METHODS FOR MEASURING FEEDING MOTIVATION IN SHEEP

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Abstract *Animal Welfare 1999, **8:** 53-63*

The effects of food restriction on the welfare of sheep are as yet unclear. An operant crate and a push-door were used to measure feeding motivation in sheep after 0h, 6h, 12h, 18h and 24h without food. In experiment 1, sheep had to push a panel with their noses to obtain a food reward. In experiment 2, sheep had to run a race and push through a weighted door to reach food; the time taken to reach various points was recorded and the work performed to push through the door was calculated.

In experiment 1, 3 out of 12 sheep became trained to push the panel and there was a difference in the mean number of rewards/session obtained by each animal ($P < 0.05$). There was no effect of treatment on the number of panel presses performed. In experiment 2, 10 out of 14 sheep were successfully trained. More sheep went through the push-door when deprived of food ($P < 0.05$), and they were quicker to enter the race, reach the push-door, and reach the food than those which had not been deprived ($P < 0.0001$). They also spent less time pushing the door than non-deprived sheep ($P < 0.0001$).

The push-door was a more appropriate method of measuring motivation to feed in sheep, as more sheep learned the task in less time than for the operant crate. As measured by the time taken to enter the race, reach the push-door, push through the door and reach the food there was an increase in feeding motivation after only 6h without food.

Keywords: *animal welfare, behaviour, food deprivation, sheep*

Introduction

Sheep can be exposed to long periods of food deprivation during transport and when held at markets and slaughterhouses. After a 15h journey by road, sheep spent an increased amount of time feeding during the first 12h after unloading compared with the equivalent period pre-transport (Cockram *et al* 1996). This would suggest that feeding has a high priority after a period of food deprivation and transport, but little is known about the motivation of sheep to feed after periods of food deprivation.

When Dumont and Petit (1995) exposed sheep to 24h and 16h fasts, they found that after fasting sheep would consume larger quantities of a readily available poor quality hay, but that there was no effect on the intake of a higher quality hay for which they had to work (by walking around an arena). This demonstrates an effect of food deprivation on food selection, increasing the acceptability of lower quality forage, which may suggest an increased motivation to feed.

Operant conditioning has been used to investigate feeding motivation in a variety of species, using the level of response as a measure of the feeding motivation. Examples can be found for a number of species including pigs (Lawrence *et al* 1988; 1989; Lawrence & Illius 1989), rats (Miller 1955; Teitelbaum 1966), and poultry (Duncan *et al* 1970; Duncan & Hughes 1972). Other methods include aversion tests, for example using food adulterated with increasing concentrations of quinine. In rats, increasing the length of food deprivation was found to increase the concentration of quinine that would be tolerated in the food (Miller 1955).

The measurement of motivation has become increasingly important in animal welfare as it attempts to provide objective measurements of subjective states. Two experiments were performed to find an appropriate technique for measuring feeding motivation in sheep. The first experiment used operant conditioning to investigate the feeding motivation after food and/or water deprivations of up to 24h (the maximum continuous journey time allowed under current EU regulations [European Council 1995]). Sheep were trained to press a panel with their noses to obtain small amounts of whole oats as a measure of this motivation.

The second experiment used a push-door, a method that has been employed with chickens to assess a number of motivational strengths (Duncan & Kite 1987; Petherick & Rutter 1990). The response required is primarily locomotion, and is more closely associated with foraging behaviour than that of experiment 1. This experiment examined the strength of the feeding motivation in sheep after deprivation times of up to 24h, using the time taken to pass through the push-door and the work performed in opening the push-door as a measure of their motivation to feed.

Experiment 1- The feeding motivation of sheep after food and/or water deprivation

Materials and methods

All experiments and procedures described in this paper were carried out under Home Office licence (individual licence details are unavailable for reasons of confidentiality).

Animals

Twelve, group-housed Suffolk ewes aged between 2 and 4 years were used. They had previously been gentled (see below) and were offered *ad libitum* hay with concentrate supplement (250g sheep^{-1} of a commercial ewe supplement fed at 0700h). The sheep were trained to use an operant crate that had previously been used with rams (Blisset *et al* 1990), in which they had to push a panel with their noses to obtain a reward of 10g whole oats.

Gentling

The sheep were given 2h exposure to the handler every day for 3 weeks, with the handler sitting passively in the home pens. When a sheep approached the handler, a handful of whole oats was offered and, as the sheep approached and fed more readily, the handler gently stroked the sheep across the shoulders/back (the head area was avoided as this is thought to

be the most guarded area of personal space). This continued until the sheep readily approached the handler and did not react to being touched.

