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Coping, stress and welfare

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1. Challenge, coping and adapting

Every human and every other animal is subject to a variety of environmental challenges, which are more or less demanding upon its response systems. For an individual, the term environmental means from outside that individual but for any particular response system, environmental means from outside that system. Substantial challenges to animal functioning include those resulting from: pathogens, tissue damage, attack or threat of attack by a conspecific or predator, other social competition, complexity of information processing in a situation where an individual receives excessive stimulation, lack of key stimuli such as a teat for a young mammal or those associated with social contact for a social animal, lack of overall stimulation, and inability to control interactions with the environment. Hence potentially damaging challenges may come from outside the body, e.g. many pathogens or causes of tissue damage, or from within it, e.g. anxiety, boredom or frustration which come from the environment of a control system. I refer to the systems that respond to such challenges or prepare for challenges as coping systems and coping means having control of mental and bodily stability (Broom and Johnson 1993). Coping attempts may be unsuccessful, in that such control is not achieved, but as soon as there is control, the individual is coping. Similar definitions referring to use of a wide range of strategies are used by White (1974), Monat and Lazarus (1985), Wechsler (1995) and Koolhaas et al (1999). However, for some people, the term coping has a narrower meaning than this and refers only to dealing with challenges by the use of sophisticated mental processes. In some cases this may be because these people are considering a narrow range of challenges (e.g. Bramson 1981). A coping system, process or strategy is a mechanism which helps the individual to cope and is in operation for some time before coping is achieved. The coping system of an individual may involve the use of one or more of several different strategies which are used to attempt to cope with a particular challenge. The system may operate successfully so that coping is achieved or may be unsuccessful in that the individual is harmed. For example, the dominant male house

mouse which must frequently act so as to control its territory is using the best coping system which it can in a difficult situation but may live for a shorter time than an individual in a less stressful environment.

It is clearer to refer to coping rather than to adaptation because of the various biological meanings of adaptation. One sense of adaptation is the evolutionary process involving natural selection and leading to the formation of a successful trait. Another, sense is the course of an effective behavioral response when learning occurs in some changed situation. The third largely physiological sense, is the waning of a response after reported stimulation. When coping systems function, adaptation is occurring but, as defined above, coping implies having control. Adaptation can occur to various degrees which do not go as far as control so, whilst coping attempts may result in only a certain degree of adaptation, coping is equivalent to successful adaptation.

Systems for attempting to cope with challenge may respond to short-term or long-term problems, or sometimes to both. The responses to challenge may involve activity in parts of the brain, various endocrine, immunological or other physiological responses as well as behavior. However, the more that we learn about these responses, the clearer it becomes that these various types of response are inter-dependent. For example, not only do brain changes regulate bodily coping responses but adrenal changes have several consequences for brain function, lymphocytes have opioid receptors and a potential for altering brain activity, heart-rate changes can be used to regulate mental state and hence further responses.

Regulation and control within an individual are achieved in two principal ways: negative feedback control and feedforward control (Broom and Johnson 1993). Negative feedback control involves detecting a displacement of body state from within a tolerable range and responding so as to counteract that displacement and return to within the range. An example is to eat when the receptors of blood glucose levels indicate that there is a carbohydrate deficiency within the body and to continue eating until the glucose levels are restored to a higher level. In feedforward control, a future deviation from a tolerable range of body state or from a desirable position is predicted and action is taken to keep within the tolerable range or at the desirable position. An example is when an ad lib fed cow (Metz 1975) predicts an overnight period when feeding will be difficult and eats enough to provide for its needs during that period so that meal size is proportional to interval to next feeding, rather than to interval since last feeding as would be the case if the control were by negative feedback. A further example on a different time scale is the migrating bird which eats and stores enough food, during a period of several days, to provide for its energy needs when it migrates over a great distance (Welty and Baptista 1988). The more that is understood about how vertebrate animals of various kinds

regulate their lives, the clearer it becomes that feed-forward control is widespread and normal in many control systems. A higher level of brain functioning, often involving considerable cognitive ability, is required for the kind of predictions which will allow effective feed-forward control than for some reactive control systems.

