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Can We Measure Distress in Animals?

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When scientists try to identify and mitigate distress in animals, an obvious first question is: can we actually measure distress? Today, after three decades of scientific research on animal welfare it must seem obvious that this is possible, but let me offer a more guarded response.

One problem with the question is the term *distress*. As discussed elsewhere in this volume, *distress* has been given a range of meanings, some broad and some more narrow. In order for us to plunge into the issue without worrying about the definition of *distress*, let us use the generic term "negative affective states" to refer to all unpleasant experiential states such as pain, fear, separation distress, etc., without dealing with the (somewhat semantic) issue of which of these should be called distress.

A second problem is the term *measure*. If by *measure* we mean "ascertain the extent or quantity of something by comparison with a fixed unit or object of known size" (paraphrasing the *Concise Oxford Dictionary of Current English, 7th edition, 1982)* then we would have to conclude that we cannot actually measure the negative affective states of animals. Some level of quantification is often possible, but rarely is there a fixed unit or scale that would allow measurement in this commonly used sense of the word. However, the term *assess* – in the sense of "estimate the magnitude or quality of something", again paraphrasing the *Concise Oxford Dictionary* – comes much closer to what we can achieve. Thus, the question can be restated as: can we assess negative affective states in animals?

In fact, a wide range of methods have been used to attempt to assess the affective states of animals. Valuable reviews and discussion are provided, for example, by Dawkins (1983, 1990), Duncan (1996), Broom (1998), and Appleby and Hughes (1997). The methods include studies of animal vocalizations, posture and other behaviors; studies involving physiological measures such as heart rate and stress responses; and studies of animals' preferences, aversions and motivation. However, the different approaches rest on some quite different underlying logic which is often not made explicit. This article will illustrate some of the methods that have been used, while providing a rough taxonomy of the underlying logic.

Type 1: Cases where animals appear to signal a negative affective state

In some cases, animals are thought to have specific signals which indicate particular affective states, and we can "listen in" when they communicate these states to each other. For example, if an unweaned piglet becomes separated from its mother, its behavior follows a typical sequence. The piglet begins by walking slowly and giving quiet grunts in a pattern so characteristic that an experienced pig keeper will recognize them immediately as coming from an isolated piglet. If the piglet does not find the mother, its movements gradually take on a more agitated appearance, and the calling escalates to loud, high-pitched squeals. Experiments have shown that newly separated piglets give more calls, especially more of the loud, high-pitched calls, if they have not been fed recently or if they are in a cool environment; both are conditions that presumably increase their need to be re-united with the mother. Moreover, sows approach these calls, and they respond more vigorously to calls given by piglets in conditions of greater need. The working hypothesis is that piglets, presumably as a result of natural selection, experience a particular affective state ("separation distress") when separated from the mother under conditions that would threaten their survival in the wild, and that this affective state stimulates agitated movement and the distinctive calling which helps to reunite the offspring with the mother. The calls thus serve as part of a communication system, and they can be used to identify (and to a degree quantify) separation distress in the piglet (Weary & Fraser 1995).

Such cases, however, may be fairly rare. We expect signals of affective states to evolve only in those cases where the signals would provide a fitness advantage. This might occur, for example, in cases where dependant offspring solicit help from their parents (begging calls, signals of separation distress), or if animals give alarm signals that are heard by genetically related animals who can then avoid danger. In many cases, however, animals would not receive fitness benefits from signalling negative affective states, so we would not expect such signalling to evolve. For example, we would not expect mature ungulates to signal pain because such signals might be more likely to attract predators than assistance.

Type 2: Cases where a negative affective state has a characteristic indicator other than a signal

In other cases we might not expect animals to signal an affective state, but the state may still be accompanied by a characteristic type of behavior or other indicator. For example when chickens (or animals of many other species) are held firmly on a flat surface for a few seconds and then released, they often remain immobile for many minutes in a reaction commonly called "tonic immobility" (TI) or "death-feigning". It can be shown experimentally that delivering a supposedly fear-producing stimulus (electric shock, loud noise) just before inducing TI results in a longer period of immobility, whereas procedures intended to calm the animals (taming, tranquillizers, habituation) reduce the reaction. On this basis, TI has been widely used as an indication of fear, and the duration of TI has been used to quantify the magnitude of fear (Gallup 1981).