Training

Initial training allowed sheep to familiarize themselves with the equipment. They were placed in a deprivation pen with a non-experimental 'buddy' sheep (another sheep from the home pen, so that the experimental sheep was not isolated) in the adjacent pen (Figure 1), and allowed to enter the operant crate as they wished. Pellets were fixed onto the panels to encourage the sheep to approach and investigate. The sheep were given 20 training sessions over an 8-week period. Each training session lasted up to 3h during which time they had free access to the crate which was left running on a training programme, starting at a fixed ratio schedule (FR) of one and increasing by one after every 10 rewards. This continued up to FR10. Once FR10 was reached, the sheep were observed as they worked the panels to ensure that they were pushing the panels reliably (ie pushing the panel with the muzzle, not inadvertently hitting it). When they had reached this stage, they were considered to be fully trained.

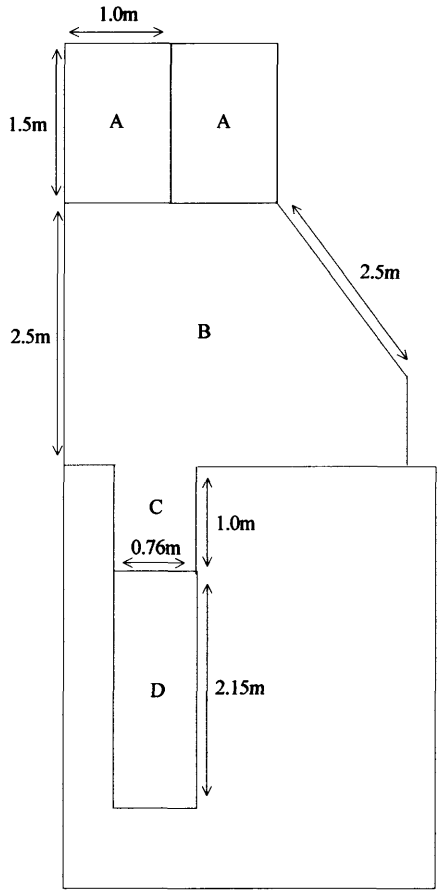

Figure 1 **Plan of deprivation pens and crate (A – deprivation pens, B – test area, C – ramp, D – operant crate).**

Procedure

At 0800h on treatment days, the sheep were placed in a deprivation pen bedded with woodshavings, with a 'buddy' sheep in the adjacent pen (Figure 1). Each sheep was exposed to four treatments: a control involving no deprivation (FW); food with no water (F); water with no food (W); no food and no water (N) – for each of four deprivation lengths (6h, 12h, 18h and 24h) in a random order. The sheep were exposed to one treatment and one deprivation length each week. A 6-day interval was allowed between treatments to enable complete recovery from the periods of food and water deprivation (Knowles *et al* 1993). It was decided to start the deprivations at the same time of day rather than complete them at the same time so that the sheep were in a similar physiological state at the start of each period of food deprivation. As work by Cockram *et al* (1997) found that following a 12h food deprivation sheep spent a large proportion of time feeding at a time of the day when feeding is usually limited (Lynch *et al* 1992), deprivation would initially seem to overcome any effect of time of day on feeding behaviour.

On completion of the deprivation period (at 1400h, 2000h, 0200h or 0800h), the sheep were placed in the test area (Figure 1), and given free access to the operant crate for 1h, with the crate running on a progressive ratio schedule, starting at one, and increasing by steps of two after each reward. A session was considered finished when there was an interval between pushes exceeding 2min. On completion of testing, the sheep were returned to the deprivation pen until 24h had elapsed from the start of the treatment. The sheep were then returned to their home pen. This was done so that no association between the completion of testing and being returned to the home pen was learned.

Statistical analysis

The mean number of rewards per session was analysed using a two-way ANOVA within SAS, version 6 (SAS Institute Inc, Cary, USA), using a General Linear Model procedure as the experiment was unbalanced with a different number of animals in some treatments (Hatcher & Stepanski 1994). The analysis examined the effects of treatment and length of deprivation. Where significant effects were found, Tukey's Studentized Range (HSD) test was used to examine differences between pairs.

Experiment 2- The feeding motivation of sheep after food deprivation using a push-door

Materials and Methods

Animals

Fourteen 'gentled' ewes (see experiment 1) aged between 2 and 4 years and housed in pairs, were trained to use an unweighted push-door to reach hay (Figure 2). Eleven of the sheep had been used 8 months previously in experiment 1. During the 8 months between experiments, all sheep had been at pasture and exposed to minimal handling. The sheep were gentled using the same procedure as for experiment 1, using concentrate pellets in place of whole oats. Sheep that had been used previously were gentled in less time than those which were naive of the handler. The sheep were then allocated to experimental pairs (with the restriction that they could not be paired with their pen mate, as this would be their 'buddy' during testing since it was the sheep most familiar to them).