2. Feelings and emotions as part of coping systems

Emotions are physiologically describable conditions in individuals characterised by electrical and neurochemical activity in particular regions of the brain, autonomic nervous system activity, hormone release and peripheral consequences including behavior. These emotions may result in feelings, for example sexual desire or anxiety, although emotion may exist without any accompanying feeling, for example as active regions of the amygdala with no cortical activity (Guyton 1982). A *feeling* is a brain construct, involving at least perceptual awareness, which is associated with a life regulating system, is recognisable by the individual when it recurs and may change behavior or act as a reinforcer in learning. Awareness, is taken here to mean "a state in which complex brain analysis is used to process sensory stimuli or constructs based on memory". In many circumstances feelings involve mental images. For further explanation and examples see Broom (1998), Sommerville and Broom (1998). The idea that feelings increased fitness and hence evolved by natural selection was pointed out by Darwin (1872) and explained in detail by Cannon (1929). Cabanac (1979) argued "We experience feelings of hunger because that is part of our mechanism for rectifying a food deficit and ..... fear and pain because they are part of our body's way of removing us from situations which are life threatening". Wiepkema (1985) asserted that feelings are involved in monitoring the effectiveness of regulatory actions, being positive when the regulation is successful and negative when it is not. The evolutionary advantage of having feelings has been emphasized by Dawkins (1997, 1990), Broom and Johnson (1993) and at length with emphasis on the role of feelings as reinforcers in learning by Broom (1998) and Rolls (1999).

Some coping systems include feelings as a part of their functioning but other high or low level brain processes and other aspects of body functioning are also a part of attempts to cope with challenge. In order to understand coping systems in humans and other species it is necessary to study a wide range of mechanisms including complex brain functioning as well as simpler systems. Both fundamental work on basic mechanisms and the application of such knowledge to human or veterinary medicine and to animal management are worthwhile.

3. Welfare

Investigations of how easy or difficult it is for the individual to cope with the environment and of how great is the impact of positive or negative aspects of the

environment on the individual, are investigations of welfare. Scientists who write about welfare and its assessment are generally agreed that, firstly, welfare refers to animals, including humans, but not to other organisms or inanimate objects, secondly, the study of the welfare of individuals is a scientific discipline in which various measurements can be used as indicators and, thirdly, welfare varies over a range (Curtis 1986, Duncan 1987, Broom 1988) so welfare can be poor as well as good. There is also wide-ranging agreement that when assessing welfare, efforts should be made to assess degrees of suffering or happiness and the extent of any pathology and its consequences. Some authors accentuate feelings largely or exclusively (Duncan 1993, 1996) when referring to welfare whilst others concentrate most on health aspects. Dawkins (1993) and Fraser et al (1997) emphasize that both must be included. My definition of welfare: "the state of the individual as regards its attempts to cope with its environment" includes feelings and health (Broom 1986, 1996, 1998). Welfare is a characteristic of an individual at a certain time and the state of the individual can be assessed so welfare will vary on a range from very good to very poor. Welfare concerns how well the individual fares, or goes through life. Equivalent words in other languages include bien-être, bienestar, bem estar, benessere, Wohlergehen, welzijn, velfærd, and dobrostan.

Health, like welfare, can be qualified as good or poor and varies over a range. It refers to body systems, including those in the brain, which combat pathogens, tissue damage, or physiological disorder. All of this is encompassed within the broader term welfare so health is a part of welfare. Hence, it is not correct to say "consider the health and welfare" but rather "consider the welfare including the health". Using this definition of welfare it is not logical to say "ensuring the welfare" but rather "ensuring the good welfare." Since welfare is a state, it is tautologous to refer to the welfare status or state of an individual.

