1980

Stress: What Is It and How Can It Be Quantified?

T. H. Friend
Texas A & M University - College Station

ORIGINAL ARTICLE

Stress: What Is It and How Can It Be Quantified?

T.H. Friend*

Abstract

An animal may be considered to be in a state of stress if abnormal behavior or extreme adjustments in its behavior or physiology are necessary in order to cope with adverse aspects of its environment. Methods used to determine if an animal is stressed can be either behavioral or physiological. Behavioral methods may be highly erroneous due to their subjective nature since alterations in behavior do not necessarily prove that an animal is stressed. There is no single measure of stress that can be used in all situations at this time. Every measure must be critically evaluated to ensure that it is valid for each application. An integrated approach using both behavioral observations and physiological measures is necessary.

Introduction

Stress is a phenomenon which everyone acknowledges, but few can agree on a definition. Fraser *et al.*, (1975) discussed various definitions and concepts of stress in a nine page paper in the *British Veterinary Journal*. These authors proposed that an animal is in a state of stress if it is required to make abnormal or extreme adjustments in its physiology or behavior in order to cope with adverse aspects of its environment or management. The behavioral and physiological responses to a challenge are the effects of stress.

It should also be recognized that animals can make both physiological and behavioral adjustments in the presence of a stressful situation which can eliminate that event from being a stressor (Moberg, 1976). In fact, morphine-like compounds (endorphins), which promote emotional detachment from the experience of suffering, have recently been identified in the brain (Goldstein, 1976). There is speculation that they may aid in tolerating stressful conditions.

It is immaterial whether the stressor is pleasant or unpleasant. All that counts is the intensity (Selye, 1973). Parents who are suddenly told that their only son died in battle would suffer the same stress if the news turned out to be false

* Dr. Friend is Assistant Professor in the Department of Animal Science, Texas A&M University, College Station, Texas 77843.

This paper was prepared for and presented at The Institute for the Study of Animal Problems Symposium on *Pain, Stress and Suffering: Definition, Quantitation and Application to Animal Welfare Issues, Orlando, Florida, November 7, 1979.*

and the son unexpectedly walked into the room. There is also evidence that psychological stressors such as being confronted with conspecifics or species enemies may be more potent in eliciting physiological reactions indicative of stress than physical stressors such as electrical shock applied to the feet of an animal (Peters, 1977).

According to Hans Selye (1973), who is generally considered to be the founder of human stress research, stress is not something to be avoided and in fact, cannot be avoided. No matter what an animal does, there arises a demand to provide the necessary energy to resist and adapt to the changing environment. Selye continues to point out that complete freedom from stress is death. Contrary to public opinion, we must not—and indeed cannot—avoid stress.

Current methods of measuring or quantifying stress of animals involve measuring its manifestations. Once a stressor is perceived, the animal reacts either behaviorally, physiologically, or most often, in combination, to enable it to resist and perhaps alleviate the challenge. The use of behavioral observations, physiological measures and combinations of both as measures of stress will be discussed as they apply to farm animals.

Behavioral Measures of Stress

A stressful condition obviously exists, for example, when overt fighting occurs or when an animal is frantically trying to break out of a cage. Measures of chronic or long-term stress, the behavioral signs of which can be very subtle, are far more controversial. What has been presented in the popular press as measures of stress range from subjective, anthropomorphic evaluations with no foundation to well substantiated, scientifically acceptable measures. Even the best measures, however, must be critically examined for each application. Several of the most frequently used methods are discussed below.

Occurrence of a Specific Abnormal Behavior

The occurrence of a specific "abnormal" behavior such as tailbiting in groups of swine kept in confinement, sterotyped movements (e.g., incessant pacing in zoo animals or stall weaving in horses), or other displacement or vacuum activities, are frequently presented as possible indicators of stress. There are, however, serious problems with their use. The behavior of an animal is very complex and even a specific behavior can be attributed to many different factors.

