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ANIMAL COGNITION IN RELATION TO FARM ANIMAL WELFARE: THE NEED FOR A DIFFERENT APPROACH

Lloyd Fell
University of New England, Australia

ABSTRACT: Reviewing various ideas about animal cognition, including the radically different approach developed by Maturana and Varela (1987), brings to light serious concerns about the ability of the current science of cognitive ethology to address issues of animal welfare or to provide useful interpretations of animal thinking and awareness. The proposition that farm animal welfare will be properly assessed only when much more is known about the cognitive abilities of the animals concerned is critically discussed. This principle is supported, but the current means of achieving it are questioned. It is argued that a broader scientific basis is needed to enhance a cognitive ethology that is merely an additive combination of behavioural observation and information-processing models of cognition.

INTRODUCTION

In recent years many scientists have said that the study of animal welfare in farm production systems requires a better understanding of cognitive processes (e.g. Curtis and Stricklin, 1991; Duncan, 1996). In fact Duncan and Petherick (1991) argued that animal welfare depends solely on the "cognitive needs" of the animals concerned and that, if these are met, most physical needs are also protected. The broad relationship between cognitive ethology and animal welfare was reviewed by Bekoff (1994). Several authors have canvassed the significance for animal welfare of the possibility, or probability, that animals conceive ideas, think about objects or events that are not part of their immediate situation or consciously formulate plans that will direct their future behaviour (e.g. Rogers, 1994; 1997). At the same time the burgeoning field of cognitive science has opened up many lines of

Address correspondence to Lloyd Fell, NSW Agriculture, University of New England, Armidale, NSW 2351, Australia.

investigation.

The broad sense in which pioneers like Griffin (1976; 1984; 1992) spoke of animal cognition - animal thinking - animal minds - spawns many fascinating lines of enquiry, but also invites criticism. Kennedy (1992) argued strongly against involving cognitive processes in causal mechanisms of behaviour calling it "resurgent anthropomorphism" and denying that the more sophisticated information processing models which are available in cognitive science today make cognition any more acceptable in ethology. He also warned against our predisposition to attribute intention and purpose to other people and animals which McFarland (1989) had called the "teleological imperative." They argued that attributing intentionality is a case of putting the ultimate cause onto the proximate cause of behaviour.

Where does cognition fit in the complex web of explanations about animal consciousness, subjective experience and welfare? By examining various uses of the term, cognition, including the radically different approach initiated by Maturana and Varela (1980; 1987), I hope to shed some new light on the study of animal cognition in the context of farm animal welfare. The literature on cognition in the human behavioural sciences, including the extensive neurophysiology involved, is beyond the scope of this paper, but some principles will be mentioned where appropriate.

THE HISTORY OF COGNITION IN ANIMAL ETHOLOGY

In animal ethology there has been considerable debate about where cognition fits in. In its very early days the causes of behaviour were studied in terms of purposive, instinct-driven mechanisms, this being regarded as a more scientific approach than the earlier culture of animal mentalism. In the first half of this century there was a profound swing to the reflex behaviourist tradition, originally led by Watson and stimulated by the publication of Pavlov's work, in which the animal's mental processing was not considered at all. There were exceptions to this such as the work of Köhler (1925) on the mentality of apes in which the idea of insight was introduced. The founders of modern ethology, Lorenz and Tinbergen, did not bring in cognition, but they opened the science for the second half of this century to the study of functional as well as causal explanations of behaviour. There has been increasing use of cognitive interpretations of animal behaviour generally in the last 20 years, but the most overt cognitivism is found in

behavioural ecology and comparative psychology where functional explanations are most widely used.

One of the fathers of the modern cognitive approach to ethology was Tolman (1932) who stated that he was not a mentalist, but a behaviourist; that his system was purposive, but not anthropomorphic. This distinction figures prominently in the subsequent debates about cognition. Tolman maintained that acts of behaviour have distinctive properties of their own which cannot be reduced to their physiological mechanism, a line of thought which is akin to an old idea known as entelechy or to the notion of emergent properties in systems theory today. He introduced the concept of cognitive maps, whereby animals acquire and store information about their surroundings, for the purpose of using it in their future behaviour.

