OPERANT STUDIES ON THE BEHAVIOR OF PIGS AND SHEEP
IN RELATION TO THE PHYSICAL ENVIRONMENT

B. A. Baldwin

Agricultural Research Council, Institute of Animal Physiology,
Babraham, Cambridge, England

Summary

An outline is given of the use of operant conditioning techniques in the study of the behavior of farm animals. Using operant methods, pigs and sheep placed in cold environments have been trained to perform simple responses in order to obtain radiant heat. Factors which influence this behavior such as level of nutrition, ambient temperature and the intensity of the radiant heat have been examined. The effect of warming or cooling the hypothalamus on the motivation to work for heat production has been studied. Experiments are also described in which, using operant methods, an attempt has been made to determine the illumination preferences of pigs and ruminants.

(Key Words: Operant Conditioning, Behavior, Thermoregulation, Illumination Preference, Sensory Reinforcement.)

Introduction

The environment of a farm animal may be considered to be composed of three main components which are indicated below.

1. The Physical Environment—temperature, illumination, type of floor, ventilation, et cetera.

2. The Social Environment—presence or absence of other animals, dominance hierarchies, group size and composition, et cetera.

3. The Managerial Environment—the diet, weaning systems, feeding regimen, et cetera.

Of the three main components mentioned above, the physical environment most readily lends itself to objective study by means of behavioral preference tests and measurements of the motivation to obtain a particular environmental situation. By means of operant conditioning techniques, the details of which are outlined below, it is possible to "ask the animal" what kind of physical environment it prefers. However, it must always be noted that the environmental conditions preferred by an animal may not be those that are economically feasible and it is also probable that the environmental preference of adults may be influenced by their previous environmental experience as has been shown in rats (Roberts et al., 1958). Before considering some of the experimental work concerned with the behavior of farm animals in relation to their physical environment, it is appropriate to explain some of the main features of the operant conditioning methods that are used in this work. For a more detailed exposition see Honig (1966).

In this paper, no attempt has been made to review the many observational studies on the behavior of pigs and sheep in relation to the physical environment (Hafez, 1968; Mount, 1968).

The Use of Operant Conditioning Methods in the Study of Animal Behavior. Operant conditioning is a procedure that will reliably increase the frequency of occurrence of any behavior in the repertoire of an animal. In very general terms, an animal's behavior may cause the appearance of an additional stimulus in its environment or the disappearance of some stimulus that was present in the environment.

If the appearance of a stimulus as a consequence of a behavioral act (response) produces an increased probability of that response occurring in the future, the stimulus is called a positive reinforcer and the process is termed positive reinforcement. If the removal of a stimulus as a consequence of a response results in an increased probability of that response occurring in the future, the stimulus is termed an aversive stimulus or negative reinforcer and the process is known as negative reinforcement. In everyday language, animals will learn to perform particular acts so as to obtain something they want or to remove something they dislike.
If we wish to study many types of behavior quantitatively we must first train our animals to perform a simple response, the occurrence of which we can conveniently measure. For example, if we place a hungry young pig in a small metal cage with a prominent panel switch mounted at one end of the cage, the pig will eventually, during its exploration of the cage, place its snout on or near the panel. When this happens the experimenter delivers a small amount of food to the animal by means of an electronically operated food dispenser. Soon the pig shows great interest in the panel switch and will usually "accidentally" press it and thus operate the feeding device. Once this has occurred the pig usually begins to consistently press the panel in order to obtain food (figure 1). Using pigs that have been trained to press a panel to obtain food we can conveniently study their detailed pattern of food intake by fitting such a device in their pens and recording when the feeder is operated.

Provided an appropriate behavioral response is selected and the animals used are tame, the domesticated farm animals make good subjects for operant conditioning experiments. Goats, sheep and calves have been trained to press panels with their muzzle in order to obtain oats and, using a two panel system in which to obtain food they had to press the panel over which a particular odor was emitted, it has been possible to study their ability to make olfactory discriminations. It has been shown that these ruminants can distinguish between individuals of their own species on the basis of odors, particularly those from urine (Baldwin and Meese, 1977a; Baldwin, 1977).

