THE EMOTIONAL BRAIN

P R Wiepkema[1] and J M Koolhaas[2]

[1] Department of Animal Husbandry, Agricultural University, P O Box 338, 6708 AH Wageningen, The Netherlands

[2] Department of Animal Physiology, University of Groningen, P O Box 14, 9750 AA Haren, The Netherlands

Abstract

Individual vertebrates are able to detect spatial and temporal (causal) order in their environment and deal with this knowledge emotionally. It is argued that this latter aspect is connected with the flexible or reversible way vertebrates may interact with their environment. Because of this flexibility, uncertainty and changes therein can be experienced and shown by means of emotional expressions. It is this brain-behaviour organization that gives meaning to questions about welfare of individual vertebrates.

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Introduction

When individual vertebrates feed, explore, fight or interact with their environment in some other way, the actions involved are often supplemented with emotional indications like facial expressions, tail movements, characteristic vocalizations, specific heart rate or neuroendocrine changes etc.

These emotional phenomena are present under certain conditions: they are by no means essential for the proper performance of the behaviour programmes (feeding, exploration, fighting etc) which have been activated. For instance, the heart-rate of a horse galloping on a treadmill is reliably predicted by the speed of that treadmill and seems to depend on metabolic factors only. However, in some horses this heart-rate may deviate from the expected one as a result of friendly patting that horse (Wiepkema 1990). This indicates that heart-rate is not solely determined by metabolic requirements.

According to Pribram (1971) emotional phenomena refer to internal processes that control the success of ongoing activities, while Bloom *et al* (1985) conjecture that such phenomena add weight to successful actions, but bring about reserve with respect to those actions that previously had dubious value. As a continuation of these biological considerations, we shall elaborate the idea that emotional phenomena refer to brain activities during which individuals assess their actual state and possibilities on the basis of previous experience and present information. This appraisal is associated with a

characteristic emotional state or experience ranging from fear to pleasure or happiness. Brains that are capable of doing so will be called emotional ones as proposed by Simonov (1986).

Originally the term welfare has no clear-cut biological meaning, in the sense that operations exist by which its attributes can be determined unambiguously. Although this is still the case, the term makes sense biologically as illustrated by recent discussions (cf Dawkins 1990). Another confusing aspect of the same term is, that for many people it primarily refers to some human quality. Although this may be a serious handicap in the use of the term, the point we want to make is that welfare is a characteristic of all individual vertebrates (including humans), because they are all subject to the same type of brains. For reason of homology (that is having common ancestors), the way in which our brains inform us about our environment and life possibilities should have much in common with the way brains of not only other humans, but also of other vertebrates do. This idea is firmly supported by numerous anatomical, physiological and behavioural reports (for an interesting discussion of this topic see Walker 1983). In fact it is the basic idea for much biomedical research as illustrated by, for instance, a recent book on psychopharmacology (Olivier *et al* 1991).

This reasoning implies, that if a welfare question exists in invertebrates (like insects, spiders, molluscs etc with their quite different 'brains'), it has a different quality from that in vertebrates, because it has to be based on biological analogy processes (resulting from convergent adaptation in the course of evolution).

Broadly speaking, welfare of individual vertebrates refers to a state of physical and mental health. Both aspects have been interwoven closely and should never be separated when we assess the actual welfare state of a given individual vertebrate. In the present discussion, however, we will focus on mental health, because here differences in opinion are more conflicting than in the field of physical health, which is generally the veterinarian point of view. Since mental health is determined by the way we think about brain-behaviour relationships, we will focus on the concept of an emotional brain.

We like this terminology as introduced by, for instance Simonov (1986), since it not only refers to a capability of an individual to detect order in its environment, but also the finding that its brain does so in an emotional way. These two aspects are basic for the way vertebrates can interact with their environment. They will form the core of the present discussion. What does 'detecting order' mean and how do we recognize an 'emotional brain'?

Detection of order

Individual organisms can only survive when life sustaining events and conditions have some order (are non-random) that can be detected by the organism involved. Only if so, are individual organisms able to predict and to control more or less reliably these events and conditions.

Since most if not all of these latter environmental changes and states have a predictable and/or controllable occurrence, in the course of evolution organisms could be adapted to this consistency of life requisites. Part of this adaptation is the result of natural selection, by which genetic information has been produced about what is more or less constant or equal for all members of the same species. From this mechanism stems a species-specific morphology and behaviour. Good illustrations of this type of information are endogenous rhythms (circadian, circannual) and predispositions with respect to the type of physical and social environment in which the adults have optimal life chances. Although this genetic information has relevance for welfare questions (we will discuss that in a later contribution), it does not directly argue in favour of an emotional brain. This latter point becomes apparent, when we consider how vertebrates collect and gain information during their adult life (for the moment we will omit any discussion of learning characteristics in early life, eg imprinting phenomena).

During development and adult life individual vertebrates are able to detect spatial and temporal relationships. The crucial point is not only that this information is stored in the brain and used effectively at later times, but also that this information has a flexible (reversible) and highly individual character.

By means of exploratory behaviour individuals obtain information about spatial details of their environment. This information is laid down in and forms the basis of a so-called cognitive map (Tolman 1948, O'Keefe 1985), that can be considered as a neural representation of the individual's environment. This cognitive map guides the individual when visiting its feeding site, when escaping to a safe place or when looking for a specific social contact. Since exploratory behaviour is performed with great regularity and increases when some environmental change has taken place, it is plausible that individual vertebrates give great priority to having a cognitive map that corresponds with the latest spatial information (cf Inglis 1983).