The tailbiting syndrome in swine is a very good example of the complexity of an apparently simple behavior. In acute tailbiting many of the pigs in a pen may be afflicted. In extreme cases, the attacking pig or pigs may continue to consume the victim, resulting in crippling and perhaps death. Frequently there is only one tailbiter and if the attacker is not removed from the group, it may be the only pig with an intact tail. The incidence of tailbiting can be increased by potential stressors such as artificially high levels of ammonia gas (Van Putten, 1969). Hence, people often perceive it as a sign of stress, but generally the cause is more complex. Pigs are "poor sports." If chased from a feeder by a more dominant pig, they will frequently retaliate by biting the tail of the defenseless dominant pig while its head is in a feeder. The tailbiter is frequently one of the smallest or a subordinate in the group, which supports the retaliation theory. Removing the tailbiter will eliminate tailbiting in the group. One would expect another tailbiter to evolve if the activity were caused by stressful conditions, but this is not the case. Also, in a typical, very large confinement farm the author observed tailbiting in only one pen. If tailbiting is an indication of stress, what can be said about the other forty-nine identical pens in which it did not occur? Other potential causes and cures of tailbiting are covered in numerous review articles (e.g., Fritschen, 1978).

The appearance of displacement or vacuum activities does not necessarily prove that an animal is stressed. There may be signs of boredom or frustration (Wood-Gush *et al.*, 1975; Hediger, 1950), but this may also indicate that the animal is coping with the situation. People will often do something they would not normally do to relieve boredom or frustration. Following this line of thought, we could even rationalize that it is the animal which does not show displacement activities (or, the person who fails to release his or her emotions) that is most probably stressed. It can also be argued that some vacuum activities are instinctive behavior patterns (e.g., nest building in swine) which the animal would perform regardless of environmental conditions.

Absence of "Normal" Behavior

Frequently the behavior of an animal in a potentially stressful environment, *i.e.*, a cage or in confinement, is compared with that of conspecifics in more natural conditions. The prevention of dustbathing, or wing flapping, or simply the ability to move about in poultry cages is often considered indicative of a stressful condition. The mere inability of an animal to show behavior that typically occurs under a different set of conditions, even though they may be less restrictive, is not necessarily indicative of a stressful condition.

The Brambell Committee (Brambell, 1965) recommended that an animal should have freedom to turn around, groom itself, get up, lie down and stretch its limbs. There is a problem with blanket recommendations (or legislation) due to the immense amount of variation across and within a species. The basic behavioral repertoire of the species in question, as well as the experience and background of each individual within the species, must be considered.

For example, a farrowing crate prevents a sow from turning around and greatly restricts her activity during the four to five weeks she is confined in it. This may be stressful for an animal with a strong drive to travel, such as a wolf. A pig, however, will normally spend 80% of its time asleep if its environment is satisfactory (Hausge *et al.*, 1965). Pigs that are accustomed to crates will not show signs of maladjustment (fighting the crate). When sows are released in the alley leading to the farrowing crates at our University Swine Center, the sows will sort themselves out and willingly enter the crate in which they last farrowed.

Defining normal behavior can also be a problem. Comparing the behavior of domestic animals to that of their wild relatives lacks meaning due to genetic differences. Domestication has exerted a strong selective pressure to develop animals that are adapted to domestic conditions. Feral or free ranging domestic animals would yield more relevant comparisons. If one thinks about this whole approach, it appears analogous to comparing a "primitive" tribe of humans to apartment dwellers in a major city. One would be making a strictly philosophical decision concerning how people should live. It would be necessary, for example, to examine the health records of *both* populations to make a meaningful decision. There is a good chance of discovering that the population with no stress-related disease also had a much greater mortality rate.

Change in Behavior Patterns

This procedure generally establishes fairly quantitative behavioral patterns (e.g., time standing, time resting, or number of vocalizations) as indices of stress or the overtaxing of resources. This approach was used to determine the minimum number of free stalls (resting sites) required by dairy cattle in confinement barns before they became overcrowded (Friend *et al.,* 1977*b*). Time spent resting per day was determined using time lapse photography as the number of free stalls were reduced at seven day intervals. A significant reduction in resting time occurred at .50 and .33 stalls per cow (Table 1). However, we could not say that the cattle were stressed based on this change in behavioral patterns alone. These data indicated only at what density the cattle were no longer able to rest as often as they had when space was abundant.