Some modern protagonists of animal cognition (e.g. Griffin, 1984; Wilder, 1990) have predicted that we should soon be able to explain the subjective mental experiences of animals, including feelings and intentions, but they appear to be using the term cognition to encompass a wider spectrum of conscious thought and knowledge than is generally addressed by the information processing models which occupy centre stage in cognitive science today. Others such as Staddon (1989) called this approach a needless complexification, while at the same time they freely use functional explanations of so-called purposive behaviour in intentional systems. Kennedy (1992) warned that cognitivism, focusing on the internal representation of knowledge - expectancies, images, intentions, goals, plans, etc. - had the hallmarks of a return to anthropomorphism.

A typical summary of this dilemma (e.g. McFarland, 1985) is that cognition refers to the mental processes that we cannot observe directly in animals, but for which we have some indirect scientific evidence. In this sense, cognition arises in the context of learning, where it is generally agreed that there is a spectrum of learning ability ranging from the most simple cases, e.g. in lower species, or Pavlovian conditioning, through to the complex cognitive ability of humans. Since cognition involves learning and thinking processes which are not directly visible, we must rely on indirect evidence to decide where on this spectrum of learning ability a particular animal lies. Thus there have been "hidden" aspects of simple conditioning revealed to be examples of "associative learning." The central issue in contemporary learning theory (Dickinson, 1980) is the idea of internal representations or mental images. Whether it is a declarative representation (mental image) or a procedural representation (set of instructions), this

cognitive process is what guides future behaviour, though (by definition) this is not regarded as intentional in the case of a procedural representation.

To the extent that it guides future behaviour, cognition must also be considered in the context of motivation theory. This has its origin in the concept of homeostasis and the idea that homeostatic requirements place behavioural demands upon animals through a feedback loop. When the internal state changes, a drive builds up which gives rise to appetitive behaviour (searching) and consummatory behaviour (satisfying the internal state). The term "drive" has been largely superseded by terms such as "motivational state." This figures in explanations of causal mechanisms, explaining why the same stimulus can produce different responses, and in functional explanations whereby beneficial consequences are achieved.

By definition, motivational state is a state of the nervous system. It is what determines the likelihood that an animal will engage in a behaviour or the strength of its tendency to do so. It describes the forces acting on or within the organism to initiate and direct behaviour towards a goal and it explains differences in the intensity of that behaviour. Toates (e.g. 1980) and McFarland (e.g. 1985) showed how models based on classical control theory could be used to explain such motivational systems as feeding, drinking, sexual behaviour and fear. McFarland developed a complex state-space approach to this type of modelling which seems to accommodate his concern that we should not attribute purpose where there is not necessarily a purpose in the terms of the animal's world (McFarland, 1989). The claimed advantage of the state-space approach was that the combined effects of both internal and external stimuli could be represented along with greater complexity of the physiological state.

A synthesis of various ethological and psychological models of motivation by Toates and Jensen (1991) showed that different models emphasise different aspects of internal or external control and therefore attach more or less importance to the question of whether animals have specific behavioural "needs." Friend (1989) and others have revived concern about the significance for animal welfare if behavioural needs are thwarted in some way. Those behaviours which seem to have primarily endogenous motivation or which increase abnormally if denied and those situations in which displacement activities occur or animals will work to be able to perform certain behaviours have been the focus of attention. Jensen and Toates (1993) said that this should not be generalised; although if one knows the environmental context a

behaviour may be called a need in a specific situation. Poole (1992) discussed the evolution of behavioural needs and distinguished between psychological needs and ethological needs.

Dawkins (e.g. 1990) developed the related idea that the cost an animal is prepared to pay for the opportunity to perform a behaviour, or to avoid something unpleasant (see Rushen, 1986), indicates the importance of that behaviour to the animal. This does not mean cost in terms of biological fitness, but cost in terms of the animal's perception at that point in time. The cost can be measured by various means, mainly preference testing and operant conditioning, e.g. by offering choices or training to gain a reward, then making the animal work harder to achieve this. The slope of the demand curve can be used as a measure of the motivational strength. Despite many obvious difficulties which have been canvassed (see Dawkins, 1990), this approach has gained wide acceptance along with Dawkins (1988) contention that behavioural deprivation is a central issue in animal welfare.