Goats can be depleted of sodium by means of loss of saliva from a parotid fistula and animals prepared in this manner will learn to press panels in order to obtain salt solutions to drink. Operant methods have proved useful in the study of sodium appetite in goats (Baldwin, 1976) and sheep (Abraham et al., 1973).

Operant Studies on Behavioral Thermoregulation in Pigs and Sheep. Thermoregulatory behavior can conveniently be studied by means of operant techniques. In most experiments animals are placed in cold environments and perform a suitable response in order to obtain heat. In a few studies, rats exposed to hot environments have learned to press levers in order to obtain cool air or showers of water. There is an extensive literature on thermoregulatory behavior (reviewed by Cabanac, 1972; Corbit, 1970; Baldwin, 1974; Satinoff and Hendersen, 1977). Following the initial experiments of Weiss and Laties (1961) with rats, most of the work has been carried out on laboratory animals, but some experiments have been done on pigs and sheep.

The factors that influence thermoregulatory behavior in pigs have been examined in a series of experiments (Baldwin and Ingram, 1967a,b, 1968a,b; Baldwin and Lipton, 1973; Ingram, 1975). Young pigs that were exposed to cold soon learned to press panel switches with their snouts to obtain radiant heat from infrared heaters suspended above their cage (figure 2). When pigs, that had been trained to operate the heaters, were exposed at a range of ambient temperatures from -10C to +40C, it was found that the rate at which they turned on the heaters declined markedly at 25C (figure 3). It has also been shown that young pigs aged 8 to 14 weeks learned to operate infrared heaters at ambient temperatures at 20C, but not at 25C and this finding shows that a marked fall of subcutaneous temperature is not needed to ensure that learning occurs (Baldwin and Lipton, 1973).

The fact that young pigs cease to operate the heaters at ambient temperatures of 25C is of physiological interest because at about this temperature they enter their thermoneutral
zone in which the ambient temperature makes minimal metabolic demand upon the animal (Mount, 1968). Experimental evidence that pigs in cold environments operate radiant heaters so as to reduce their metabolic rate to levels similar to those observed when in their thermoneutral zone has been obtained (Baldwin and Ingram, 1967a; Ingram, 1975). There would be little physiological advantage in operating the heaters at ambient temperatures above 25°C. The main point of behavioral interest in that operant methods enable the accurate determination of the ambient temperature at which trained pigs are no longer motivated to obtain extra radiant heat and may be assumed to be comfortable.

Young pigs that were kept on a low plane of nutrition operated the radiant heaters more often than pigs that were on a high plane of nutrition when both groups were tested at ambient temperatures of 10°C (figure 4) (Baldwin and Ingram, 1968b). These results suggest that hungry pigs feel the cold more markedly than well fed ones.

Behavioral thermoregulation has also been investigated using operant methods, in a group of four young pigs aged 8 to 14 weeks that lived outside in a small hut with an adjoining yard (Baldwin and Ingram, 1968a). A 3 kW set of infrared heaters was suspended over a portion of the yard and was turned on for 6 sec when a pig pressed a switch panel mounted on the wall of the pen near the heaters. The experiments were started during the winter and all pigs in the group learned to operate the heaters. The results obtained showed that the pigs operated the heaters during the daytime, but at night they preferred to huddle together in the hut even though the ambient temperatures were lower at night. This behavior of huddling at night and operating the heaters only during the daytime persisted even when the outside yard and the hut were continuously illuminated for over a week.

In the preceding experiments, in which the pigs spent the nights inside the hut, the possibility arose that, if the switch panel and heaters were placed in the hut, heat might be obtained during the night and daytime. This idea was tested using natural lighting and also when the hut and yard were continuously illuminated. It was found that, under natural illumination, the pigs only operated the heaters during the daytime. However, when the hut and yard were continuously illuminated some reinforcements
were obtained during the night and there was a tendency for the period during which most reinforcements were obtained to change so that the pigs started to operate the heaters later in the morning and continued to do so until about midnight. The above experiments illustrate the use by the young pigs of two types of thermoregulatory behavior, the inate tendency for them to huddle together and the operant behavior of turning on the radiant heaters. It is, of course, possible that there is a learned component in huddling as the piglets would rapidly sense the beneficial effects of their behavior. The physiological effects of huddling, in terms of reducing metabolic rate, have been fully investigated by Mount (1960).