All three measures of stress discussed to this point need supporting evidence before they become valid measures of stress. It must first be established that preventing an animal of a particular species from turning around, or having a normal amount of resting time is stressful. This generally means measuring some change in an animal's physiology indicative of stress.

TABLE 1 — Effect on reducing number of free stalls on daily free stall utilization per cow.

	Free stalls per cow				
	1.0	**.83**	**.67**	**.50**	**.33**
Average time resting in stalls (hr)±SD	14.2±1.5	14.2±1.9	13.2±2.0	10.4±2.0*	6.9±2.0*

*Differs from 1.0 free stall/cow (Dunnett's test).

Choice Tests

Why not give the animal a choice between conditions and see which one(s) it prefers? This approach does not necessarily discern what is stressful or adverse to an animal's welfare, but merely indicates the animal's preference. The choice could be due to comfort or familiarity, especially if the second choice is novel. The influence of prior experience in choice tests was shown by Dawkins (1976). She found that when hens were offered a simultaneous choice between a battery cage and an outside run, birds from battery cages initially preferred cages. Hens given continuous access to both did not show evidence of a preference. Operant conditioning techniques in which the animal indicates its discomfort have the same limitation.

Physiological Measures of Stress

Once a stressor is perceived, physiological changes will occur within the body to help the animal resist stress. The degree and type of physiological measures of stress involve measuring some type of parameter that indicates that the body is responding to a stressor. Many parameters have been used; however, each has only limited application. In order to understand the commonly used physiological measures of stress, we must understand the changes in physiology that occur in a stressed animal.

Figure 1 is a simplified diagram of the major pathways by which an animal initiates physiological responses that are associated with stress. Neutral pathway A influences the body almost immediately whereas neural endocrine pathway B

