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Consciousness, emotion and animal welfare: insights from cognitive science

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Abstract

The assumption that animals are conscious and capable of experiencing negative sensations and emotions is at the core of most people's concerns about animal welfare. Investigation of this central assumption should be one goal of animal welfare science. We argue that theory and techniques from cognitive science offer promising ways forward. Evidence for the existence of conscious and non-conscious cognitive processing in humans has inspired scientists to search for comparable processes in animals. In studies of metacognition and blindsight, some species show behaviour that has functional parallels with human conscious cognitive processing. Although unable to definitively answer the question of whether the animals are conscious, these studies provide fresh insights, and some could be adapted for domestic animals. They mark a departure from the search for cognitive complexity as an indicator of consciousness, which is based on questionable assumptions linking the two. Accurate assessment of animal emotion is crucial in animal welfare research, and cognitive science offers novel approaches that address some limitations of current measures. Knowledge of the relationship between cognition and emotion in humans generates a priori *frameworks for interpreting traditional physiological and behavioural indicators of animal emotion, and provides new measures (eg cognitive bias) that gauge positive as well as negative emotions. Conditioning paradigms can be used to enable animals to indicate their emotional state through operant responses. Although evidence for animal consciousness and emotion will necessarily be indirect, insights from cognitive science promise further advances in our understanding of this fundamentally important area in animal welfare science.*

Keywords: *animal welfare, blindsight, cognition, consciousness, emotion, metacognition*

Introduction

'Clever animal' stories fascinate the public. Amusement and quirkiness are probably the main selling points, but the stories are sometimes used to underpin arguments for or against particular forms of animal use. This is most noticeable for the great apes, where studies investigating 'higher' cognitive abilities such as self-concept, language, and theory of mind have been used as a significant part of the case for rights being extended to these species (Cavalieiri & Singer 1993). It seems then that information about the intellectual abilities of other species can affect our attitudes to them (Davis & Cheeke 1998; Serpell 2004, pp 145–151, this issue). If so, research into the cognitive capacities of our common farm and laboratory animals could have a similar impact. But what if the research showed that they had quite limited cognitive capacities? Would this mean that we could use them with little regard for their welfare? Conversely, what if we discovered high levels of cognitive complexity? How should we treat them then?

To answer these questions we need to consider what exactly an understanding of the cognitive abilities of animals tells us about their capacity to suffer. Here we will focus on how knowledge of cognitive abilities, and how techniques and theory from cognitive science, may be able to offer new ways of investigating (i) animal consciousness and (ii) animal emotion — two areas of fundamental importance in animal welfare science. Given limited space, our aim is to provide a brief introduction to this area, and more detailed treatment of some of the issues that we discuss can be found in the review articles that we cite in this paper. Throughout, we refer to non-human animals as animals.

In the first part of the paper we consider what studies of animal cognition can tell us about animal consciousness. Cognition is to do with *information processing*, and we use a broad definition of cognition as referring to the range of processes involved in the acquisition, storage and manipulation of information (see Shettleworth 1998). Consciousness, however, is usually defined in terms of the capacity to *be aware of* feelings, sensations, thoughts and emotions. This basic ability is often referred to as *phenomenal* or *feelings* consciousness (Block 1998; Macphail 1998), while the capacity to be subjectively aware of oneself as a unique thinking, feeling individual is referred to as *self-consciousness* (Macphail 1998; Damasio 2000). The simple cataloguing of complex cognitive capabilities as potential indicators of the presence of conscious experience in animals has rightly been criticised (eg Dawkins 2001), and we briefly discuss this approach. But this does not mean that the study of animal cognition offers no insight into the existence of consciousness in other species. In particular, we suggest that recent developments in the study of metacognition and blindsight may be especially illuminating.