Here again, the working hypothesis is that a type of behavior (TI) evolved to accompany a particular affective state (fear) because it conferred a fitness advantage. The most likely evolutionary explanation is that tonic immobility is an adaptive response to being captured by a predator, because predators may simply store an immobile prey animal (who can later escape) without making further attempts to kill it. This fortuitous situation leaves us with a plausible tool for assessing fear, or at least the type of fear induced by predators. However, many affective states may lack any such specific manifestation, and other approaches are needed instead.

Type 3: Situations where there is an *a priori* reason to believe that a certain negative affective state is involved

Even if an affective state has no specific indicators, there may be an *a priori* reason to expect that a given state may occur in a given context; in that case, indirect measures (heart rate, plasma cortisol levels, bodily movements) may be taken as evidence of the presence and magnitude of the state.

For example, when "chicken harvesters" (mechanical devices used to transfer broiler chickens from the barn floor into shipping crates) were first invented, there was concern that they would cause excessive fear in the birds. To investigate this concern, Ian Duncan and co-workers monitored the heart rate of birds when they were captured by hand or by machine, and found that the rapid heart rate of newly caught birds returned to normal more quickly if they had been caught by machine rather than by hand. This, combined with a TI test used as a corroborating measure, suggested that machine catching actually caused less fear than manual catching, probably because the mechanical device, being so foreign to the birds, did not trigger a predator-recognition reaction (Duncan et al. 1986).

Other physiological indicators have been used in similar ways. For example, cortisol responses have been used to help quantify post-surgical pain. In one study, lambs showed a surge in plasma cortisol after castration and tail-docking, but the surge was reduced if they first received an injection of local anesthetic (Sutherland et al. 1999). Here the surgical procedures provided the *a priori* reason to expect that pain might be present, and the cortisol response was interpreted as an indicator and metric of the pain.

Bodily movements have also been used for this purpose. In one study, beef cattle were branded by either hot-iron or freeze branding while restrained in a chute, and their movements were video-recorded and later analyzed. Cattle that were branded with the hot iron showed more head movements, and more rapid head movements, than those that were freeze branded. The result was taken as evidence that freeze branding is the less painful method (Schwartzkopf-Genswein et al. 1998).

Changes in heart rate and plasma cortisol levels are “downstream” measures which indicate activation of certain general physiological processes. They are not specific to any one affective state, nor do they necessarily indicate that affective states are involved at all. For example, increased heart rate might occur merely from increased exertion. In the above examples, however, because there was an *a priori* reason to expect that a particular affective state might be present, the non-specific measures were interpreted as helping to demonstrate and quantify the state.

At this stage in the development of animal welfare science, most or all of the physiological measures in use are downstream measures which do not by themselves indicate that affect is involved, nor the nature of the affect. The emergence of "affective neuroscience" (Panksepp 1998) – the study of the neurological processes involved in emotion in animals and humans – may in the future be able to supply physiological measures that are more specific to different affective states.

Type 4: Cases where an affective state is deliberately induced in order to identify how it is manifested

In a related approach, scientists have attempted to induce an affective state deliberately in order to see whether it is manifested in characteristic ways. One concern about housing laying hens in standard “battery” cages is that the hens are prevented from entering a secluded nesting area before laying an egg, and it was expected that this would cause a state of frustration. To address this concern, Duncan (1970) attempted to create frustration experimentally in various ways in order to identify whether there are any characteristic signs of frustration in the hen. In one case, for example, he trained hens to expect a large meal in a certain dish at a certain time of day, and then observed the hens when the food was covered with a glass panel so that they could not eat. He noted that hens responded to the frustrating situation with characteristic behavior including stereotyped back-and-forward pacing, displacement preening, and increased aggression toward less dominant birds. Duncan then looked for these indicators of frustration to assess whether birds in standard cages are frustrated when prevented from entering a nest box at the time of laying an egg.

The approach gave convincing results in this case, but there is a risk that a given affective state might be manifested in different ways in different situations. There is also a risk that different affective states – say, hunger and frustration – might give rise to similar general indicators. Ideally, in the example above, we would want to know not only that frustration produces certain characteristic changes, but that other affective states do not produce these same changes so that we can distinguish between these states in order to identify potential solutions.