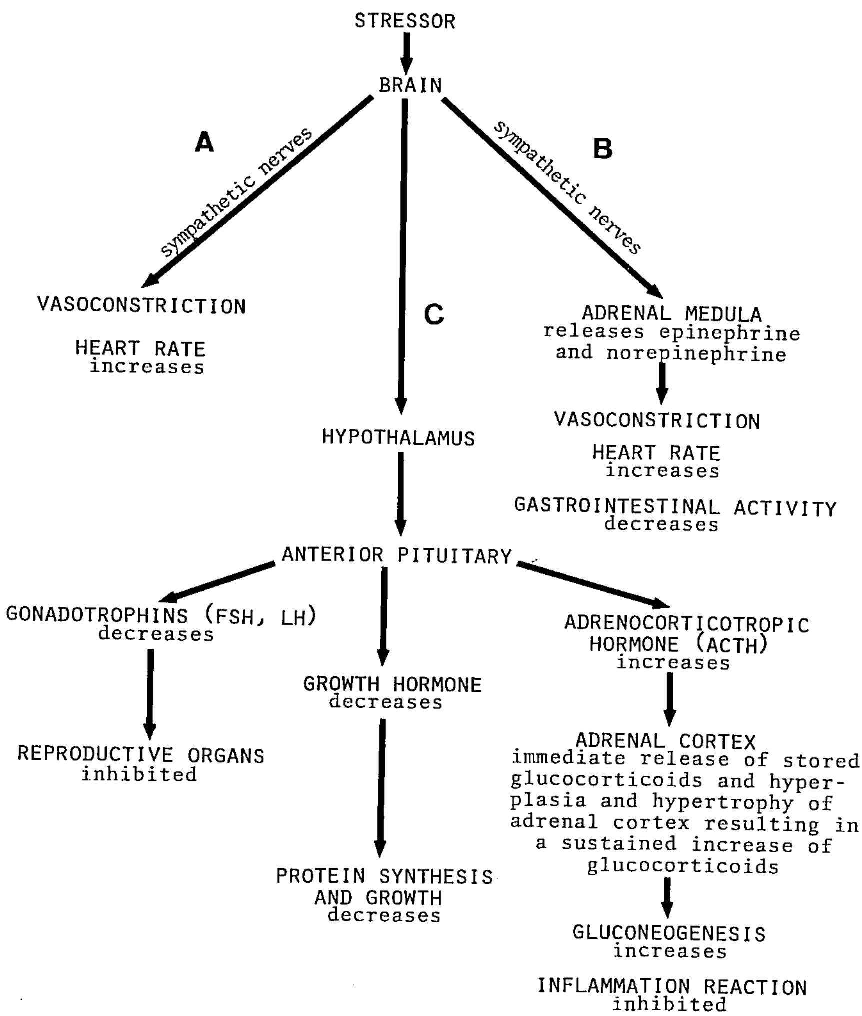

FIGURE 1— Major pathways by which an animal responds physiologically to stressors.

may have a lagtime of several seconds. Vasoconstriction stimulated by these pathways causes an increase in blood pressure and a reduction of body surface temperature (less blood near the surface of the skin). Along with these changes, increased heart rate, respiration rate, and occurrence of ulcers (due to interference with normal digestion) have been used to measure stress. These pathways react rapidly, making them indicators of short-term stress. However, heart rate, blood pressure, and respiration are readily influenced by physical activity, which frequently confounds their use as measures of acute stress.

Pathway C is concerned primarily with long-term stress. While stimulation of this pathway occurs immediately, a 48 hr period of continuous stimulation is required before full symptoms appear. Due to alteration of gonadotrophins, such measures as conception rates, embryonic mortality, and irregular estrus can be signs of stress. Due to the suppression of growth hormone, growth rates can also serve as indicators of stress. People involved in livestock production, where reproduction and growth rates are extremely important, should be cognizant of this relationship for economic as well as ethical reasons.

The hypothalamic-pituitary-adrenal cortical axis is vital in enabling an animal to cope with stress (Selye, 1973). Adrenalectomized animals cannot survive even mild physical exertion without glucocorticoid therapy. Several minutes after a stressor commences, stored glucocorticoids are released from the adrenal in response to initial ACTH secretion. The stores are quickly depleted and glucocorticoid secretion returns to low levels until the adrenal undergoes hyperplasia and hypertrophy.

This surge can be measured by obtaining blood samples at close intervals after the onset of stress (Smith *et al.,* 1972). Approximately 48 hrs after initiation of the stress, detectable hyperplasia and hypertrophy of the adrenal occurs (Selye, 1936; Friend *et al.*, 1977a). Increased glucocorticoid secretion then continues until either the stress is removed, adaptation occurs, or adrenal exhaustion occurs and the animal dies (Selye, 1973). Change in adrenal weight has been widely used as an indicator of stress exceeding 48 hrs (Christian, 1961; Selye, 1973), but this requires euthanizing the animal.

Measuring the adrenals' response in the form of glucocorticoid output after a massive dose of ACTH appears to be a good alternative to euthanizing an animal to determine adrenal function. Figure 2 (Friend *et al.,* 1979) shows a change in adrenal output of glucocorticoids for cows kept at different free stall densities. A crowding condition probably occurred (P .01) when the cows (four per treatment) had access to .50 or .33 stalls. This procedure shows considerable promise as a means of measuring long-term stress; however, what occurs during adaptation to long-term stressors requires more research. We are beginning to see trends in unpublished data which indicate that adrenal response decreases to normal levels after one or two weeks of exposure to certain stressors. It is not yet known if the return to normal indicates that the animal has adapted and the condition is no longer stressful or if the hypothalamic-pituitary-adrenal cortical axis is becoming refractory (Selye's "state of exhaustion," 1936). The severity of the stressor is probably a controlling factor in adaptation.