In the second part of the paper we suggest ways in which studies of animal cognition can inform us about animal emotion. Most contemporary emotion researchers view emotions as multifaceted phenomena (eg Frijda 1988; Lang 1993; Lerner & Keltner 2000). That is, any emotional response can be regarded as comprising behavioural, physiological, cognitive, and conscious components. For example, 'fear' may involve fleeing behaviour, physiological stress responses, enhanced attention to threatening stimuli, and — what we would usually refer to as the emotion — a subjective feeling of terror or panic. There is debate as to whether this conscious component is present in non-human animals and, if so, in which species (see Damasio 2000; Berridge & Winkielman 2003). Although the cognitive science approaches that we describe here do not directly address this issue, they nevertheless provide powerful frameworks and methods for identifying the specific type or valence of an animal's emotion state.

Cognition and consciousness

For most of us, the conscious mental experiences of animals lie at the heart of our concern for animal welfare. We may also be concerned that animals should live natural lives, and that their biological functioning should be unimpeded (Duncan & Fraser 1997; Appleby & Sandøe 2002), but if we were really convinced that they could not suffer, we would probably be no more worried about their welfare than we are about that of plants. The problem is that most of us would also agree that we cannot know for sure whether and what another animal consciously experiences. If we accept this problem, and some argue that it is a constraint of a particular philosophical view of subjective experience (eg Wemelsfelder 1997) or that subjective experience is not the central determinant of animal welfare (eg McGlone 1993), then our research into animal welfare needs to be based on an *assumption* that the species we study are capable of conscious experience, particularly of negative states.

The need for this assumption is well recognised by animal welfare researchers (eg Dawkins 1990; Mason & Mendl 1993; Duncan & Fraser 1997), but the uncertainty of whether it is correct or not, and if so for which species, is an inherent weakness in animal welfare science (Sandøe *et al* 2004, pp 121–126, this issue), making the area vulnerable to those who simply do not believe it. Indeed, scientists and philosophers differ widely in their views. Some suggest that only humans and perhaps the great apes have conscious experiences, while others encourage us to consider the possibility that invertebrate species may also be sentient (eg Carruthers 1989; Griffin 1992, 1998; Kennedy 1992; Macphail 1998; Baars 2001; Bermond 2001; Sherwin 2001). Overall, we are sympathetic to the call that we should give animals the benefit of the doubt (Bradshaw 1998). However, we also argue that the gathering of evidence for or against the assumption should be one goal of animal welfare research because the assumption is so central to all that we do. Here we suggest that theory and techniques from cognitive science may be particularly useful in trying to tackle this difficult issue. However, we start by considering the limitations of a commonly held view about the links between cognition and consciousness.

Cognitive complexity and the emergence of consciousness: do clever animals suffer more?

A popular, and often implicit, assumption (or pitfall — see Dawkins 2001) is that the more 'cognitively complex' an animal is, the more likely it is to be conscious. However, this raises problems including how to define cognitive complexity, how to distinguish complex from 'simpler' processes, and why increasing complexity should necessarily be linked to the emergence of consciousness. We do not have the space to tackle these issues here, but they have been discussed at length by others (eg Gallup 1982; Griffin 1992, 1998; Bekoff 1994, 1998; Byrne 1995; Nicol 1996; Vauclair 1997; Macphail 1998; Bermond 2001; Dawkins 2001). Suffice to say that the thrust of this approach appears to be to grant potential 'consciousness status' to those species that demonstrate cognitive abilities which we view as key, perhaps even defining, attributes of humans (eg human-like language, theory of mind, sense of self). The research agenda is therefore to collect and catalogue examples of 'clever' behaviour. Notwithstanding the difficulties in ruling out 'simpler' associative learning explanations for behaviour that indicates the presence of these abilities (see Coussi-Korbel 1994; Nicol 1996; Heyes 1998; Held *et al* 2001a, 2002a), it is not clear why these abilities should necessarily indicate the capacity for conscious experience. Conversely, and importantly from an animal welfare perspective, it is also not clear that absence of these abilities indicates a lack of conscious experience — especially *feelings* consciousness (see below).

