

## METHODOLOGY

### Assessment of Welfare and Needs

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#### Abstract

Welfare assessment requires a wide range of measures as there are many ways in which individuals cope with the environment in which they live. Welfare can be good or poor so the measures of behavior, physiology, brain function, immune system function, injury etc. must provide information about positive and negative states. Measures of feelings and of health are of particular importance. Behaviors such as stereotypies, low or abnormal responsiveness, and excessive aggression are direct indicators of poor welfare. They are especially important when the welfare problems are of long duration. In addition, the behavior of animals is also needed to interpret other welfare measures such as adrenal cortex activity and some aspects of brain function. Glucocorticoids and heart-rate are useful indicators of short-term welfare problems. Acute phase proteins, immune system measures and pathology indicators provide information about welfare in the longer term. In most scientific studies of animal welfare, a combination of behavioral and other measures is needed. The strengths of preferences of animals, for or against resources or environmental impacts give information about needs. They are best indicated, using the methodology of microeconomics, by indices of demand, such as the consumer surplus, that are assessed using behavioral experimental studies.

#### Keywords

Adrenal function; Behavior; Brain; Heart-rate; Immune system function; Injury; Welfare assessment; Welfare-outcome measures

### Welfare Assessment: The Range of Measures

Welfare is a term used to refer to any animal, including humans. The welfare of an individual is its state as regards its attempts to cope with its environment and coping means having control of mental and bodily stability. Welfare assessment involves direct indicators of the extent of any failure to cope, any difficulty in coping, and signs of good welfare. One method of attempting to cope is to show behavioral or physiological responses that are part of one of the various functional systems, such as regulation of body fluid concentration. A second method is to utilize a behavioral strategy, that is additional to those that are normally part of the functional system, in order to minimize risks such as those of predator attack, disease, or other injury. A third method of coping is to use emergency behavioral and physiological responses, which include fleeing, freezing, activation of the hypothalamic-pituitary-adrenal (HPA) axis, and activation of the sympathetic nervous system-adrenal medulla pathways. A fourth coping method is to use the immune system, principally but not entirely in combating invasion by pathogens. A fifth coping method involves cellular responses to tissue damage or tissue invasion, such as the action of the wound-healing system and apoptosis as a defence against tumor cell proliferation. The coping methods involve brain control and, in many cases, feelings are involved. As explained by Broom (1998, 2014), positive and negative feelings are adaptive mechanisms that aid in coping with the environment. A list of measures of poor welfare is presented in Table 1. Some measures are most relevant to short-term problems, such as those associated with human handling or a brief period of adverse physical conditions, whereas others are more appropriate to long-term problems. The needs of animals can be investigated by studies of avoidance and positive preferences and also by using direct negative welfare indicators if it appears that needs are not being met or positive welfare indicators if they are met. For a detailed discussion of measures of welfare, see Fraser (2008) and Broom and Fraser (2015).

The measures of welfare in Table 1 are sometimes not independent of one another. Some non-behavioral measures require observations of behavior for their interpretation. When an individual decides to show an adaptive response, for example to change physiological or immunological function, there may be a parallel behavioral change or a behavioral consequence. For long-term welfare problems, behavioral measures are usually the most important means of attempting to cope, and hence the best welfare indicators, but the behaviors will change various other aspects of the biology. When the environmental challenge is short-lived, initial responses commonly include physiological components and these may facilitate appropriate behavioral responses. Changes in behavior can result in modified physiological or immune system responses, for example where there is feedback on cytokine production mechanisms or stimulation of opioid production and effects of opioids via receptors on lymphocytes. Brain mechanisms for coping with environmental change normally lead to a range of adaptive responses. For example, the behavioral components of active escape or fighting responses are associated with sympathetic adrenal medullary responses while passive responses

**Table 1** Measures of welfare

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Physiological indicators of pleasure
Behavioral indicators of pleasure
Extent to which strongly preferred behaviors can be shown
Variety of normal behaviors shown or suppressed
Extent to which normal physiological processes and anatomical development are possible
Extent of behavioral aversion shown
Physiological attempts to cope, including pain, fear, pleasure, etc. responses
Immunosuppression
Disease prevalence
Behavioral attempts to cope, including pain, fear, pleasure, etc. responses
Behavior pathology
Brain changes associated with coping attempts and pleasure
Body damage prevalence
Reduced ability to grow or breed
Reduced life expectancy