The assessment of welfare (Broom and Johnson 1993) should be carried out in an objective way, taking no account of any ethical questions about the systems, practices or conditions for individuals which are being compared. Once the scientific evidence about welfare has been obtained, ethical decisions can be taken.

Much of the evidence used in welfare assessment indicates the extent of the problems of individuals but it is also important to recognise and assess good welfare, i.e. happiness, contentment, control of interactions with the environment and possibilities to exploit abilities. We should try to assess the specific functioning of the brain when welfare is good in humans and other animals; the methods of recognising when welfare is, or is likely to be, good; and the factors which contribute to good welfare in man and other species.

Good welfare in general, and a positive status in each of the various coping systems, should have effects which are a part of a positive reinforcement system, just as poor welfare is associated with various negative reinforcers. Good welfare should have various recognisable effects on individuals. We need to identify these so that the assessment of welfare is as effective at the good end of the range as at the bad end.

Feelings, which have a substantial role in many coping systems, are an important part of welfare. Many methods of assessing welfare give information about feelings. However, whilst the description of the state of the individual which we call welfare is much concerned with the extent of any suffering or happiness, it does not concern only feelings. Measures of the extent of the effects of disease, or of injury, or of physiological and behavioral responses to adversity all provide information about welfare whether or not feelings are involved. Evidence of absence of problems for an individual and of ability to carry out all normal activities, indicate good welfare even if there is no direct evidence of pleasure. Particular problems with a definition of welfare referring only to feelings are exemplified by the following examples where most people would say that the welfare of the individual was poor but a welfare definition based only on feelings would not: an individual with a broken leg but asleep, an addict who has just taken heroin, an individual greatly affected by disease but unaware of it, or an injured individual whose pain system does not function.

Each assessment of welfare will pertain to single individual and to a particular time range. In the overall assessment of the impact of a condition or treatment on an individual, a very brief period of a certain degree of good or poor welfare is not the same as a prolonged period. However, a simple multiplicative function of maximum degree and duration is often not sufficient. If there is a net effect of poor welfare and everything is plotted against time (Fig 1), the best overall assessment of welfare is the area under the curve thus produced.

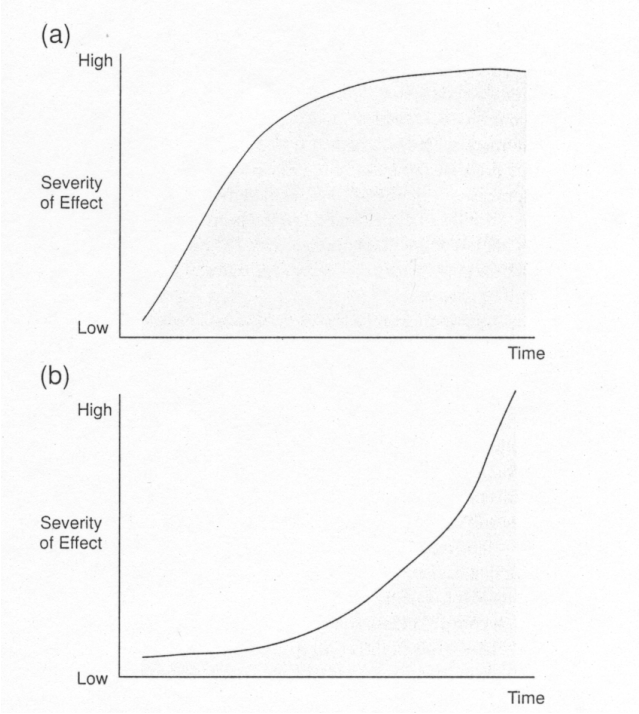

Figure 1 The overall effect on welfare up to a certain time is the area under the curve when severity of effect (e.g. pain) is plotted against time (duration of effect). Although both (a) and (b) reach the same degree of poor welfare after a given time, the individual in (a) has had substantially more poor welfare than that in (b).