Type 5: Cases where animals show aversion or learned avoidance of a situation

In cases where there is reason to think that a situation may cause a negative affective state, evidence that the animal will avoid or learn to avoid the situation has been used to provide confirmation and quantification of the state.

"Electro-immobilization" involves passing a pulsed, low-voltage current through the body to immobilize animals temporarily for procedures such as shearing. The technique has been claimed to have analgesic properties – specifically that it makes procedures such as shearing less unpleasant for the animals. To test this claim, Jeff Rushen (1986) trained sheep to move along a runway to a pen where they received mildly aversive treatments such as rough shearing, with and without electro-immobilization. Over repeated trials, sheep that received electrical immobilisation became more difficult to move along the runway than those that received the mildly aversive treatments without electro-immobilization. Rushen concluded that electro-immobilization actually made unpleasant procedures more aversive, not less.

In this example, we are not sure of the exact nature of the affective state caused by electro-immobilization. It may itself cause pain, or it may cause alarm or some other type of discomfort. However, because the animals learn to avoid electro-immobilization, we can at least conclude that the sign of the affect is negative. Similar approaches have been used to test whether other unknown treatments – such as exposure to gases used for euthanasia – are perceived by animals as aversive.

Type 6: Cases where animals show a preference or motivation for certain environments or environmental features

Aversion testing is a special case of a broader group of methods that gather evidence that animals select one environment over another, or demonstrate a motivation to obtain or avoid particular environmental features or resources. A consistent preference for one environment over another is often taken as evidence that the environments cause different levels of positive or negative affect. An early example was a study by Dawkins (1977) who allowed hens to choose between restrictive cages and larger enclosures in an attempt to ask whether hens "suffer" in cages. She concluded that simply determining a preference was not enough to allow conclusions about animal suffering, but the approach has been expanded and refined over the years to include (1) testing the strength of animals' preferences, for example by establishing how hard they will work for a preferred situation, (2) "titrating" an unknown motivation (e.g., for a dust-bathing substrate) against a known motivation (e.g., for food); and (3) determining whether animals will increase their efforts to obtain a preferred option when the "price" (the amount of work needed to obtain it) is increased (Dawkins 1990; Fraser and Matthews 1997; Kirkden et al. 2003).

As one example of this approach, Georgia Mason and co-workers (2001) tested the motivation of American mink for various resources that are present in their natural environment. In the wild, mink perform many types of behavior that are impossible in captivity; for example, they swim, rest in several nest sites, survey the environment from raised perching places, and explore the burrows of potential prey animals. Mason et al. trained mink in standard cages to push against weighted doors for access to various rewards that roughly mimicked these natural features: a tunnel, a raised platform, an alternative nest box, and a small pool of water where they could swim. The experimenters then varied the amount of weight that the animals had to push in order to open the different doors. The animals used some resources, such as the tunnel and the raised platform, when the price of entry was low, but not when it was high. For other resources, especially the pool of water, the mink worked harder and harder as the price increased, and they maintained a relatively high rate of use. As corroborating evidence, Mason et al. also found that the mink showed an increase in plasma cortisol levels if prevented from swimming. They concluded that the mink were strongly motivated to obtain water for swimming, and that preventing mink from swimming caused frustration in the animals.

In a second example Widowski and Duncan (2000) studied the motivation of domestic hens for opportunities to “dustbathe” – a common type of behavior which helps to maintain feather condition but which is impossible in standard cages. Various studies have tried to assess whether hens are highly motivated to perform dustbathing, but the results have been equivocal. Widowski and Duncan gave hens the opportunity to gain access to peat moss (as a dustbathing medium) by pushing against doors carrying varying amounts of weight. Six of ten birds lifted more weight for access to peat moss when they had been previously deprived of the opportunity to dustbathe, but other birds did not. The authors noted that because the hens were not "consistently more willing to work for substrate when deprived" than when they had recently dustbathed, the results were not consistent with the idea that deprivation of dustbathing leads to the build-up of a negative affective state.

A demonstration that animals will work hard for a resource shows that the animal registers the resource as important in some way, presumably indicating some form of affective response. However, the nature of the affect – even whether the emotional state is positive or negative, pleasant or unpleasant – may remain unclear. We know from human experience that our actions are sometimes motivated by a negative affective state (eating when very hungry) and sometimes by a positive affective state (eating for pleasure). Can we find ways to separate these different types of affect?