She maintained that the unpleasant subjective feelings of an animal constitute its suffering and that the key to recognising suffering is to find out how strongly the animal is motivated to do something. Her stated aim is to look scientifically at subjective experience, "from the animal's point of view," which implies that the animal's awareness of its suffering is reflected in its behaviour in a choice test or operant conditioning situation. The central issue here is the ability of the animal to act with purpose, as we understand it, or to possess an understanding of its situation which includes at least some of the same parameters which we are using to assess this situation.

The difficulty is that the purpose might be only in our minds. There have been many deep and far-reaching analyses of this problem which will not be discussed here. Dennett's analysis (see Dennett, 1991) of intentional systems with different orders (levels of complexity) which can be distinguished empirically has been considered favourably in an ethological context (e.g. McFarland, 1985). Many related questions about the possibility of self-awareness in animals and whether consciousness is a necessary prerequisite for suffering will be left aside here, but they have been discussed elsewhere (e.g. see Bekoff, 1994).

It is apparent in all these discussions that the idea of awareness or understanding is not purely concerned with mental experience, but also embraces the emotional experiences of animals. Emotion in human experience is said to have subjective, physiological and behavioural

manifestations. At one level it is an intensely private experience, but at the physiological level there are autonomic nervous responses, for example, which are clearly defined. This physiological emotional arousal is very similar whatever the arousing stimulus may be, although humans can reflect on these responses differently in the process of describing their feelings. In comparative psychology a continuum is described through conation, cognition, affect to self-awareness. Thus subjective feelings are considered to refer to the self-awareness of affect (Salzen, 1989). In dealing with what we perceive to be an animal's awareness of its affect or its emotions we are also dealing with our awareness of our affect in this situation. The need to clarify the distinctions and the connections between mental and emotional experience is one of the major challenges we face in considering cognition in animal ethology.

COGNITIVE ETHOLOGY TODAY

Cognitive ethologists tend to give mental state priority over the physical state of the animal, while also including the emotions. Duncan and Petherick (1991) held that the animal's mental state is crucial to its welfare. Duncan (1996) maintained that the animal's "feelings, emotions or affective subjective states" were "cognitive representations of their needs" and that the concept of welfare could only be applied to sentient animals, i.e. those capable of feeling. Bekoff (1994) also considered sentience to be a central issue and said that cognitive ethologists are interested in comparing thought processes, consciousness, beliefs and rationality in animals by a broad spectrum of natural behavioural observation, with particular emphasis on individual animal characteristics. The challenge is to understand the way in which animals perceive their environment. Perception of the environment is almost invariably described in terms of information and it is the processing of that information by the central nervous system which has been the main focus of attention.

Duncan and Petherick (1991) considered an animal to be aware of stimuli through both its feelings (for internal events) and its perception (for external events). A feeling is a specific activity or process of a sensory system of which an animal is aware and it is part of the animal's emotions (Duncan, 1996). A higher level of cognitive processes consists of memory and learning which they said are more likely to involve neural network reorganisation (dispositions to form

particular connections) rather than the storage of information per se; a point which has been amply supported by more recent developments in cognitive science (see next section). Duncan and Petherick (1991) acknowledged that conclusions about an aspect of suffering such as fear or frustration are based on an interpretation of behavioural responses without directly answering the question of whether the animal is aware of unpleasant feelings. The finding that chickens will learn a procedure "to avoid being frightened" was taken as evidence that the birds had suffered an unpleasant mental experience.

Phillips and Piggins (1992) gave an interesting overview of research on the perception of the environment by farm animals which summarises the mainstream approach, i.e. that the animal acquires information ("that which reduces uncertainty") from its environment. They distinguished between sensation, perception and cognition while also considering these to be overlapping terms. Sensation is the initial processing of this information by transducers and their immediate neural connections. Perception is an awareness of that information as a pattern or in a context which is a physiological substrate. Cognition refers to the inference or meaning which the stimulus has and thus involves some degree of memory. They describe this as a spectrum of increasing complexity of both event and purpose occurring at progressively higher levels of the brain.