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Modified after Broom, D.M., Fraser, A.F., 2015. Domestic Animal Behaviour and Welfare, fifth ed. Wallingford: CABI, p. 472.

such as freezing may be associated with adrenal cortex activity. Hence, the division into physiological, behavioral, and immunological responses may have been convenient for some scientists but it does not reflect biological reality. An integrated range of measures is needed in order to evaluate coping and assess welfare.

### Welfare Assessment: Direct Physiological and Behavioral Measures

Some signs of poor welfare are usefully indicated by physiological measurements (Broom and Johnson, 1993). For instance, increased heart-rate, adrenal activity, adrenal activity following ACTH challenge, increases in some acute-phase proteins, or reduced immunological response following a challenge. All of these can indicate that welfare is poorer than in individuals that do not show such changes. Care must be taken when interpreting such results, as with many other measures described here. Observation of behavior often provides a means to determine how to interpret physiological measures. Adrenal activity can occur during courtship, mating, and active hunting for food so in this case, an increase in plasma cortisol concentration does not indicate poor welfare. Lack of normal adrenal cortex activity can be a consequence of depression or inanition and reduce the efficacy of learning. As a result of the range of function of cortisol, increases in plasma cortisol have to be interpreted in the context of previous behavior. However, measurements of glucocorticoids, such as cortisol, are valuable indicators of short-term welfare, for example during handling and transport of animals. Cortisol can be measured in blood or saliva and cortisol metabolites in urine, faeces or hair. Heart-rate, heart-rate variability, acute-phase proteins, various enzymes and other hormones are also useful indicators in such circumstances. Impaired immune system function indicates longer-term welfare problems (Broom and Fraser, 2015). Some housing conditions lead to anatomical inadequacies, such as muscle and bone-weakness, that make coping with the environment much more difficult. For example, battery cages for laying hens and individual stalls for sows prevent normal exercise and result in bones being weak and more liable to breakage (Knowles and Broom, 1990; Marchant and Broom, 1996).

Behavioral measures are of particular value in welfare assessment and an understanding of motivation is important in interpreting them (Toates and Jensen, 1991). If any animal with a potential for awareness avoids an object or event strongly, this gives information about its feelings and hence about its welfare. The stronger the avoidance, the worse the welfare while the object continues to be present or the event continues to occur. For example, an individual that is completely unable to adopt a preferred lying posture despite repeated attempts will have poorer welfare than one that can adopt the preferred posture. Such an individual may show abnormalities of behavior. The behavioral evidence for frustration in hens that cannot reach a food source (Duncan and Wood-Gush, 1971, 1972), Duncan are of particular interest because the very existence of the feeling of frustration in hens is impressive to many people and because the results help in the interpretation of other welfare measures such as stereotypies and aggressive behavior. Abnormal behavior such as stereotypies, self-mutilation, tail-biting in pigs, feather-pecking in hens or excessively aggressive behavior indicates that the perpetrator's welfare is poor. The welfare of other individuals, affected by the abnormal behavior, will also be poor.

*Stereotypies*, which are repeated relatively invariable sequences of movements without obvious function, were first described in humans with neurological disorders and those imprisoned in isolation for long periods. Stereotypies have been described in animals confined in zoos and on farms, for example crate-housed calves, sows in stalls, and mink in fur-farm cages. In all of these cases and in many other situations including stabled horses, it seems that the stereotypy arises because the animal lacks control over important aspects of its environment. Some stereotypies persist after the animal moves from its adverse environment. However, fully functional individuals do not show prolonged stereotypies and these abnormal behaviors always indicate poor welfare.