The policy which should be adopted in relation to the number of individuals affected is ethical rather than scientific. When many subjects are used in a study of the effects of a condition or treatment on welfare, a larger number of individuals with poor welfare overall indicates a greater problem than a smaller number. Hence if a million broiler chickens have a problem, this is more important overall than one thousand chickens or one thousand cows or dogs with the same degree of problem. However, most people would consider that any individual whose welfare is very poor merits consideration so decisions about policy are not just taken on the basis of the function of the severity of the problem and the numbers of individuals concerned.

4. Stress

Most people who speak of stress refer to a situation in which an individual is subjected to a potentially or actually damaging effect of its environment. However, the usage of the term by many people, including Selye (1950, 1976) has been confusing. Stress has been referred to as an environmental change which affects an organism, as the process of affecting the organism or as the consequences of effects on the organism. It has been limited to one kind of physiological response mechanism hypothalamic-pituitary-adrenal cortex (HPA) activity, or to mental rather than physiological responses or has been

regarded as a much more wide ranging phenomenon. Despite this confusion, the concept of stress is very important if we are to understand biological functioning and we should refine and use the term rather than discarding it. The responses of organisms to potential adversity are amongst the most important functional systems for every animal including man. We know a lot about the various mechanisms for trying to cope with challenge and we should facilitate the further development of the subject by trying to agree on key words which can be used in describing such mechanisms and their consequences.

Knowledge of the functioning of the HPA axis led some people to assume that stress can be equated with activity in this system. It was assumed that HPA activity occurred during all challenges to effective functioning and control within the individual but this was demonstrated to be untrue by Mason (1971) and many other studies. It is also well known that HPA activity is temporarily increased during courtship, mating, active prey catching and active social interaction, none of which would be considered to be stressful by the majority of the general public or of scientists. To equate stress with HPA axis activity renders the word redundant because we can refer directly to HPA activity in a general or a specific way. Hence this usage of the term stress to refer only to HPA activity is considered unscientific and unnecessary by most scientists working in the area.

Another meaning which has been ascribed to stress makes it largely synonymous with stimulation. If every impact of the environment on an organism is called stress, then the term has no value. Many stimuli which affect individuals in beneficial ways would never be called stressors by most people. Hence it is pointless to speak of stress as the process of response to any environmental event, however small. An effect of the environment on an individual which involves some response and neural development which is beneficial in the long-term is stimulation rather than stress. For most people, stress implies the effects of some challenge to the individual which disrupts homeostasis, rather than just activating simple, energetically cheap control mechanisms.

A further area of general agreement amongst scientists studying the attempts of individuals to cope with challenge is that there are many coping systems. Hence it is incorrect to speak of "the stress response" if this means that there is only one. There are many different responses which are used by individuals in challenging and potentially adverse situations.

If stress implies some degree of adversity for the individual, the key question is how much adversity? The definition of stress which I find most useful is: "stress is an environmental effect on an individual which overtaxes its control systems and results in adverse consequences, eventually reduced fitness" (modified after Broom 1983, Broom and Johnson 1993). The ultimate measure of fitness is the number of offspring reaching

future generations and there are many different ways in which challenges overtax control systems and have such effects. The environmental variable which has the effect on the individual can be called a stressor. Stress can have a variety of short-term and long-term effects including metabolic changes, cardiovascular malfunction, immunosuppression, increased incidence of parasitic bacterial and viral diseases as well as psychological disorders such as interludes of panic, anxiety or depression.

Using this definition, stress may or may not involve the activation of the HPA axis but stress is never good for an individual. If the eventual effect is good, it is stimulation or challenge but not stress. Consider, as an example, an individual such as a human or zebra that is detecting and responding to a predator such as an approaching lion. The fitness of the prey individual is reduced if it is (a) killed by the predator, or if it is (b) chased and escapes but is (b1) injured, or (b2) rendered less able to obtain food, or (b3) less able to combat disease, in such a way that survival or reproductive ability are impaired. In these cases the prey individual is stressed. However, if the prey individual sees the predator and easily hides or moves away with only slight elevation of heart rate and effort, it is not stressed. Stress is defined by the likely consequence and not by the mechanism of response, for there are very many possible responses.