It seems logical to argue that if an animal can be demonstrated to possess a cognitive concept of self (eg in a mirror recognition test [Gallup 1970, 1982; de Veer & van den Bos 1999; for critiques see Heyes 1994; Macphail 1998]), then it has the potential for *self-consciousness* — subjective awareness of itself as a unique thinking, feeling individual. However, self-consciousness is usually viewed as a rather special form of conscious experience (Macphail 1998; Damasio 2000), in contrast to *feelings consciousness* — the basic awareness of feelings such as sensations and emotions (Block 1998; Macphail 1998). From an animal welfare perspective, it is feelings consciousness that is really important. Suffering may be equally great in a species that experiences "I feel pain" as in one that experiences "this is painful" (Bekoff 2002). Basic awareness of sensations or emotions *per se* is crucial, and it is difficult to see why this should depend on either self-consciousness or cognitive complexity (see also Dawkins 2001). Therefore, the presence or absence of a self-concept is of limited use in identifying which species can or cannot consciously experience feelings.

In humans, language is clearly associated with conscious experience. Some take the view that language, or at least a basic capacity for syntactic manipulation, may be important for conscious experience (Dennett 1996; Macphail 1998;

Rolls 1999). This view is supported by evidence from split-brain patients who appear to lack conscious awareness of information presented solely to the non-linguistic (usually right) hemisphere (Gazzaniga 2000). But the fact that much conscious experience — touch, smell, joy, sorrow — feels so independent of language, and indeed appears to occur in people with catastrophic damage to their linguistic capabilities, leads others to the popular view that such feelings are likely to be common to linguistic and non-linguistic animals alike (eg Damasio 2000).

We therefore argue that the cataloguing of examples of 'cognitive complexity' — information processing abilities that may not be easily explained in terms of 'simpler' (eg associative) forms of learning — is of limited use in identifying the existence of feelings consciousness. However, if we were to make the assumption that a particular species did have feelings consciousness (ie to give them the 'benefit of the doubt' [see Bradshaw 1998]), knowledge of cognitive complexity could shed light on the types of situation in which suffering was or was not likely to occur (see Nicol 1996). For example, the possession of well-developed episodic memory and the ability to do anticipatory planning (eg Clayton & Dickinson 1998; Emery & Clayton 2001) could have a profound effect on the range of situations in which the animals might suffer, rendering them capable of brooding over past or potential future events (Byrne 1999; Lea 2001) but also able to pre-emptively avoid harmful situations. Individuals with the ability to perceive time and to learn that an aversive husbandry procedure has a limited duration would likely suffer less than those that treated each occurrence as the start of a potentially interminable ordeal (Duncan & Petherick 1991; Bekoff 1994). Therefore, assuming feelings consciousness to be present in the species under study, the search for cognitive complexity could help identify situations in which suffering is likely, and hence suggest ways of managing animals to avoid these (Held *et al* 2001b, 2002b; Mendl *et al* 2001). For example, it may be possible to signal the duration of aversive procedures to animals with well-developed time perception abilities (Spinka *et al* 1998; Taylor *et al* 2002), and thereby to increase predictability and reduce the perceived aversiveness of such procedures.

Metacognition and blindsight: conscious and non-conscious information processing in animals?

In contrast to gathering disparate examples of 'cognitive complexity' in animals, focused research on aspects of cognitive function that are known to be directly related to conscious information processing in humans may be a more fruitful approach to investigating animal consciousness. Here we discuss two research topics — metacognition and blindsight — that may be particularly informative.

Cognitive processes appear to be dissociable from conscious experience in humans. For example, memory processes may occur either 'explicitly', involving conscious recall, or 'implicitly', when people's behaviour or answers to questions are influenced without them being consciously aware of retrieving the relevant information (see discussions in Seger 1994; Shanks & St John 1994; Cleeremans *et al* 1998; Dienes & Perner 1999; Butler & Berry 2001; Curran 2001). The possibility is raised that animal cognition is primarily of this implicit, unconscious type. This has led cognitive scientists to develop ways of studying whether animals also demonstrate two levels of cognitive functioning similar to human implicit and explicit information processing.