If housing conditions fail to meet the needs of the individual, the resulting poor welfare lasts for a long time so has a greater magnitude than that caused by short-term problems. Some of the most dramatic stereotypies are shown in confined sows. It is now very well established that sows' needs are not met at all well in stalls and tethers so they show either substantial amounts of stereotypy or apathetic, unreactive behavior. Confined sows are also aggressive and can grow to a smaller size than those living in groups (Broom *et al.*, 1995). In a study of sows that show high levels of stereotyping, they were found, after slaughter, to have low mu and kappa receptor densities and low dopamine concentrations in the frontal cortex. Inactive, unresponsive sows, on the other hand, had more mu receptors in the frontal cortex (Zanella *et al.*, 1996). The current view of animal welfare scientists is that the close confinement of sows is one of the most cruel ways to treat any animal, much worse than causing pain for a few minutes or hours. Other brain studies of animals showing stereotypies include those of housed horses. Those that performed more stereotypies such as crib-biting and pacing had more dopamine (DI) receptors in the nucleus accumbens than those housed horses that performed few stereotypies (McBride and Hemmings, 2009). Individual housing of a social animal, such as a sow, calf, or horse, causes very poor welfare.

The welfare of any animal that shows self-mutilation, such as some zoo, laboratory, fur farm, and pet animals, is poor because of the behavior abnormality itself, as well as because of any direct pain or lost usage effects. Similarly injurious behavior, causing injury to others, indicates that the welfare of the perpetrator is poor as well as having an effect on the welfare of the target individuals. Much of the injurious behavior that occurs in farm animals, for example, tail-biting in pigs and feather-pecking in hens, is not aggressive behavior. Both this behavior and true aggressive behavior indicate that the welfare of the aggressor is poor because of some environmental inadequacy and coping difficulty. The welfare of the subject of the aggression will usually be poor also. The assessment of pain often involves measures of behavior, perhaps combined with the use of analgesics.

Confined animals may be inactive and unresponsive to stimuli, rather like depressed humans. When people are depressed, there are various negative effects on hippocampal and other brain function, as well as impairment in immune system function (Dantzer, 2001; Irwin, 2001). Those who study animal welfare have much to learn from the literature on human depression and those who investigate, or try to treat, human depression have much to learn from work on the welfare of confined, defeated, or seriously frustrated pigs, cows, dogs, rats, and hens.

A wide range of environmental impacts have specific consequences for brain function. Stressful events have been shown to lead to impaired learning ability, impaired memory, damage to hippocampal neurons, remodeling of hippocampal dendrites, suppression of neurogenesis, changes in neurotransmitter distribution, and disorganization of brain function (McEwen and Sapolsky, 1995). All of these brain measures can be associated with changes in behavior. The assessment of emotional responses as welfare indicators has progressed rapidly in recent years (Boissy and Lee, 2014). Measures of cognitive bias are promising in this respect (Mendl *et al.*, 2010). Disease in animals can have effects on behavior and these may be of great value in diagnosis, for example of particular pathogens and parasites, and hence in the improvement of welfare. In some of these physiological and behavioral measures, it is clear that the individual tries to cope with adversity and the extent of the attempts to cope can be measured. In other cases, however, some responses are solely pathological and the individual fails to cope. In either case, the measure indicates poor welfare.

### Welfare Assessment: Direct Indicators of Good Welfare

Good welfare is sometimes detectable from the occurrence of certain behaviors. Care must be taken in interpreting such behavior as there may be more than one explanation for the occurrence of a particular behavior, such as tail-wagging in dogs which is often an indicator of submission and fear rather than pleasure. Physiological changes may also indicate pleasure. Oxytocin concentrations in blood are elevated during several pleasant experiences, such as during milk ejection and suckling in mammalian mothers, other maternal care, and social bonding. Oxytocin binds to receptors that regulate HPA axis activity and increases in plasma oxytocin are associated with decreases in glucocorticoids and adrenocorticotrophic hormone (ACTH), proliferation of lymphocytes, increased gamma-amino-butyric acid (GABA), and increased vagal tone. Investigations including measurement of such changes will involve behavior observation in preliminary studies and evaluation of the meaning of the measures will be aided by measuring behavior at the same time. A range of brain measures, including brain-scanning methodologies, have proved valuable as welfare indicators (Broom and Zanella, 2004).