When the term stress is limited to effects on individuals which are adverse, whilst natural selection will lead to the spread in the population of genes whose effects are to improve coping ability, genes which minimise the occurrence of stress will also spread. Individuals will not choose an option likely to result in stress unless there is some other functional system involved, that is unless any risk is likely to be counterbalanced by a significant benefit such as increased chances of mating or avoiding starvation. Individuals do of course prepare for effective future responses by gaining useful experience. An action or experience which could be difficult and temporarily affect homeostasis might be advantageous overall because of the learning involved. Stimulation, some of which may be initially unpleasant, is necessary for the development of many aspects of systems for coping with challenge. Individuals which are prevented from having adequately varied experience may prove unable to cope with certain problems. The stimulatory effects which are ultimately beneficial are not stress.

Many other biological definitions of stress have been presented, e.g. Selye (1936), Banks (1982), Moberg (1987), Levine and Ursin (1991), Sapolsky (1992), Chrousos (1998). Some of these refer to any disturbance of homeostasis but this would mean that almost all functioning of body maintenance systems involves stress. Some refer to any non-specific response or to any activation of the HPA axis but again a high proportion of functional responses, some of which are clearly beneficial, would be included as stressful. Many of

these definitions make reference to control systems in some way but it is impossible to be precise if both good and bad consequences are included and a more precise criterion is needed for the threshold beyond which adversity is sufficient for the effect to be called stress. At present, the likelihood of eventual fitness reduction seems to be the criterion which is most usable.

5. Welfare of humans and non-humans

It is clear that there are many similarities between humans and non-human animals in the various kinds of coping mechanisms. Indeed, the question to pose here is "are there any differences?" rather than the reverse. Studies of awareness and its various levels (Broom 1998, Sommerville and Broom 1998) make it clear that whilst some degrees of cognitive processing are widespread in animals, at least in vertebrates, others occur in humans but are rare or lacking in other species. There is a range in such complexity amongst animal taxa. More complex cognitive processing should make it more likely that there will be effective control of interactions with the environment. However, there are also drawbacks associated with having a high degree of understanding. Are these drawbacks as great as the advantages? I should expect that they are not because the capabilities would probably not have evolved if there were no net benefit to the individuals bearing the genes which promoted them.

Some data collection on the extent of coping difficulties, or on the extent of failure to cope, in humans involves clinical observation or is part of research in which behavioral or physiological abnormalities are quantified. Other data are obtained from questionnaires. In any questionnaire study there is the possibility that the respondent modifies answers to please the questioner, or to confuse the questioner, or in some other attempt to protect themselves? If there are any of these modifications of answers the result is partially or wholly invalid so the inclusion of appropriate checking methods in the study, or care in interpretation of such results, are necessary.

6. Developmental and genetic aspects of coping systems

Individuals vary in how they cope with challenges. Some of this variation is a consequence of the use of different strategies in apparently similar circumstances. Genetic variation between individuals can affect such strategies, as can variation in the environment during development. There are problems associated with coping with the social situation in non-human species and a variety of physiological measures can indicate that the coping system is failing.

When the coping strategies used by individuals and their effectiveness are investigated, it is clear that there are some genetic predispositions and that the functioning of all individuals is affected to some extent by early experience and by genetic factors. There is

much to find out about how each kind of source of individual variation has an effect on vulnerability to psychiatric disorders and on the methods of coping which are used. Interchange of ideas between those studying humans and other species is likely to be particularly valuable here. Indeed, such exchange of ideas about all aspects of the study of coping systems and welfare, should be facilitated in future.

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