In another series of experiments a group of young pigs that had learned to operate the heaters mounted in the small yard were offered access to a paddock 18 m x 8 meters. It was found that although the overall pattern of responding was similar to that seen when they were in the small yard the number of heat reinforcements received by the pigs, which could move all over the paddock, was greatly reduced. This happened because social interactions or behavior such as rooting in the soil took precedence over operating the heaters. The experiment illustrates the fact that in a complex environment activities such as thermoregulation do not have absolute priority but must compete for precedence with other types of behavior. In natural conditions animals have to seek food, avoid enemies, find mates, etc., and thermoregulatory behavior has to fit into the animals' lifestyle, its importance varying with the prevailing environmental conditions.

Ingram and Legge (1970) studied the thermoregulatory behavior of young pigs living in a natural environment and found that they showed no tendency to shelter and huddle until the ambient temperature fell below 5C. They noted that the pigs did avoid exposure to wind, but did not select areas of their environment that had the highest mean radiant temperature. These results again emphasize that thermoregulatory behavior does not take precedence over other activities until the environmental conditions begin to threaten the animals.

Recently, operant conditioning methods have been applied to the study of thermoregulatory behavior in sheep. In the initial experiments (Baldwin, 1975) a fully fleeced sheep was placed inside a cage fitted with a photoelectric beam so that interruption of the beam, by the sheep's muzzle, provided infrared heating for as long as the beam was interrupted. It was found that, when the sheep lived in the cage for 4 days at an ambient temperature of 5C it very seldom operated the heaters. However, after shearing, the sheep soon learned to operate the heaters (figure 5). Using shorn sheep that had learned to operate the radiant heaters the effect of exposing them at various ambient temperatures has been examined and as can be seen in figure 6, at OC they had the heaters on for about 35% of each 24 hr, while at 25C they used the heaters for only a few minutes per 24 hours.

It has also been demonstrated that sheep can compensate very accurately for changes in the intensity of the radiant heat. The shorn sheep were trained to operate the infrared heaters by interrupting a photoelectric beam with their muzzles and were exposed for 48-hr periods at an ambient temperature of 10C with either 900 Watts of infrared heaters suspended above them or 1800 Watts. As shown in figure 7, the sheep halved the duration of heating obtained when the intensity was doubled. This result illustrates the precision of the neural system controlling thermoregulatory behavior and implies that sheep have very effective peripheral tempera-
BEHAVIORAL THERMOREGULATION AND ILLUMINATION PREFERENCE

Figure 5. The effect of close shearing on the duration of intra-red heating obtained by sheep at an ambient temperature of +5°C. Mean results from three sheep exposed for 6 days. Vertical bars indicate ± SE of mean. (Courtesy: J. Physiol.).

Sheep can be chilled by rapidly loading the rumen with ice-cold water via a fistula. This procedure makes the sheep expend extra energy to raise the water temperature up to body temperature and the energy required is obviously related to the volume of water administered. Experiments have been carried out in which the effect on thermoregulatory behavior of loading the rumen with 1 or 2 liters of ice-cold water have been studied.

The experiments were done with the sheep restrained in a metal stand and operating the heaters by interrupting a photoelectric beam with their muzzle. They were allowed to operate the heaters for a 1-hr control period before the rumen was loaded with cold water. At the end of the control period the rumen was rapidly loaded using a hand pump, with 1 or 2 liters of water at 0 to 1°C. The duration of infrared heating obtained in the 1-hr period following loading was recorded. The experiments were carried out at ambient temperatures of 0, 10, 20 and 30°C and in the case of the 2 liters loading also at 40°C. The results obtained are shown in figures 8 and 9. At ambient temperatures of 0, 10 and 20°C the increment seen after intraruminal loading with 2 liters of water at 0 to 10°C was almost exactly double that obtained with 1 liter loading (compare figures 8 and 9). At an ambient temperature of 30°C loading the rumen with 1 liter of water did not result in the sheep increasing the duration of infrared heating, but a 2-liter load was effective. At an ambient temperature of 40°C even the 2-liter load was ineffective.
Figure 8. The effect of loading the rumen with 1 liter of water at 0 to 1°C at ambient temperatures of 0, 10, 20, and 30°C on the duration of heating obtained by shorn sheep. The unhatched bars indicate the duration of heating obtained in the 1-hr control period preceding loading and the hatched bars indicate the duration of heating obtained in the 1-hr period following loading. Both 1-hr periods are divided into half-hour increments. Mean results from three sheep each tested three times at each temperature. Vertical bars indicate SE of mean (Courtesy: J. Physiol.).

