiler chickens to experience a sensation, so that when given the opportunity to include a painkiller in their food they do so. This choice test then suggests that lameness is a welfare problem, but has this test actually shown that the lame chickens are suffering, i.e. experiencing negative emotional state?

A major drawback to preference tests is their anthropocentric nature: we are asking an animal to choose between variables we believe are important to it. In reality, we may be i) providing an animal with a selection of poor resources between which it chooses the least aversive, or ii) other environmental variables may be of greater importance. The second point is illustrated in a study by Dawkins (1981). Here, battery hens preferred to spend time in a larger over a smaller cage, but that flooring was even more important than space, as they would choose a very small cage with litter flooring over a much larger one with a wire floor. The importance of a particular resource to an animal can be more carefully investigated by tests that manipulate '*work load'*.

3.3. Work load

This assay is based on the concept that an animal will work harder to access a resource that is of greater importance. This can be obtained by the use of weighted doors. Typically an animal is put into a central 'home compartment' and there are a number of doors leading to further compartments containing different resources. Weights can be added to these doors, so the 'cost' of accessing a particular resource increases. For example, given a choice of seven different resources, mink will work much harder for access to swimming water, pushing against heavier weights than for other resources (Mason *et al.*, 2001). This suggests that swimming is highly valued by mink, and in some countries it is now necessary to provide swimming water for mink. More recently, Seaman *et al.* (2008) found that rabbits will pay a similar price (again through pushing weighted doors) for social contact as they will for food, suggesting they value social contact highly.

While this approach is clearly superior to the simpler 'Preference tests', it still has drawbacks as a method. For example, it is not suitable to use to test animals that are physically debilitated as there cannot be a fair comparison between these and physically healthy animals (*e.g*. lame vs. sound broiler chickens).

3.4. Affective state - behaviours associated with noxious stimuli

These assays are aimed at determining how an aversive stimulus, *e.g*. a noxious substance, affects behaviour, in order to determine if the stimulus is experienced on a higher cognitive level (*e.g*. the sensory component of pain). The International Association for the Study of Pain (IASP, 2008) defines pain as "an unpleasant *sensory* and *emotional* experience associated with acute or potential tissue damage, or described in terms of such damage". It goes on to further say "**Note:** The inability to communicate verbally does not negate the possibility that an individual is experiencing pain and is in need of appropriate pain-relieving treatment. Pain is always subjective." It is possible that the sensory effects could be experienced without the emotional (this would then be termed nociception – simply the detection of and reflexive response to noxious stimuli), but if the emotional (or affective) component is experienced by particular animals then pain is a welfare issue for those animals.

One group of animals where there is great debate over their capacity to experience the emotional side of pain is fish. They certainly have the ability to experience the sensory aspects of pain, responding to it neurologically, behaviourally and physiologically (Sneddon *et al.*, 2003a). There is a debate over whether these reactions are simply reflexive or whether higher cognitive levels are involved (Chandroo *et al.*, 2004; Huntingford *et al.*, 2006; Braithwaite & Boulcott, 2007; Rose, 2002, 2007). Attention tests have been used to investigate this in trout. Trout will initially avoid a novel object before orientating to and approaching it. The delay between avoidance and approach is a measure of their neophobia. When trout are given a noxious stimulus (acetic acid), they spend a greater amount of time close to the object, in other words, their neophobic response is diminished (Sneddon *et al.*, 2003b). This affect is decreased if the acetic acid treated fish are given pain relief in the form of morphine. This suggests the trout were cognitively distracted by the experience of the noxious stimulus, suggesting they may have experienced an emotional component of pain.

Behaviour after the application of a noxious stimulus has also been investigated in a decapod crustacean, the prawn *Palaemon elegans*. Here, application of noxious stimuli to the antennae invoked grooming of the antennae and rubbing of the antennae against the tank (Barr *et al.*, 2008). An analgesic (Benzocaine) inhibited these responses, but did not affect general activity, suggesting the shrimp were experiencing more than a reflexive response to the noxious stimulus. In this type of assay it is important to ensure that any observed differences in behaviour between noxiously treated animals vs. animals treated with a noxious stimulus and an analgesic is not simply due to any inhibitory/excitatory effects of the analgesic.