In a comparable way the same organisms detect temporal (causal) relationships in their environment. In other words their brains are most sensitive to the occurrence of phenomena that follow each other in a non-random way. This associative capability has been investigated and demonstrated in all sorts of learning experiments (Dickinson 1980). It makes sense to distinguish two types of associated or successive events, since this corresponds with two types of learning experiments. In the first type, animals are able to associate some external event (signal) with a second one if it reliably precedes this latter one; *conditioning*. Thanks to this information individuals can more or less reliably predict and anticipate future events or conditions. In the second type of learning animals associate an own activity with a resulting (following) effect (event); *operant learning*. Thanks to this information the individual will be able to more or less reliably control relevant events or conditions like obtaining food or escaping from a perceived danger. The fact that there are considerable species-specific constraints in associating successive events (ie signals/operants are not equipotential, Seligman 1970) has great significance for welfare questions and will be discussed later.

A high acquired reliability of environmental contingencies which are represented in the brain as neural associations is a prerequisite for optimizing individual homeostasis and safety, since only then behaviour programmes like feeding, resting, reproduction, etc have a good chance to realize individual's interests and needs.

What matters now is that individual vertebrates are able to correct their spatial and temporal knowledge and that this seems to be connected with the peculiar capability to doubt this same knowledge.

Emotional brain

The possibility of correcting existing neural information refers to the fact that individual vertebrates are not always absolutely sure about the reliability of this information. The interesting point is now that changes in the certainty involved appear to be associated with emotional expressions (Wiepkema 1990). For reason of homology, as mentioned in the introduction, we assume an emotional brain in all vertebrates.

This way of thinking can be illustrated with the following examples. It is plausible, that the certainty is low or high when the predictability and/or controllability (p/c) of relevant events is low or high. A change from low towards high p/c is present in the initial phase of a normal learning process. It is intriguing that exactly this first phase of learning is called the emotional one, since emotional expressions are common then. These emotional activities appear to be visible or measurable activities of the autonomic nervous system (changes in blood circulation, heart-rate, pupil diameter, saliva production, etc), neuroendocrine changes, facial expressions, tail and ear posture/movements, sounds and odours produced etc (cf Boer *et al* 1990, Dantzer 1989, Darwin 1872, Koolhaas & Bohus 1989, Levine & Coover 1976).

Such activities are also common when the reliability of external conditions suddenly changes as, is the case, for instance, immediately after the start of an extinction procedure. They also occur when a conspecific behaves in a way quite different from what is expected, or when during safe conditions some unexpected damage (pain) is experienced. In short, each unexpected phenomenon reduces certainty (or produces doubt) about the reliability of existing information and by this means facilitates the performance of emotional expressions.

Changes in existing p/c are not by definition accompanied by negative emotional expressions. It is also possible that unexpected events are of better quality than foreseen. For instance, an often used operant may lead to more or better food than expected or a conspecific behaves in a more amicable way than experienced ever before, etc. In such cases positive emotional expressions may occur indicating some form of pleasure (cf Levine & Coover 1976, Lorenz 1953).

The point we want to make here is that changes in certainty as occurring in flexible individual vertebrates are often associated with emotional expressions that refer to an underlying emotional state that ranges between two extremes: fear and pleasure. It is

because of this vertebrate characteristic, that welfare statements make sense; vertebrates may suffer or may experience pleasure and well-being. We think this is what Dawkins (1990) had in mind, when she started her discussion on motivation, fitness and animal welfare by saying that 'animal welfare involves the subjective feelings of animals'.

In this context we have to comment briefly on the use of the term 'feelings'. Until now we have avoided this latter term, because it may be useful to distinguish emotional states (and their expressions) from feelings (and their possible expressions). Feelings refer to the perception of some deficiency: feeling hungry, thirsty, sleepy etc. Whether or not such feelings are linked with some emotional state, depends on whether the individual involved knows that food, water or a resting site are within reach. Feeling hungry but not knowing whether food can be obtained in the near future implies fear and suffering (emotional states), whereas feeling hungry but knowing that food will be available soon does not produce fear; it even may elicit positive excitement.

Conclusions

The foregoing remarks on detecting order and dealing with the environment in an emotional way, stress the idea that vertebrates interact with their surroundings in a declarative manner (Dickinson 1980). This implies that the organisms involved behave on the basis of information they have about causal relationships in their life situations and, moreover, have expectancies that can have a different degree of reliability. However, this conclusion does not imply that vertebrates never behave in an automaton like way, in which routine programmes are central. This so called procedural way of interacting (Dickinson 1980) may dominate in some vertebrate species or in specific life-phases of individual vertebrates. It is likely that these routine like programmes are less associated with emotional expressions.

Welfare questions are highly relevant when vertebrates experience long lasting uncertainty, or loss of control, which is the case during chronic stress (to be discussed in a future contribution) or when they have insufficient or no opportunity to actively collect information (eg highly monotonous conditions, cf Wemelsfelder 1990).

Vertebrates, and especially the higher ones like mammals and birds, appear to deal with their environment as individuals that interpret their interactions in an emotional way, on the basis of both present and previous experience. The consequent emotional states may vary from highly attractive to strongly disturbing. The latter condition should always be prevented under farm, zoo, laboratory and other housing conditions for which we are responsible.

In follow up contributions we will discuss topics like stress and disturbed behaviour (stereotypies, apathy), the significance of different types of coping, the relevance of early experience and of good social relations (conspecifics, role of the caretaker).

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