Figure 9. The effect of loading the rumen with 2 liters of water at 0 to 1°C at ambient temperatures of 0, 10, 20, 30, and 40°C on the duration of infrared heating obtained by shorn sheep. The unhatched bars indicate the duration of heating obtained in the 1-hr control period preceding loading and the hatched bars indicate the duration of heating in the 1-hr period following loading. Mean results from three sheep each tested three times at each temperature. Vertical bars indicate SE of mean. (Courtesy: J. Physiol.).

The Neural Control of Behavioral Thermoregulation. In studies on the neural control of thermoregulatory behavior the usual experimental method has been to apply localized thermal stimulation (warming or cooling) to those parts of the brain that are known to be concerned in temperature regulation and see whether this procedure altered the rate at which animals worked to obtain heat. Following the initial experiments of Satinoff (1964) with rats, experiments of this type have been carried out on a large number of species including monkeys (Adair et al., 1970), baboons (Gale et al., 1970), pigs (Baldwin and Ingram, 1967b), sheep (Baldwin and Yates, 1977), lizards (Hammel et al., 1967) and fish (Strømme et al., 1971). In addition to thermal stimulation of localized brain regions the effect of brain lesions (Carlisle, 1969; Satinoff and Rutstein, 1970) or chemical stimulation of the brain (Beckman and Carlisle, 1969; Avery and Penn, 1973; Crawshaw, 1973) on operant behavioral thermoregulation have also been studied. Much of the recent literature on the neural control of thermoregulation is summarized by Satinoff and Hendersen (1977), and in the present paper the emphasis is on studies in which sheep or pigs were used.

The effect of heating and cooling the preoptic region of the hypothalamus on the rate at which trained pigs operated infrared heaters has been investigated (Baldwin and Ingram, 1967b). The pigs had metal “thermodes” implanted in the preoptic region of the hypothalamus so that
this region could be cooled or warmed during operant thermoregulatory behavior. The effects of cooling the preoptic region were examined at various ambient temperatures between 0°C and 35°C. When the pigs were at low ambient temperatures the rate at which the heaters were turned on increased during central cooling, while in a thermoneutral environment at 25°C the pigs often only operated the heaters during central cooling. At the higher ambient temperatures of 30 and 35°C cooling the preoptic region was an ineffective stimulus in about one-half the trials. Warming this region decreased the rate at which the heaters were turned on at low ambient temperatures, but the effects were not as marked as the increases seen during central cooling. The effects on operant thermoregulatory behavior of cooling the anterior spinal cord in the pig have been studied by Carlisle and Ingrain (1973). They found that spinal cooling increased the response rate, but the effects were not as marked as those seen during cooling of the preoptic region.

The neural control of thermoregulatory behavior in sheep has been examined by Baldwin and Yates (1977). Shorn sheep were trained to press panels with their muzzles in order to obtain infrared heat. At ambient temperatures of 5, 15, 25 and 35°C cooling the preoptic region by means of an implanted thermode for periods of 20 min resulted in a marked increase in the rate at which the heaters were used. The relationship for trials conducted at 15 and 25°C is shown in figure 10. At ambient temperatures of 25 and 35°C the absolute size of the response to cooling was less than that seen at 15°C and this reduction indicates that a warm peripheral input can reduce the behavioral effects of hypothalamic cooling.