Training

Training initially involved familiarizing the sheep with the race layout (Figure 3). They were left in the holding pen for 2h with continual access to the reward pen through the open push-

door. Each pen measured 2.5x1.0 m. Hay was available in the reward pen, with water in the holding pen. Following this, the sheep were given training sessions consisting of 15 presentations at the door. The push-door was gradually closed over the training period, each half of the door being closed by a quarter after five successful passes. This was continued until they had completed 10 consecutive passes through the closed push-door, when they were considered to be fully trained. Throughout training, the pen mate was in the 'buddy' pen (Figure 3). There was no difference between the number of training sessions required for sheep that had been used in experiment 1 and the new sheep.

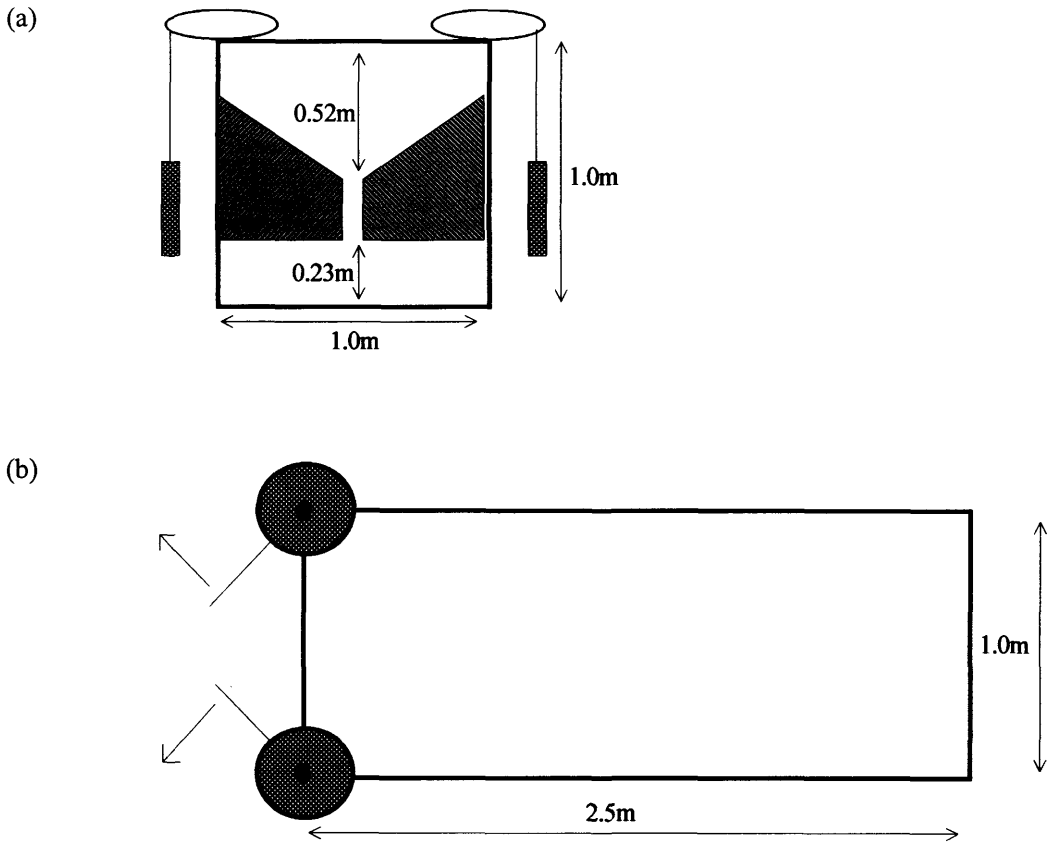

Figure 2 **(a) Push-door and weights; (b) aerial plan of push-door and race.**

Procedure

Six treatments were used: no food deprivation with no food reward, tested after 6h (control 1); no food deprivation with a food reward, tested after 24h (control 2); 6h food deprivation; 12h food deprivation; 18h food deprivation; and 24h food deprivation. These treatments were paired to allow two sheep to be tested each day with an interval of at least 12h between testings to allow the sheep to settle after any disturbance caused by one of the pair being tested. Each pair was then exposed to the pairs of treatments in a random order. A 6-day interval between treatments was allowed, as for experiment 1.

At 0800h experimental sheep were placed in deprivation pens (Figure 3) bedded with wood-shavings and containing water. On completion of a treatment, one sheep was moved to the holding pen and their pen mate was moved to the 'buddy' pen (Figure 3). The experimental sheep was then released into the race. The times taken to enter the race, reach the push-door, open the push-door and reach the food, as well as the distance the weights were moved by the sheep pushing through the door were recorded.