Consideration of the animals' natural history may provide an initial means of proposing whether positive or negative affect is involved. In a hypothesis linking affective states to evolutionary biology, Fraser and Duncan (1998) distinguished between "need situations" where an action is needed to avoid a potential fitness cost (e.g., needing to drink when dehydrated, or needing to protect young when they are in danger) and "opportunity situations" where there is a potential fitness benefit from performing certain behavior (e.g., playing, exploring) at times when the cost of performing the behavior is low. According to this hypothesis, negative affective states (thirst, alarm) evolved to stimulate behavior in need situations, whereas positive affective states (the pleasure of playing or exploring) evolved to motivate behavior in opportunity situations.

Notice also that in the two examples above, different criteria were used to draw conclusions about the sign of the affect involved. The mink study looked for increased effort to gain access to a resource in the face of increasing price as evidence of a negative affective state. The dustbathing study looked for a consistent increase in motivation in response to deprivation. There is scope for more explicit development of the logic whereby different features of motivation are taken as evidence of the type and extent of affective states (Kirkden et al. 2003).

Type 7: Cases where the animal performs an abnormal behavior

Psychiatrist David Levy (1944) published a classic article on behavioral disturbances in children, especially hyperactivity and stereotyped movements such as repeated rocking. In the article he also described similar behavior in farm animals (repetitive weaving movements of horses in stables, stereotyped head movements by caged chickens), and he argued that these behavioral abnormalities in animals reflect the same kinds of emotional disturbance seen in children in severely deprived environments. This thinking gave rise to substantial interest in abnormal animal behavior as an indicator of negative affect.

For example, pregnant sows housed in gestation stalls (narrow stalls where the animals cannot walk or turn around during most of pregnancy) often develop stereotyped movement patterns. Various researchers have proposed that the stereotyped behavior develops from exploratory motivation, or from attempts to escape from a confined space, or that the behavior helps animals to "cope" with an aversive environment, for example by causing a release of endogenous opioids which tend to have a calming effect (see Lawrence and Rushen 1993). Pregnant sows are typically fed a restricted diet to prevent them from gaining too much weight, and research by Appleby and Lawrence (1987) showed that sows in stalls are much more likely to perform stereotyped behavior when food-restricted in this way. This finding gave rise to the hypothesis that food restriction causes a motivation to forage for food, but in a barren caged environment where normal foraging is impossible, this motivation leads to elements of foraging behavior being repeated in stereotyped sequences. In a critical experiment, Claudia Terlouw and co-workers (1991) housed some sows in narrow stalls where they were tethered by a chain while others were loose-housed in larger pens equipped with chains hanging from the walls. In each housing treatment, sows that were fed a restricted diet spent more time in chewing, biting, and rooting the chain and in other seemingly functionless and stereotyped behavior, than more generously fed animals. The stereotyped behavior thus appeared to be related more to hunger than to other motivational states that could arise from being caged.

In this case, it was not originally known whether the stereotyped behavior reflected a negative affective state or not, nor what state was involved. It took observations and experiments to build up a plausible case that the abnormal behavior reflected chronic hunger. There is no guarantee, of course, that similar behavior seen in other situations will reflect the same type of affective state. Thus, abnormal behavior serves to alert researchers to the possibility that a negative affect state may be involved; it then takes investigation and evidence to build an argument one way or the other.

Type 8: Cases where the environment prevents animals from performing a natural type of behavior

One of the most difficult issues for animal welfare science is the concern that preventing animals from carrying out their natural behavior will lead to states of thwarted motivation that have usually been grouped under the term “frustration”. In a classic essay W.H. Thorpe (1965) cited, for example, the case of captive migratory birds fluttering continually in their cages during the normal season of migration, presumably because the bird experienced a motivation to fly at that time, and he suggested that such situations might cause “intense and prolonged emotional disturbances” in animals. This thinking led to a body of research whereby scientists have used the behavior of animals in natural or semi-natural circumstances as a guide to the types of behavior that should be provided for in captivity.

Stolba and Wood-Gush (1984) used this approach in creating a novel housing system for pigs. They began by observing the behavior of pigs that had been turned loose in a hilly, wooded area, and they identified certain characteristic features of the animals' behavior. For example, the pigs rooted in soil, exercised their neck muscles by levering against fallen logs, built nests in secluded areas before giving birth, and used dunging areas well removed from their resting areas. The research also identified certain key stimuli in the environment which were important for these behaviors to be performed. This then inspired the design of a complex commercial pen which incorporated these key stimuli.