Robert Hampton (2001) trained rhesus monkeys on a delayed-matching-to-sample task. An image (sample) was shown on a computer screen followed by a delay during which the screen was blank. In 33% of trials the monkey was then presented with four images, one of which was the original sample. Touching this image resulted in the delivery of a peanut — a preferred reward — but touching any of the other three images resulted in no reward. In 67% of trials the monkey was allowed to *choose* whether to take this test or not. If the test was declined the monkey received a primate pellet — a less preferred reward. If the test was taken the preferred peanut reward was only provided for a correct choice. Hampton reasoned that if monkeys could reflect on the quality of their memory for the task, they would choose to take the test only when their memory was good and their chances of getting the peanut were high. If they perceived their memory as poor, they should decline the test and go for the guaranteed but boring primate pellet. Overall, their performance on the test would therefore be better when they could choose whether to take it than when they were forced to take it, in which case their memory might be good on some occasions but poor on others. This is indeed what he found. He also found that with longer delays between presentation of the sample image and the option to choose whether to take the test, the monkeys tended to opt out more frequently, indicating that they perceived their memory for the sample to fade with time.

These findings suggest that monkeys can monitor the quality of their memory and use this information to moderate their behaviour in a memory task. They appear to have 'metacognition', ie to 'know what they know'. This represents a functional parallel with human explicit, conscious memory. Although the underlying mechanisms remain to be elucidated, and definitive evidence that conscious processes are involved cannot be provided by this study (Hampton 2001), this research illustrates how ingenious but also quite simple experiments on animal cognition can start to investigate whether animals do have something like an explicit, conscious memory.

Other studies of metacognition have tested humans and animals in psychophysical discrimination tasks. For example, subjects are required to categorise a stimulus (eg an image of a box containing illuminated pixels [Smith *et al* 1997]) as being either 'dense' (2950 pixels) or 'sparse' (450–2949 pixels). Correct responses are rewarded, but incorrect responses are penalised by a delay. An 'uncertain' response is available which allows a trial to be skipped and followed by a guaranteed but slightly delayed rewarded trial. The prediction is that if subjects are able to monitor their ability to solve the task, then they should choose the 'uncertain' response when the task is difficult (eg a box containing 2700 pixels). Humans, monkeys and dolphins use this response as predicted, and in a strikingly similar way, whereas rats and pigeons do not (Smith *et al* 1995, 1997, in press; Inman & Shettleworth 1999). Again, there are a number of interpretations for these findings, but one is that some species are able to refer to the quality of their knowledge, and to use this information to avoid making incorrect responses. This referral process involves conscious awareness in humans and may do so in other species. The failure of some species to show this behaviour may indicate that they possess a more limited form of metacognition (Smith *et al* in press).

A quite different paradigm involving the phenomenon of 'blindsight' has also been used to investigate the existence of conscious and non-conscious processing in animals. Humans with damage to the V1 area of the visual cortex report that they are blind in one part of their visual field, and yet they are able to detect and discriminate visual stimuli presented in this area (Weiskrantz 2001). It appears that there are conscious and non-conscious pathways mediating their behaviour in these visual tasks. Research has revealed parallels in rhesus monkeys. Cowey and Stoerig (1995) showed that monkeys with damage to the V1 area could be trained to detect and touch a visual stimulus on a computer screen when it was presented in both damaged and intact parts of their visual field. However, when trained to report the presence or absence of the stimulus by touching either a 'there' or 'not there' symbol, they reported that it was 'there' when presented in the intact part of the visual field, but 'not there' when presented in the damaged part. These findings once more indicate that two levels of cognitive processing appear to occur in monkeys.

We should emphasise that none of these studies can definitively answer the question of whether the animals involved are conscious or not. However, they do provide the best behavioural evidence to date that some animals may process information at two levels, one of which may be similar to human conscious information processing. One limitation of this approach is that the studies have so far focused on whether animals can report on their 'knowledge' state. It remains unclear whether an inability to do this, as may be the case in rats and pigeons, also reflects an inability to access and be aware of the subjective states most relevant for animal welfare — emotions and sensations (cf Dawkins 2000; Panksepp 2003). In the second part of this paper we consider how a knowledge of cognition–emotion relationships can be used to help develop better measures of animal emotion.