These authors (Phillips and Piggins, 1992) also differentiated three appropriate methods of study for these phenomena: physiological, psychophysical and ethological. In the first case they refer to conventional neurophysiology; in the second they speak of interpreting the relationship between stimulus and response as in experimental psychology (e.g. operant conditioning), in which environmental variables are strictly controlled; while the third case is non-intrusive behavioural observation under natural conditions. Each of these methods is currently being employed in studies of farm animal welfare and considerable detail has been accumulated, but the explanation of these perceptual phenomena in cognitive ethology and their implications for animal welfare are far from clear. There is a body of neurophysiological and behavioural evidence about the ways in which farm animals use their visual (Entsu *et al.*, 1992; Piggins, 1992), auditory (Heffner and Heffner, 1992) and olfactory (Perry 1992) sensory processes (Kendrick, 1992) and also their tactile receptors, particularly in relation to the perception of pain (Livingston *et al.*, 1992).

With a view to understanding the significance of cognitive

processes in farm animals, the pioneering work of Kendrick (1992) warrants close attention. He considered that cognition refers to the mental facility of knowing, which includes knowledge about objects and individuals in its environment and knowledge about itself. At a higher level it includes a knowledge of association and context and, at the highest level, the capacity to see this from another individual's point of view, which he said has only been clearly demonstrated to occur in primates. Like others previously mentioned, Kendrick maintained that we cannot assess the mental health of animals unless we can understand their cognitive behaviour.

Kendrick and Baldwin (e.g. 1987) appear to be the only people to have undertaken detailed neurophysiological studies of cognitive processes in farm animals (see Kendrick, (1991; 1992). They studied the activity of single neurones in the temporal cortex of the brain of conscious sheep to investigate the process whereby this animal recognises other animals and humans and various types of food. The involvement of the temporal cortex of sheep in visual processes was clearly shown. The importance of specific visual features such as horns on faces was demonstrated and it was concluded that sheep (and probably other farm animals) possess a specialised neural circuitry for the recognition of other individuals and objects which is similar to that of primates. Kendrick (1991) commented on the importance of social learning and previous experience on the brain responses. Kendrick (1992) emphasised the finding that the activity of visual recognition cells is clearly influenced by the emotional or behavioural significance of what is seen, e.g. favourite foods are more potent stimuli than are less preferred foods, etc.

Kendrick (1992) regarded the visual information processing as being "coded more on the basis of similar emotional/behavioural significance to the animal than on the basis of physical similarity." This author concluded, as a principle of cognitive behaviour, that the neural processing mechanism for recognition of individuals and objects was inextricably linked to the brain centres which are involved in emotional behaviour and memory saying that: "it is impossible for an animal to identify an individual independently from experiencing the emotional/behavioural significance that it has. As such we should not regard sensation and emotion as separate systems, but as an integrated continuum." He considered this remarkable influence of context, learning and motivation on an animal's sensory analysis system to be proof that animals have a conscious interaction with their environment, not merely a response mechanism.

This author also mentioned that temporal cortex cells responding to food or faces sometimes continue to show changed activity even in the absence of these stimuli (Kendrick, 1992). In my opinion he has shown that, while it is possible to demonstrate stimulus-specific activity in brain cells, much of this activity appears to be state-dependent rather than stimulus-dependent. In other words it is the internal organisation of the neural network that mainly determines its activity in the course of the animal's perception of its environment. This parallels closely other developments in cognitive science which will be described in the next section.

A further interesting development of the link between emotional and mental experience in the context of farm animal welfare is the idea of the "emotional brain" (Simonov, 1986) which has been elaborated by Wiepkema and Koolhaas (1992). This is essentially a neural information-processing model in which emotions are considered to be brain activities whereby animals assess their actual state and possibilities on the basis of their previous experience and present information. Thus the brain enables animals to detect order in their world by constructing cognitive maps and to predict and control it, but this is fundamentally an emotional experience depending on the degree of predictability and control which arises in this appraisal process.