3.5. Affective state - cognitive bias

Perhaps one of the most promising applications for cognition lies in recently developed assays that investigate cognitive bias. Cognitive bias originates from well-established human psychology findings where human cognitive processes have been shown to be influenced by an individual's emotional state (*e.g.* Phelps, 2006). For example, people in a negative emotional state (*e*.g. pessimistic, depressed or anxious) have been shown to interpret ambiguous stimuli in a more negative manner than people in a positive emotional state (optimistic, happy, calm) (*e.g.* Matthews *et al.*, 1997).

This assay has been modified to allow us to test for cognitive biases and hence affective state in animals. For example, Harding *et al*. (2004) trained rats to press a lever in response to one tone in order to obtain food (positive event), and to refrain from pressing the lever in response to a different tone in order to avoid a burst of white noise (negative event). Rats were then given probe trials with tones in between the two they had been trained to. The researchers found that rats housed in non-stable conditions (hypothesised to promote mildly 'depressive' affective states in rats) took longer to press the lever in response to the food tone and ambiguous tones close to it, and also showed fewer responses to these tones compared to rats housed in normal, standard conditions. This suggests that unpredictable housing does promote negative cognitive bias in rats. Similar studies have been conducted with rats and dogs (Burman *et al*., 2008; Casey *et al.*, 2008) using latency to approach spatial location instead of tones.

Interestingly, there tends to be a focus on negative affective states (Paul, 2005), and the field may benefit from increased study of positive affective states. This bias is also seen in the human cognitive-emotion literature, but here there are now enough studies showing positive biases, particularly in judgement and decision-making (Nygren *et al.*, 1996; Erez & Isen, 2002), to expect that similar findings may be found in animals.

Affective states can be seen as adaptive traits that allow animals to avoid harmful stimuli and seek rewarding ones. However, animal affective states are likely to be quantitatively and qualitatively different to those experienced by humans. In particular, as animals cannot directly communicate their feelings, we have to use behaviour to infer this. Thus we need to be careful with our interpretation of behavioural experiments.

Assessments of animal welfare are 'value laden' – we have our own preconceptions of what we think is important to the animals. Many methods of animal welfare measurement are based on what we experience as humans. For example, we know that when a human feels fear, their levels of certain stress hormones rise. We know that given the choice, humans tend to choose what they prefer (*e.g.* a soft comfortable bed over a hard wooden floor). In these examples, we know that the observed outcomes (hormone levels, behavioural choice) are mostly associated with feelings, emotions, and conscious choice. We must recognise that just because the same outcomes are observed in animals when they are tested under similar situations, it does not mean that their internal experiences are the same. Hence, we need to be careful in devising experiments that accurately test affective state and we should then be cautious in interpreting results.

4. Concluding Remarks

While some cognitive measures have short-comings (for example, preference tests or measures of learning ability), there do appear to be others (measures of cognitive bias) that can inform us about animal emotion and affective states. Such approaches, combined with carefully designed behavioural experiments, look like a promising route for us to obtain a better understanding of what is good or bad

for an animal's welfare. Methods that reveal an animal's capacity for emotion and awareness could also, importantly, provide us with a useful tool to determine which animals should be included in welfare guidelines and legislation, and which we can legitimately exclude.

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Nichola M Brydges took her Ph.D. in the Institute of Evolutionary Biology at the University of Edinburgh, where she focussed on the effects of natural and artificial environments on fish behaviour, and considered the implications of routine laboratory procedures on fish welfare (2007). Since her PhD she has been employed in the Division of Veterinary Biomedical Sciences at the University of Edinburgh, where her research involves investigating the neural mechanisms of pain and conditioned responses in canines and rats.

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