Cognition and emotion

As mentioned in the introduction, emotional responses can be regarded as comprising behavioural, physiological, cognitive and subjective components (eg Frijda 1988; Lang 1993; Lerner & Keltner 2000). Here we consider cognitive components of emotion. These have been investigated extensively in humans as detailed below, but have received little attention in animal studies.

In humans, initiation of an emotional response depends in part on 'cognitive inputs' — how the eliciting stimulus that gives rise to the emotion is 'appraised' by the subject (eg Scherer 1984; Ortony *et al* 1988; Lazarus 1991). Appraisal is the process by which the relevance of the stimulus is classified, for example, either as threatening, in which case a fear response will occur, or as non-threatening, in which case there will be no fear response. Essentially a cognitive process — though not necessarily conscious (Öhman & Soares 1993; Gray 1999) — appraisal is influenced by innate 'automatic' responses that may have evolved over many generations (eg responses to a snake-like object), and also by learning and memory of previous encounters with stimuli during the individual's lifetime (LeDoux 1996).

Emotional events can also lead to changes in cognitive functioning such as an increased tendency to attend to threatening stimuli during fear, or an enhanced memory for unhappy events during sadness (eg Clark & Teasdale 1982; MacLeod *et al* 1986; Burke & Mathews 1992; Mogg *et al* 1992; Keogh *et al* 2001). These have been extensively studied in humans and are viewed as important functional 'cognitive outputs' that could well occur in other species.

Currently, measures of animal emotion focus primarily on the physiological and behavioural components of the emotional response (see Broom 1998 for examples). Escape behaviour, elevations in heart rate or 'stress hormones' such as cortisol, avoidance of moving to open arms in an elevated plus maze, and high levels of defecation, are all examples of responses used as indicators of 'fear' or 'anxiety'. Although such measures are the bedrock of animal emotion assessment, they do have limitations. Standard measures of negative emotions far outweigh those of positive ones (although the approach of Wemelsfelder and colleagues [2001] emphasises positive as well as negative states). There is no *a priori* framework for interpreting different profiles of response. Is an animal showing high heart rate, low avoidance and moderate rises in cortisol exhibiting a different emotion from one showing another response profile? If so, which emotions map onto which responses? Finally, in humans at least, there is evidence for dissociations between physiological and behavioural responses and reported conscious experience of emotion. For example, some people appear unaware of subjective emotion despite showing behavioural and physiological emotional responses (Lane *et al* 1997a; Stone & Nielson 2001). Given that our ultimate goal in animal welfare research is to provide accurate estimates of conscious components of emotion, behavioural and physiological measures may be found wanting. We propose that approaches based on the measurement of cognition and information processing may help to address these problems and to develop new and better indicators of emotion (see Harding *et al* 2004).

Cognitive inputs: appraisal theories as frameworks for interpreting physiological and behavioural components of emotional responses

Much research on human emotion has focused on how cognitive appraisals of stimuli determine different felt emotions.

For example, the work of Scherer (1999) has shown that if a stimulus is appraised as being unfamiliar, unpleasant, unpredictable, and occurring suddenly, an emotion of fear is usually reported. In contrast, a stimulus evaluated as being pleasant, of moderate predictability, and not sudden, triggers a happy emotion (in this case, familiarity appears to have little impact). Other appraisal characteristics are also important (see Scherer 1999), but the key point is that specific appraisal patterns appear to be linked to specific felt emotions. Recently, Dantzer (2002) and Desiré and colleagues (2002a) have proposed applying Scherer's theory to animals. They suggest designing stimuli that have properties that mimic appraisal criteria for different emotions. For example, by presenting a stimulus that is unpredictable, unfamiliar, unpleasant and sudden, the *profile* of behavioural and physiological responses that an animal shows to this stimulus could, *a priori*, be labelled as an expression of 'fear'. This approach offers the possibility of identifying the features of a variety of different emotions, thus establishing the range of emotions that a particular species can exhibit, without relying on *a posteriori* assessments of what kind of emotion a particular situation might be expected to induce. Limitations include the assumption that Scherer's theory of the link between human appraisal processes and emotions is correct — there are related theories (eg Ortony *et al* 1988; Lazarus 1991; Clore *et al* 1994; Smith & Kirby 2000) — and that it has validity in other species.