This approach makes it possible to define stress as a state of the animal resulting from a significant decrease in predictability or control. Changes in certainty arising from the neural processing of information are accompanied by the expression of emotions (Wiepkema, 1990) and a decrease in certainty results in an unpleasant emotional experience. The underlying emotional state ranging between fear and pleasure was said to give meaning to questions about welfare and to be instrumental in guiding subsequent behavioural adaptation. Wiepkema and Koolhaas (1993) summed up this approach saying that: "individual vertebrates give great priority to those activities that promote and maintain a *reliable grip* on their actual life conditions" (emphasis added). They also said that when individuals "loose grip on their life conditions stress symptoms appear and their welfare becomes problematic." This also has parallels in modern cognitive science.

None of these approaches in cognitive ethology today can be said to deal effectively with the basic issue of the "mind-body split", the separation of mental from physical states, nor do they address the circularity problem mentioned at the beginning of this paper which arises from ascribing intentionality in interpreting an animal's behaviour and thereby running the risk of confusing functional with

causal aspects of behaviour (see Hinde, 1982; Kennedy, 1992). The cognitive ethology implied by these approaches is simply an additive combination of behavioural observation and an information-processing model of cognition.

SOME DEVELOPMENTS IN COGNITIVE SCIENCE

The historical development of cognitive science is too complex to review thoroughly here, but there have been certain crucial changes which may provide opportunities for a different approach to the study of animal cognition. My very brief interpretation of these changes follows that of Varela (1979; Varela *et al.*, 1991), Ceruti (1994) and Mingers (1995). The transmission of information, from the outside of the animal to its inside, was the major thread in the early stages of cognitive science. By the mid 1950's the computational approach to cognition had become widespread. Essentially cognition referred to the neural processing of information which provided an internal representation of the external environment, e.g. specific neurones in the visual cortex responding to edges and movement etc. This remains the most prevalent view of cognition in the applied sciences such as animal ethology today.

From the 1970's onwards, however, increasing attention has been given to the self-organising properties which arise from the rich network of connections in the central nervous system. In this case cognition was seen to embrace a more complex form of processing environmental information from which something new may arise, i.e. an emergent property, according to its operation as a self-organising system. Edelman's (1992) "neural Darwinism", which he hailed as "the beginning of the neuroscientific revolution", referred to the selective optimisation of this self-organising process, thus giving cognition an evolutionary perspective. In this scenario the idea of the outside as an absolute reference point still existed, but it had diminished in importance.

Meanwhile, the advent of second-order cybernetics (see Varela, 1979; Ceruti, 1994), against a backdrop of post-modern philosophy in which the foundations of absolute knowledge were being questioned, purported to do away with the idea of internal cognitive representations altogether. In this view the cognitive process was said to be "bringing forth" the regularities, not detecting them; the rich network was regarded as capable of constructing order through its interaction or

connection with its surrounding medium. Every sensory operation is a pro-active, two-way, cognitive process of coupling between animal and environment. Every change in the animal's nervous system is associated with a corresponding point of change in its perceived environment. This process was termed "enaction" (Varela *et al.*, 1991).

Therefore there are three distinctly different approaches to cognitive science which co-exist at the present time. They may be summarised as (1) cognitivism (or information processing), (2) connectionism (or emergent properties) and (3) enaction (the model based on second-order cybernetics). The first two agree on the centrality of representation, but differ on how it occurs, while the third approach disagrees that representation is the essence of the workings of the mind. Instead a history of two-way connection, without information being collected or representations being made, is the basis for the cognitive state of the animal at any point in time.

The first approach is the one which holds sway in the mainstream of research on cognitive ethology and in discussions of animal welfare. The more advanced connectionist model of cognition, with emergent properties channelled by Darwinian selection principles, has come into use in behavioural ecology where functional explanations predominate. The current strong emphasis on evolutionary adaptation in explanations of behaviour tends to favour the increased use of complex computational models of cognition. The third approach has not yet been considered in cognitive ethology, probably because it is a more radical development which is still controversial even within cognitive science.

The relevance of the enaction model of cognition to cognitive ethology lies firstly in its ability to deal with the problem of circularity. This is what sets second-order cybernetics apart from other explanatory frameworks. In the enaction model, cognition is circular by nature and its results arise as a self-organising system, not as a result of a linear sequence of events. The system is described, not by its constituent parts, nor by a beginning and an end, but in terms of its circularity.