### Assessment of Needs: Strength of Preference Measures

The majority of indicators needs and of good welfare are obtained by studies demonstrating positive preferences by animals (Hughes and Duncan, 1988; Dawkins, 1990, 2004). Early studies of this kind included that showing that hens could indicate their needs. Given a choice of different kinds of floor to stand on, hens did not choose the rigid floor that biologists had expected them to choose but selected a wire mesh floor that supported their feet well (Hughes and Black, 1973). As techniques of preference tests developed, it became apparent that good measures of strength of preference were needed. Taking advantage of the fact that gilts preferred to lie in a pen adjacent to other gilts, they were offered the choice of different kinds of floors that were either in pens next to another gilt or in pens further away. With the floor preference titrated against the social preference, better information was obtained about strength of preference. In a further example of strength of preference tests, operant conditioning with different

fixed ratios of reinforcement was used. Pre-parturient sows would press a panel for access to a room containing straw or one containing food (Arey, 1992). Up to 2 days before parturition, they pressed, at ratios of 50–300 per reinforcement, much more often for access to food than for access to straw. At this time, food was more important to the sow than straw that could be used for manipulation or nest-building. However on the day before parturition, at which time a nest would normally be built, sows pressed just as often, when a large number of presses (50–300) per reinforcement was required, for straw as for food. Another indicator of the effort that an individual is willing to use to obtain a resource is the weight of door that is lifted. In a study of the floor preferences of laboratory rats, it was found that rats would lift a heavier door to reach a solid floor on which they could rest than to reach a grid floor (Manser *et al.*, 1996).

The various measures, described above, of how strong the strength of preference of an individual is for a resource or a possibility for action help us to understand what is needed for good welfare. The methods of microeconomics research have been useful in precise evaluation of the strengths of preference of animals (Kirkden *et al.*, 2003). Preference tests require an animal to make a sacrifice of some kind whenever it gains access to some quantity of a resource or spends a given amount of time consuming it. In operant tests, a cost is imposed upon access to the resources by requiring the subject to perform a task. Performance of the task requires time and effort, which could otherwise have been spent doing other things. The task may sometimes be unpleasant to the subject. Choice tests involve choosing between resources that satisfy the same motivation to different extents. The resource that an animal consumes more, or spends more time interacting with, is the one that satisfies that motivation more fully but identification of this resource does not mean that strength of motivation is measured. Simple choice tests are not suitable for comparing resources that satisfy different motivations. These may vary, not only in their strength, but also in other properties, such as the rate at which subjects can be satisfied and the quantities of the resources required to satiate them. Terminology used in motivational strength estimation, described in Table 2, is used in economics research as well as in evaluation of animal needs.

In operant tests, the sacrifice required from an animal in order to get a resource is manipulated by varying the duration, difficulty, or unpleasantness of the task. The consumption level or time is recorded and the price paid for a fixed quantity of the resource measured. Motivational strength is calculated from the observed relationship between price and consumption, or between income and consumption.

It has sometimes been assumed that animals strive to maintain their consumption of important resources in the face of increasing access or consumption costs. One proposal was that the more strongly motivated an animal was to consume a given resource, the less its demand should be observed to decline when the price of the resource was increased or when its income was reduced, that is, the less elastic its demand should be with respect to price or income.

Some shortcomings of elasticity of demand indices are as follows:

- (1) The fitness cost of being prevented from performing an activity is not correlated with price elasticity.
- (2) The sacrifice that a subject makes when attempting to maintain an initial level of consumption is not accounted for.
- (3) Readiness to defend a preferred consumption level is confused with the tendency to become satiated with a resource.
- (4) Single elasticity values are seldom generally valid for a resource.

These shortcomings do not apply to the consumer surplus index, indicated by the area under a demand curve. This curve is produced when the price, such as the number of lever presses needed to open a door and get to a resource, is plotted against the demand, which is the frequency of opening the door. The consumer surplus should be used instead of price elasticity (Kirkden *et al.*, 2003; Broom and Fraser, 2015).

## Other Welfare Measures

Concerns about animals may be affected by whether or not the animal is considered to be sentient. For many people, the capacity to feel pain, as mentioned above, is of particular importance. Decisions about this will depend upon a range of observations of the animal, largely observations of its behavior in controlled circumstances. Nonetheless, the term welfare applies to both sentient and non-sentient animals, so welfare assessment does not require determination of sentience.