Since the enlarged adrenal releases increased amounts of glucocorticoids, many researchers have presented plasma concentrations of glucocorticoids as a measure of stress. However, there is a problem in interpreting plasma concentra-

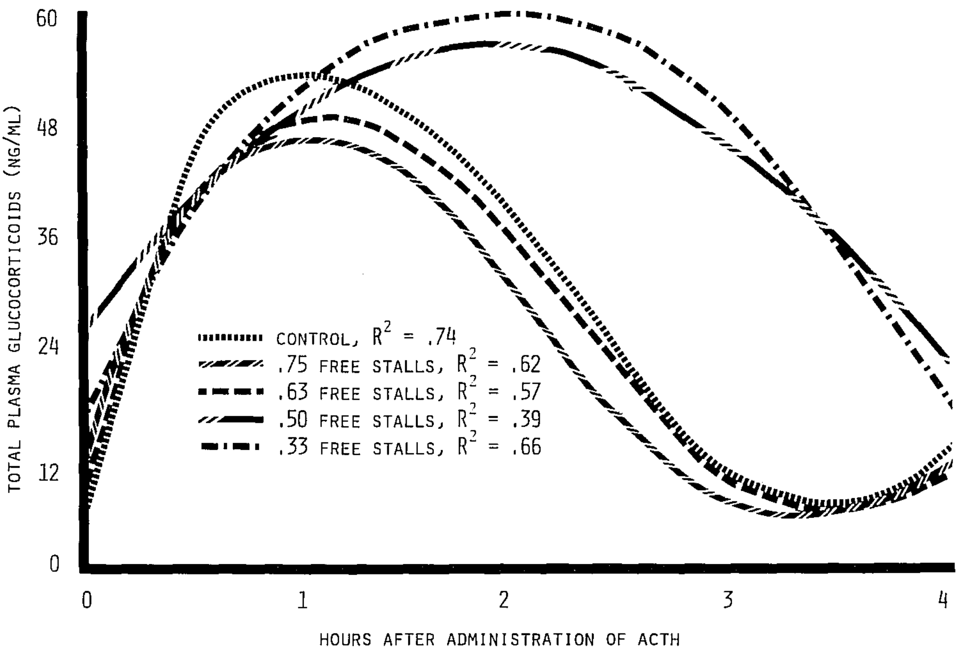

FIGURE 2—Adrenal output of glucocorticoids after a massive dose of adrenocortocotropin (1.98 IU ACTH per kg body weight $^{.75}$) in cows under different free stall stocking rates (Friend *et al.*, 1979).

tions of any hormone. What is present in the blood is a product of secretion and clearance. Without knowing turnover rate, blood concentrations of any hormone are poor indicators of what is actually occurring. For example, Christison and Johnson (1972) showed that under conditions of prolonged heat exposure, adjustments are made in turnover rate of glucocorticoids.

The effects of glucocorticoids on the body are very complex and are the object of considerable study. Figure 1 lists two effects that have been well documented. Glucocorticoids are known to be gluconeogenic; therefore, researchers can relate changes in plasma glucose to the occurrence of stress (Pearson and Mellor, 1976). The anti-inflammatory effect of glucocorticoids and the resulting change in resistance to standardized disease challenges also serve as measures of stress (Gross and Colmano, 1969; Gross, 1972). Animals that have been transported long distances often show a high incidence of disease. "Shipping fever" is considered a major problem in the cattle industry.

Discussion

The common anthropomorphic approach of assessing an animal's welfare by attempting to place oneself in an animal's situation as one perceives it lacks credibility. Each species lives in a totally different *Umwelt* (a term to describe the world around a living organism as that creature experiences it). Differences in perception (sight, taste, smell, touch, hearing), sense of time, experience and genetic factors can make what would appear idyllic to human beings exceedingly stressful to another animal and vice versa. People's opinions about various species are also greatly influenced by experience and education (Kellert, 1980).

At present we do not have a simple, all-inclusive technique for determining when an animal is being stressed. The use of behavioral observations alone could easily lead to erroneous conclusions. Techniques based solely on physiological changes must be thoroughly evaluated for their applicability to the situation. An integrated approach combining behavioral observations with physiological data is more credible. For example, even though the free stall behavioral data presented earlier quantified a significant change in behavior, it was the concurrence of the physiological data that gave it credence.