Further consideration of its biological basis may be helpful. Maturana and Varela (1980; 1987) coined the term "autopoiesis" to describe the self-producing and self-referring property which they said characterises the operation of all living things. They developed the first systemic definition of living systems based on second-order cybernetics claiming that this provided a theoretical framework for addressing the relationship between a system's form and its behaviour. Thus a cognitive system was defined as "a system whose organisation defines a

domain of interactions in which it can act with relevance to the maintenance of the system itself" and the process of cognition is the acting or behaving in this domain (Maturana and Varela, 1987).

The mathematical foundations of circular systems are quite different from those applied to linear systems (see Varela, 1979). A system which computes its own organisation, as in the autopoietic nature of living things, also has the systemic property of "operational closure" which means that it can only deal in variations on what it already is; it cannot add anything from outside.

If we regard our animals in this way, then their interactions with the environment could never be instructive, i.e. consisting of external, unambiguous information. Instead environmental changes are non-specific triggers for change in the animal. The operation that results from the trigger is determined solely by the internal state of the animal at the time of the interaction. Maturana and Varela (1987) described the operation of the nervous system as operationally closed and totally state-dependent rather than stimulus-dependent. The findings of Kendrick (1992) on visual perception in sheep reviewed earlier are not inconsistent with this explanation even though they were interpreted using a different model.

Of course it is well known in ethology that the internal state can modulate the response to external stimuli, but in the enaction model the internal state is the sole determinant of the nature of the "response" which means that objects and events need to be examined for their connectability or perceivability rather than for their information content.

Maturana and Varela (1987) described the "structural coupling" of the animal with the environment at any moment as the mechanism which, by continuing recursion, determines the cognitive state of the animal and the course of its physiological and behavioural adaptation. The explanation of Wiepkema and Koolhaas (1992) of emotions generated in the brain, although it is an information-processing model, appears to have a good deal of agreement with this when it refers to the animal's need to "maintain a reliable grip" on its living conditions.

The enaction model of cognition also appears to have relevance for cognitive ethology in that it makes the cognitive state of an animal a more direct reflection of its observed behaviour without the necessity to speculate about the animal's motivations or memory or "top level" cognitivé processes. The idea of the "embodied mind" (e.g. Varela *et al.*, 1991) attempts to restore the mind-body split and does not give the animal's mental state priority over its physical state as has been the case

in most reported studies of animal cognition.

IMPLICATIONS FOR COGNITIVE ETHOLOGY

There is inevitably some overlap between the causal, ontogenetic, functional and evolutionary aspects of ethology. The original classification by Tinbergen of these four types of question has contributed greatly to the development of ethology, but it can also create difficulties such as the circularity already mentioned (Hinde, 1982; Kennedy, 1992). Kennedy (1992) argued strongly against introducing cognitive processes at the top level of a hierarchy of causal mechanisms because he said it broke the coherence of the study of causation of behaviour.

Whether to attribute intention or purpose to the behaviour of animals has always been a vexed question. There is a good argument that to do this should help us to understand the behaviour as a whole, but if we fail to acknowledge the teleological confusion about function and different types of causation, we could be restricting opportunities for further scientific progress. Similarly, it is commonly stated that beneficial consequences should be referred to as functions which is to say that purposive means the same as adaptive. Once again there is a danger of being locked into a closed loop without acknowledging it.

Advocates of cognitive ethology such as Bekoff (1994) claim that it can inform wide-ranging issues such as consciousness, intentionality, self-awareness and the social and perceptual worlds of animals without saying how this is to be achieved. While I agree wholeheartedly with the stated advantages of enlarging our interpretation of behaviour to include cognitive issues, I doubt that the difficult questions can be answered while the circularity of the argument is not fully acknowledged.

Writing on conceptual and biological aspects of stress, one of the pioneers of the use of systems theory to explain behaviour, openly acknowledges that the best definitions and models of stress which are available at present do not escape the criticism of being essentially circular (Toates, 1995). Discussion about stress and welfare has been blessed and bedevilled by circularity of this kind. For example, a rise in glucocorticoids in the animal's blood stream is both a sign that the animal has been stressed and an indication of its ability to cope successfully with its environment. Stressors are obviously more than simply inputs to the system and stress is more than just the outcome

that results from them. It is more of a bi-directional engagement such as was proposed in a "transactional model of stress" by Cox and others (see Toates, 1995).