A similar approach can be taken using simpler frameworks for categorising emotions that may be more applicable to animals. For example, Rolls (1999) proposes that stimuli are appraised principally according to whether they are rewarding or punishing (see also Millenson 1967; Gray 1975). Emotional responses are determined by the intensity of reward or punishment and also by whether the stimuli are presented, omitted or terminated. Presentation of rewards leads to emotions such as happiness, while omission of rewards leads to frustration, anger or rage. The behavioural and physiological response profiles observed under these conditions could thus be used as indicators of putative animal emotions.

These approaches offer *a priori* frameworks for mapping behavioural and physiological responses to particular emotion states, including positive ones. Initial studies suggest that they can be used with farm animals. Sheep exhibit different response profiles to stimuli with different characteristics (Desiré *et al* 2002b). Further studies may reveal whether distinctive response profiles are reliably observed and can be used to assess the impact of real life husbandry conditions. It remains to be seen if such studies can contribute to an understanding of whether and how the felt component of emotions arises in animals.

Cognitive outputs: cognitive biases as indicators of emotions

Numerous cognitive changes occur in humans experiencing particular emotions or moods (Mathews & MacLeod 1994; Mineka *et al* 1998). For example, anxious people bias their attention towards threatening stimuli or information (eg Kindt & Van Den Hout 2001), tend to recall negative autobiographical memories (eg Williams *et al* 1997), and have negative expectations of future events — a pessimistic outlook (eg MacLeod & Byrne 1996). Opposite biases are observed in happy people (eg Wright & Bower 1992; Nygren *et al* 1996). Such cognitive biases have a survival function, increasing the likelihood that under threatening circumstances stimuli are appraised in a negative way, and actual dangers are identified more quickly (Bradley *et al* 1997). In cases of ongoing pathological anxiety or depression, however, such biases can become detrimental, perpetuating negative affective states and preventing recovery (MacLeod *et al* 1986).

Given that cognitive processes are so intimately and functionally involved in emotions in humans, it is conceivable that some animal species also exhibit cognitive emotional biases or 'outputs'. We are currently investigating whether this is indeed the case. In particular, we have been developing methods to determine whether animals are more likely to anticipate future events as being negative or positive, and whether any observed cognitive biases are affected by how stressed the animals are (Harding *et al* 2004). Such measures of cognitive bias may be especially informative as they indicate both the presence of current emotions, including positive ones, and a predisposition to future emotions. They may also be particularly useful for identifying ongoing, perhaps pathological, emotional states in captive animals that are no longer subject to direct stressors. Furthermore, human emotion theorists suggest that some cognitive biases associated with emotional states arise directly as a result of conscious emotional feelings being made use of as 'information' in processes of judgement and decision-making (Schwarz & Clore 1983, 1996; Bower & Forgas 2000). If this is correct, the possibility that certain cognitive components of emotion are directly indicative of the presence of conscious emotion, even in non-human animals, will need to be explored.

Cognitive techniques: using conditioning to investigate emotional states

Two other approaches to the measurement of animal emotion employ techniques from cognitive science. Similar to Harding and co-workers (2004), anticipatory behaviour has been identified as a potential indicator of emotion by Spruijt and colleagues (Spruijt *et al* 2001; van den Bos *et al* 2002; see Berridge 1996 for background to this approach). They suggest that animals experiencing an anhedonia-like state (decreased reward-sensitivity) attributable to stress or negative affect, will show reduced anticipation of rewarding stimuli such as sweet foods. They propose that 'anticipatory behaviour' can be measured in a Pavlovian conditioning paradigm as the number of behavioural transitions occurring between the presentation of a conditioned stimulus predicting a sucrose reward and the arrival of that reward. Experimental studies have shown that rats exposed to social stress or isolation do indeed exhibit a reduced frequency of behavioural transitions (van den Berg *et al* 1999; von Frijtag *et al* 2000). Although the rationale behind their proposal is quite different from that developed by Harding and colleagues (2004), both approaches emphasise that measures of cognitive function such as anticipation can provide information about animal emotion.