Stolba and Wood-Gush were also explicit about the rationale behind the approach. They argued that animals have "behavioural needs" including "the needs to perform the obligatory ... elements of a behaviour sequence", and "the needs to perceive specific external key stimuli or compound features, without which these obligatory elements cannot be released or oriented, enhanced or inhibited for a satisfying performance of the sequence" (p. 289). They argued that depriving animals of the key stimuli or resources, and hence of the ability to perform certain behavior, would lead to some form of negative affective state perhaps deserving the term "frustration".

The inference, however, is far from water-tight. For example, pigs pant when hot, huddle when cold, and squeal when captured. These are elements of their natural behavior which are evoked by certain stimuli in the environment, yet we do not generally think that depriving an animal of the stimuli that elicit these types of behavior is likely to cause negative affect. One way to resolve the problem is to use the prevention of natural behavior as a starting point for further study, and then to look for other evidence that the situation does give rise to negative affect, as done by Duncan (1970), Widowski and Duncan (2000), and Mason et al. (2001) in the examples given above.

Science and affective states

The eight types of cases given above form a rough progression. In types 1-4 the assumption is that we can identify specific affective states such as pain and fear, either because the animal has an evolved signal or other indicator which predictably accompanies the affective state, or because there is an *a priori* reason to expect that that state may be present and we can use indirect evidence to detect it, or because we can induce the state deliberately and identify a characteristic set of indicators. In types 5-6, in contrast, we may not know what affective state is involved, but the fact that the animal learns to avoid an option, or conversely works to obtain an option, is taken as evidence that the animal registers the situation as either positive or negative, pleasant or unpleasant, not hedonically neutral. Finally, in types 7-8 the presence of abnormal behavior or the absence of normal behavior does not by itself indicate that affect is involved, but rather provides a starting point for further enquiry. Thus, we move from what we believe are relatively specific indicators of specific affective states, to situations of increasing uncertainty.

Notice how the above scientific work cuts a swath through several thorny philosophical issues. First, rather than engaging in debate about whether animals experience affective states, the science presupposes that they do, and sets about developing hypotheses that assess these states. Second, rather than asking whether mental states are mere epiphenomena that accompany but do not influence behavior, the science presupposes that affective states play a sufficient role in the behavior and physiology of the animal that changes in behavior and physiology can be used as evidence of affective states. And third, rather than asking whether affective states are products of evolution like other aspects of animal biology, the science presupposes that they are, and that we can gain insight into affective states by considering the natural history of the animals and their wild ancestors.

These three presuppositions – that animals experience affective states, that these states can play a role in causing behavioral and physiological changes, and that the capacity to experience affective states is (at least in some cases) an evolved adaptation – mark the field of animal welfare science as a distinct paradigm (in the sense of Kuhn, 1962), different from the paradigms of behaviorist psychology and classical ethology which sought to explain behaviour without reference to any mental or affective states (Fraser 1999).

The presuppositions are, of course, no more than presuppositions – working assumptions that scientists adopt to guide further study, and which could conceivably be rejected in the future if contrary evidence or arguments accumulate. But does this use of presuppositions make the study of the affective states of animals somehow less scientific than other areas of research?

Actually, this type of approach is fairly common when science deals with “big” questions such as whether species have evolved, and whether matter is composed of subatomic particles. When tackling such questions, science often proceeds not by “proving” one way or the other, but by presupposing one way or the other, usually based on some evidence or theoretical arguments that make such a presupposition plausible. This presupposition provides a working model, and then a program of investigation and practical action is based on that working model. If the program provides more satisfying explanations, correct predictions and useful actions than competing programs, then the presuppositions are likely to become more and more accepted. In the reverse situation, such presuppositions would be re-examined and rejected.

Thus far, then, animal welfare science has not provided positive proof that animals have affective states. Instead it has provided a plausible set of presuppositions that reflect evolutionary theory, and an emerging set of methods that create a plausible and sometimes counter-intuitive understanding of the nature and causes of affective states in animals. If and when the methods are refined, the logic tightened, and the resulting understanding becomes richer and more rigorous, the presuppositions are likely to become increasingly accepted as part of science.

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