In the enaction model of cognition there is no input-output, no first-order causal relationship between stimulus and response, and no information processing. Instead, what the animal perceives depends on how its internal organisation can connect with its outside world at that point in time. It does not depend on the nature of the external stimulus and is not defined externally, although often it may appear that way because of a particular history of coupling which has produced a particular internal state that we denote as a certain knowledge of the environment.

A cognitive animal is sometimes described as a thinking animal; where cognition is said to refer to the use of "internal mental operations in generating specific behavioural responses to sets of external stimuli" (Real, 1993). Thinking is just a word we use to describe something we have inferred from our observations, but it does not explain how or what an animal perceives? The alternative suggested by modern cognitive science is not to consider that animals process information or have specific knowledge of anything outside themselves, but to consider each "stimulus-response" situation as a connection between the animal and its environment and to examine the history of such connections. The idea is that the "meaning" of any object or event, "from the animal's point of view", may be revealed more clearly in the history of these connections.

The current way of dealing with this as a higher level cognitive process is to invoke the idea of memory. This is a word we use to represent certain changes in internal state that have resulted from the animal's previous experience, but its direct measurement is still questionable; it must be inferred from other observations of behaviour. The neural organisation of memory and emotions was reviewed by LeDoux (1993) whose work has gone a considerable way towards establishing the existence of emotional memory systems in the brain. These are still not clearly defined, however, and even if they were, they are seen as storage houses for external inputs, so their ramifications for subsequent behaviour still have to be explained as well. Similar gaps exist in our understanding of learning. Despite a huge literature and body of théory on how learning occurs we still rely on indirect assessment of it and we have had to develop a very elaborate theoretical framework in order to interpret behavioural or physiological data.

Second-order cybernetics offers no easy solution and is not an

alternative paradigm to the present understanding of memory, learning and cognition. It simply provides an additional set of tools that may be helpful, particularly in studies of animal welfare. In a society which is more familiar and more comfortable with the idea of manipulating controllable systems than with the idea of understanding self-organising systems it is unlikely that second-order cybernetics or the enaction model of cognition will replace the better known theoretical frameworks, nor should it. It may add another dimension to the examination of these very complex subjects.

At the very least it implies that caution is warranted in attributing animal responses to external stimuli at any point in time without having a detailed knowledge of that animal's previous experience. An analysis based on the so-called "information" contained in any particular object or event is not the only way of interpreting animal behaviour in a cognitive sense for the purpose of assessing its welfare. Too often we seem to regard the objects and events of the environment as the causes of stress or welfare problems. But, as Duncan and Petherick (1991) and others have pointed out, it is the awareness of the animal which is critical; what would be stressful in one case might not be in a different situation.

An example of the way in which the explanatory framework affects the interpretation of behavioural observations is in the use of preference testing. These are usually interpreted as if the animal has made a choice, conscious or otherwise, but the results often raise doubts about whether animals do know what is best for them, particularly in the longer term and what other factors influence the apparent decision (see Dawkins 1990). Grandin (1994) was concerned that previous experience can affect choices and she presented evidence that the reluctance of cattle to change a learned choice may confound the results of preference testing. If the enaction model of cognition is used it is far more important to know the precise cognitive history of each individual animal than to be concerned with the supposed nature of the choices offered.

It may not be sufficient to call this, as Dawkins (1990) has done, the animal's awareness of its suffering that is reflected in its behaviour in a choice situation; it is the animal's entire history – its cognitive ontogeny. This approach questions the necessity of invoking the idea of conscious choice in our explanation of this process. Conscious choice is essentially a post hoc analysis of the situation when the alternatives have become known. The animal could be predisposed to act differently as a result of cognitive processes ensuing from its

previous experience, but this could be achieved by connecting differently with its environment – being aware of different features - rather than by weighing up any alternatives at the time of the action.

The debate about stimulus specificity or stimulus generalisation (e.g. the ability of farm animals to discriminate between people, see de Passillé *et al.*, 1996) provides another example of the influence which the particular theory of cognition has on the interpretation of behaviour. It has proved very difficult to demonstrate that a particular response is stimulus specific or that responses to stimuli become more generalised over time. Using the enaction model one would be attempting to relate the particular response to the history of contacts, not to the nature of the stimulus itself.