Physiological parameters, especially hormone determinations, are expensive and time consuming. A practical alternative for many situations would be to use physiological data to establish whether a behavioral observation is indicative of stress and then to use that behavior (or change in behavior) as a measure of stress in comparable situations.

There has been very little research directed toward developing an objective method of assessing stress. Most of what is known is drawn from work with other objectives. People have become interested in this area only relatively recently, and financial support for such work in farm animals in the United States is still negligible.

Acknowledgements

The author appreciates the assistance of G.R. Dellmeier in the organization and editing of the manuscript.

References

Brambell, F.W.R. (1965) Chairman. Report of the Technical Committee to inquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems. H.M.S.O.

Christian, J.J. (1961) Phenomena associated with population density, *Proc Nat Acad Sci 47:*428-449.

Christison, G.I. and Johnson, H.D. (1972) Cortisol turnover in heat-stressed cows, *J Anim Sci 35:*1005-1010.

Dawkins, M. (1976) Towards an objective measure of assessing welfare in domestic fowl, *App Anim Ethol 2:*245-254.

Fritschen, B. (1978) Tailbiting in pigs, *Confinement 3(2):*11.

Fraser, D., Ritchie, J.S.D. and Fraser, A.F. (1975) The term "stress" in a veterinary context, *Brit Vet J 131:*653-662.

Friend, T.H., Polan, C.E., Guazdauskas, F. and Heald, C.W. (1977*a*) Adrenal glucocorticoid response to exogeneous adrenocorticotropin mediated by density and social disruption in lactating cows, *J Dairy Sci 60:*1958-1963.

Friend, T.H., Polan, C.E. and McGilliard, M.L. (1977*b*) Free stall and feedbunk requirements relative to behavior, production and individual feed intake in dairy cows, *J Dairy Sci 60:*108-116.

Friend, T.H. Guazdauskas, F. and Polan, C.E. (1979) Change in adrenal response from free stall competition, *J Dairy Sci 62:*768-771.

Goldstein, A. (1976) Opioid peptides (endomorphins) in pituitary and brain, *Science 193:*1081-1086.

Gross, W.B. (1972) Effect of social stress on occurrence of Marek's disease in chickens, *Am J Vet Res 33:*2225-2279.

Gross, W.B. and Colmano, G. (1969) The effect of social isolation on resistance to some infectious diseases, *Poult Sci 48:*514-520.

Haugse, C.N., Dinussen, W.E., Erickson, D.O., Johnson, J.N. and Buchanan, M.L. (1965) A day in the life of a pig, *N Dak Fm Res 23:*18-23.

Hediger, H. (1950) *Wild Animals in Captivity,* Butterworths Scientific Publications, London, UK, pp 207.

Kellert, S.R. (1980) American attitudes toward and knowledge of animals: an update. *Int J Stud Anim Prob 1:*87-119.

Moberg, G.P. (1976) Effects of environment and management stress on reproduction in the dairy cow, *J Dairy Sci 59:*1618-1624.

Pearson, R.A. and Mellor, D.J. (1976) Some behavioral and physiological changes in pregnant goats and sheep during adaptation to laboratory conditions, *Res Vet Sci 20:*215-217.

Peters, M. (1977) Hypertension and the nature of stress, *Science 198:*80.

Selye, H. (1936) A syndrome produced by diverse nocuous agents, *Nature 138:*32.

Selye, H. (1973) The evolution of the stress concept, *Am Scientist 61:*692-699.

Smith, V.G., Convey, E.M. and Edgerton, C.A. (1972) Bovine serum corticoid response to milking and exteroceptive stimuli, *J Dairy Sci 55:*1170-1173.

Van Putten, G. (1969) An investigation into tail-biting among fattening pigs, *Brit Vet J 125:*511-516.

Wood-Gush, D.G.M., Duncan, I.J.H. and Fraser, D. (1975) Social stress and welfare problems in agricultural animals. In *The Behavior of Domestic Animals,* 3rd ed. E.S.E. Hafez, ed, Williams and Wilkins Co, Baltimore, MD, pp 182-200.