A final approach uses operant conditioning techniques to reveal emotional states in animals. Carey and Fry (Carey *et al* 1992; Carey & Fry 1993, 1995) were able to train pigs to show one operant response when they were in a 'normal' state and a different response when they were in an 'anxious' state (dosed with an anxiogenic drug), indicating that the pigs could discriminate between these two states and alter their lever pressing behaviour accordingly. They also went on to show that undrugged pigs would make the response indicative of drug presence after having been exposed to a novel pen, a novel object, transportation or mixing with an unfamiliar pig (Carey & Fry 1995). The implication was that the pigs experienced a state similar to drug presence (or anxiety) following these treatments. These studies demonstrate another way in which cognitive techniques can be used to probe animal emotions.

Conclusions and animal welfare implications

Approaches to the measurement of welfare that sidestep the problem of animal consciousness have been highly successful in providing a pragmatic way forward (see Broom 1991; Duncan & Fraser 1997; Mendl 2001). But there should also be space in animal welfare science for attempts to further develop our understanding and measurement, however indirectly, of animal consciousness and the sensations and emotions that constitute suffering or happiness. Our aim in this paper has been to show that recent developments in cognitive science offer promising ways forward in this difficult endeavour.

The general tendency to search for examples of cognitive complexity to support arguments for the humane treatment of animals, or for the provision of rights, runs the risk of speciesism and the danger of ignoring those that may most need our protection (Burghardt 1997; Bekoff 1998). We and others (eg Dawkins 2001) argue that an individual's cognitive complexity, and this usually means its cognitive similarity to humans, tells us little about its capacity for feelings consciousness — the conscious awareness of sensations and emotions which lie at the heart of suffering. However, if we make the assumption that a particular species does have feelings consciousness, an understanding of its cognitive capacities may help identify those situations in which it is likely to suffer, and hence may suggest ways of changing management to eliminate or minimise these situations (Duncan & Petherick 1991; Bekoff 1994; Nicol 1996; Mendl 1999; Held *et al* 2001b, 2002b; Mendl *et al* 2001). More importantly, recent developments in cognitive science offer promising new ways of probing the possible conscious experiences of animals. Studies of metacognition and blindsight should yield fresh insight into the issue of whether animals process information consciously, and some of the techniques used (eg Smith *et al* 1997; Hampton 2001) could be adapted for common captive species.

Cognitive science also offers novel approaches to the measurement of animal emotion. Innovative use of traditional conditioning paradigms may provide new ways of assessing emotions. Knowledge of the links between cognition and emotion in humans can generate *a priori* frameworks for interpreting traditional physiological and behavioural indicators of animal emotion, can suggest new measures of positive and negative emotion such as cognitive bias, and may even identify cognitive components of emotion that might indicate the presence of subjective emotional states.

Could a programme of cognitive research provide evidence to confirm the assumption underpinning animal welfare research that the species we study are capable of conscious experience? On its own, we think this is unlikely. Nevertheless, we feel that it will provide important strands of evidence that, together with developments in philosophical approaches to the study of mind and brain, brain imaging studies and neuroscience research in humans and animals (eg Lane *et al* 1997b; Gray 1999; Bush *et al* 2000; Chalmers 2000; Damasio *et al* 2000; O'Regan & Noe 2001; Crick & Koch 2003; Panksepp 2003), may take us closer to tackling the problem of whether we can ever know that another being is conscious.

Studies of animal cognition are of intrinsic interest to the general public. They are potentially powerful tools in changing attitudes and perceptions and hence the treatment of animals in society. They are also within the realm of study of animal welfare scientists, and represent a route by which we can contribute to an understanding of animal consciousness and emotion — critical issues in animal welfare science. The search for cognitive complexity has dominated thinking and research in this area. It is now time to take on board new ideas and methods from cognitive science that promise fresh advances in our understanding of animal consciousness, animal emotion, and animal welfare.

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