IMPLICATIONS FOR FARM ANIMAL WELFARE

The mechanism by which animal welfare issues are researched and discussed and community decisions are made involves human cognitive processes in providing satisfactory explanations of the processes of animal cognition. The circularity which is inherent in this operation has often caused problems. There are elegant ways of addressing the problems such as the incorporation of human values into the discussion so that different levels of concept are defined and animal welfare can be regarded as a "type 3" concept which cannot be measured in an entirely objective way (Fraser, 1995). Whatever device is used there is a self-organising property inherent in the animal welfare debate which may be easier to manage if it were more openly acknowledged.

The whole issue of animal welfare can be described as a self-organising system because the enaction model of cognition can also be applied to the human conduct of cognitive ethology. It is something of a blind spot that we tend not to examine what it is that we are doing when we make our explanations of cognitive ethology. The application of second-order cybernetics to human communication and understanding is further discussed by Fell and Russell (1994). A particular animal welfare issue arises and is defined in our conversation, i.e. in the language we use. It may be solved eventually in precisely the same way when someone provides a satisfying explanation for how the animal is expressing itself in that situation. This process has the properties of coupling, recursion, closure and circularity that can be clearly defined only by second-order cybernetics.

It is likely that new measurements as well as new interpretations

will be needed to further the application of cognitive science to complex farm animal issues. Evidence is accumulating rapidly that the way animals perceive their environment is reflected in their immune system (Husband, 1995) and so measures of immune competence are assuming increasing importance (e.g. Skandakumar *et al.*,1995). There are some prominent immunologists who, although in a minority, have persisted for many years in choosing to explain immune responses as part of a cognitive system (e.g. Vaz and Varela, 1978; Vaz and Carvalho, 1994). There is a somewhat controversial, but well-developed theory in which the immune system is seen as a part of the mind (Booth and Ashbridge, 1993). This points the way to a considerable broadening of the concept of cognition and the conceptual framework that we use to explain and understand animal welfare.

Measurements of complex behaviour in sheep such as the approach-avoidance test of Fell and Shutt (1989) and Fell *et al.* (1991) have been related to the animal's motivational state and to immune function (Gates *et al.*, 1991), but have not yet been applied to animal welfare decisions. This test pits the natural flocking ability of sheep against their natural flight distance or fear of humans by placing them in a specially designed arena that has sheep in view at one end and a person standing in front of the sheep. The way the test animals behave can be interpreted as a result of their learning (conditioning), their memory, and/or their psycho-physical (cognitive) state at that point in time.

The enaction model of cognition attempts to avoid splitting off higher-order processes (such as the processing and storage of what we interpret as information and the resultant intentions) from the rest of the animal. The approach-avoidance test mentioned above provides a readily quantifiable assessment of the state of the animal when it is put into a situation that requires it to "think" (that makes certain specific sensory connections available) and therefore is more likely to reveal its true condition. Its behaviour is seen to be revealing what it "knows" about its world at that point in time. These measurements coupled with a detailed dossier of the animal's history (and especially if neurophysiological measurements can be added) provide a basis for a richer, less subjective, assessment of the animal's welfare. A more complete review of this testing procedure is being prepared for publication.

Much effort is currently being put into the testing of farm animals for "temperament" (see review of individual differences by Manteca and Deag, 1993) or measurement of their fear reactions to different

stimuli in various behavioural test situations (e.g. Boissy and Bouissou, 1995), but the interpretation of fearfulness as an "underlying psychobiological profile" is not universally accepted because not everyone agrees that fear can be described as a unitary phenomenon (see review by Boissy, 1995). This is another example of the difficulty of interpreting behavioural tests within existing models of cognition, particularly with reference to animal welfare.

Duncan and Petherick (1991) concluded that effects of management on animal welfare will be properly assessed only when very much more is known about the cognitive abilities of the animals concerned. My conclusion is that the concepts which have been reviewed here support their statement, but show also that this line of inquiry is fraught with difficulty and suggest that we will need to explore different approaches to the study of animal cognition in order to maximise our opportunities for progress.

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