The effect of warming the preoptic region by means of an implanted thermode has also been studied and at ambient temperatures of 5 and 15°C warming the hypothalamus caused a considerable reduction in the response rate (figure 11). An inherent problem, when using implanted metal thermodes to alter hypothalamic temperature, is that the neural tissue adjacent to the thermode is subjected to abnormal temperatures when the thermode is heated or cooled. It is therefore possible that some of the effects on behavioral thermoregulation are due to unphysiological levels of thermal stimulation applied to temperature sensitive neurons. In order to determine whether lowering brain temperature by 1°C could produce changes in thermoregulatory behavior similar to those obtained using thermodes, a method has been devised for the intracarotid injection of cold saline while the sheep pressed a panel to obtain infrared heat.

At ambient temperatures of 15, 25 and 35°C the cephalic region was cooled by intracarotid injections of cold normal saline for periods of 15 minutes. Hypothalamic temperature fell by about 1°C and increases were seen in the rate at which the heaters were used which were similar to those observed when the thermodes were cooled. To elicit large increases in the rate at which the radiant heaters were used, it was not...
necessary to lower hypothalamic temperature outside the normal range. Intracarotid injections of saline at body temperature had no effect on response rate (figure 12).

It is known that thermal stimulation of the medullary region can influence behavioral thermoregulation in rats (Lipton, 1971, 1973) but experiments of this type have not been carried out on other species.

The study of the neural control of behavioral thermoregulation provides an excellent model for the investigation of the physiological basis of motivational processes as the relevant biological stimulus can be applied to the central and peripheral receptor systems and the effect on behavior observed.

Studies on Sensory Reinforcement and Illumination Preference in Pigs and Ruminants. Rats and mice placed in darkness learn to perform operant responses in order to obtain illumination and the literature on this behavior has been reviewed by Kish (1966). The term sensory reinforcement is usually applied to the demonstration of the reinforcing properties of stimuli, such as light, that are unrelated to primary needs such as food, water or warmth.
In intensive husbandry systems the level of illumination provided for pigs and calves is of interest to those concerned with animal welfare. Recently, operant methods have been used to determine illumination preferences in pigs (Baldwin and Meese, 1977b) and also sheep and calves (Baldwin and Start, 1978).

In the experiments on illumination preferences in pigs the animals were individually housed in a metal pen situated inside a sound proof room. The pigs were placed in the pen in darkness. In one wall of the pen were two adjacent slits through which the pig could place its snout. Both slits contained infrared beams, and it was arranged such that when one beam was interrupted the room lights came on and remained on until the other beam was interrupted (the equivalent of an on/off switch). The pigs remained in the pen for a 2-day period and the position of the “on” and “off” beams were alternated each day in order to avoid position preferences. The total duration of light obtained each hour was rated to the nearest second. As can be seen in figure 13, the pigs tended to keep the light on for a mean of 72% of the time and there was no obvious tendency for the pigs to leave the lights off for prolonged periods. The results indicate a definite preference for light over darkness.

In the experiments on the reinforcing properties of light, the pigs were placed in the darkness in the pen containing two slits, and it was arranged that when one beam was interrupted the room lights came on for as long as the beam was interrupted. When the pig put its snout through the other beam, it had no effect on the lights but the duration of interruption of the “control” beam was noted. It was found that the pigs only had the lights on for about .5% of the possible time. However, they interrupted the “stimulus” beam for significantly longer periods than the “control” beam (mean values per 24 hr of 133 ± 26 sec for the stimulus beam compared with 57 ± 17 sec for the control beam, P<.001). Results indicate that the light was only a weak reinforcer to pigs kept in darkness. It appears that, although pigs prefer light to darkness, they are not highly motivated to perform operant responses to obtain light.

Similar techniques have been used to study illumination preferences in sheep and calves (Baldwin and Start, 1978). The sheep lived in the test pen for a 5-day test period and were provided, using the infrared beam system, with an “on/off” switch. The mean duration of lighting obtained per 24 hr was 1,175 ± 100 min (82% of 24 hr). No obvious circadian pattern of lighting was seen.

The above examples illustrate the value of operant methods in the evaluation of illumination preferences in farm animals. They can provide an objective means of “asking the animal” what its environmental preferences are, and the information can be of value in the design of husbandry systems.

Literature Cited