One kind of decision that has to be taken in relation to welfare assessment concerns the quality of the evidence. This is part of the normal scientific process of deciding whether or not the data are methodologically and statistically robust enough to use. After this, the way in which different kinds of measurement can be considered together has to be decided in order to form an overall

**Table 2** Terminology in studies of strength of preference

Resource	– a commodity or an opportunity to perform an activity
Demand	– the demonstrated amount of action that enables resources to be obtained
Price	– the amount of that action required for unit of resource
Income	– the amount of time or other variable limiting that action
Price elasticity of demand	– the proportional rate at which consumption or demand changes with price
Consumer surplus	– a measure of the largest amount that a subject is prepared to spend on a given quantity of the resource. It corresponds to an area beneath an inverse demand curve

evaluation of welfare. Some of the relationships among direct measures of welfare were mentioned earlier. Measures of what is important to animals as estimated by their strengths of preference are of particular value when designing systems for keeping and managing animals. All of such information has to be evaluated in relation to the impact of something preferred on the animal species concerned. An individual might choose to eat inappropriate foods, or eat too little, or self-administer a harmful drug, so the consequences of showing the preference must be considered in properly controlled studies. The assessment of welfare should be quite separate from any ethical judgement but once an assessment is completed, it should provide information that can be used to take decisions about the ethics of a situation.

Qualitative behavioral assessment (QBA) (Wemelsfelder *et al.*, 2009) may be useful because it can be carried out by non-scientists and may add information to other studies. However, it should never be the only method of welfare assessment as it is not possible at present to exclude the possibility of observer bias. Wemelsfelder *et al.* found that some components of QBA of pigs were affected by the perceptions of observers about the environment of the animals. This is not surprising because, in most studies, it is not possible for the observer to be entirely blind to the environment and treatment of the animals. In the study of Tuytens *et al.* (2014), veterinary students were shown the same videos of animals but the QBA scoring was more positive when the students had been told that the conditions of the animals were good than when they had been told that the conditions were less good. Bokkers *et al.* (2012) found no correlation between QBA results and other welfare measures.

Measures which might be used in laws or codes of practice to predict or assess welfare may be: resource-based, management-based or welfare-outcome indicators that are animal-based. As an example of the latter, because lameness in broiler chickens and dairy cows is a problem, it is possible to monitor the number of animals that are lame as a welfare-outcome indicator. This involves using an animal-based measure. The welfare-outcome scored is the animal's ability to walk and this is done using a scientifically designed scale of walking ability. Animals on farm or arriving at a slaughterhouse can be checked and a threshold level of lameness can be used to decide whether or not their welfare complies with the law or code of practice. For dairy cows, the EFSA report and opinions on the welfare of dairy cows (EFSA, 2009) proposed that the threshold for a group of dairy cows on farm or at the slaughterhouse might be 10%. Reports on animal-based welfare-outcome indicators for several farm species have been produced. The links between factors that might affect welfare and their consequences, which might be used as measures, need to be validated (EFSA, 2012; Broom, 2014). Some are very clear, for example a bitten pig's tail is easily recognisable, or they are clearly negative, for example frequent stereotypies indicate substantial problems. However others are less clear, for example various factors may affect the ratio in the blood of heterophil to lymphocyte white blood cells. A further example is that many causes of poor welfare do not increase cortisol so absence of cortisol increase does not mean that the individuals have no problems.

There are many different measures of welfare because there are so many coping methods. Hence it is important to use a wide range of scientific measures of the positive and the negative when evaluating welfare. However, poor welfare can be identified whenever a clear indicator is found. When planning housing, management and treatment of animals, information about the needs of that kind of animal is of crucial importance. Some of this information is obvious from a knowledge of the biology of the animal, for example fish that cannot breathe air suffer if left in air, but detailed scientific information about what is important to animals is also required. There is now a very substantial body of information on animal welfare science.

**See also: Animal Welfare and Conservation:** Stress, Health and Social Behavior; Indicators of Good Welfare; Indicators of Pain; Stereotypies and Other Abnormal Behavior in Welfare Assessment. **Overview Essays:** Welfare Concepts and Behavior.

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