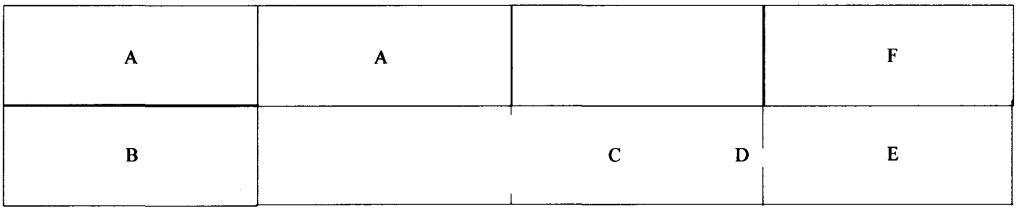

Figure 3 **Plan of pen layout. A – Deprivation pens, B – Holding pen, C – Race, D – Push-door, E – Reward pen, F – 'Buddy' pen.**

On reaching the reward pen, a sheep was allowed to feed from *ad libitum* hay for 1min, after which it was returned to the holding pen. This was repeated for five weightings of the push-door (unweighted, +4.4kg; +8.8kg; +13.2kg and +17.6kg). The maximum weight used was around one-third of the liveweight of the sheep. Sheep were then returned to the deprivation pen until 24h had elapsed from the start of the treatment, after which they were returned to their home pen. The sheep were returned to the deprivation pens so that no association between the completion of testing and being returned to the home pen was learned. While in the deprivation pens both control treatments had access to *ad libitum* hay.

Statistical analysis

Chi-square tests were performed on the percentage of sheep that were successful/ unsuccessful at passing through the door, comparing food-deprived treatments with non-deprived treatments, and control 1 with control 2.

For the treatments involving food deprivation, the rate at which the sheep worked to push through the door was calculated from the distance the weights were moved, the time spent pushing the doors and the added weight (Abbott 1978). Analyses of the times taken to perform each procedure and the rate at which the sheep worked to push through the door were made using a two-way ANOVA using a General Linear Model procedure as the experiment was unbalanced (Hatcher & Stepanski 1994). The analyses examined the effects of treatment and weight added to the push-door. Where significant effects were found, Tukey's Studentized Range (HSD) test was performed to examine differences between pairs. Due to the absence of work to obtain feed in most of the control sheep (few control sheep moved through the push-door), only the four deprivation treatments were examined in this analysis.

Results

Experiment 1

Only 3 out of the 12 sheep became fully trained. Figure 4 shows the mean number of rewards/session for all treatments for the three sheep that were trained. There was no effect

of either the presence of water during food deprivation or length of deprivation on the mean number of rewards/session. There was high individual variation in the mean (± SEM) number of rewards/session when taken over all 16 experimental sessions (eg sheep 1: 29.8 ± 1.36; sheep 2: 19.6 ± 1.00; sheep 3: 11.7 ± 0.79; $P < 0.05$).

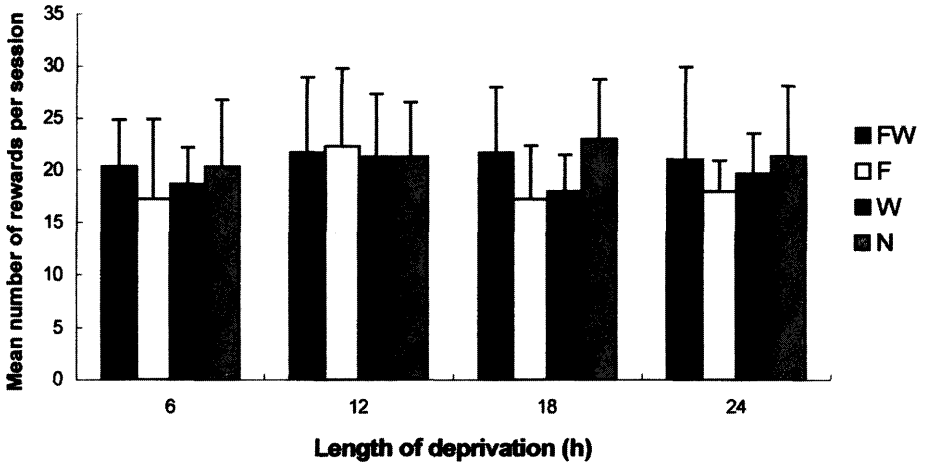

Figure 4 **Mean (± SEM) number of rewards per session obtained by the sheep using the operant crate in experiment 1 after periods of food deprivation. FW – food and water; F – food no water; W – water no food; N – no food no water.**

Experiment 2

Ten out of 14 sheep became fully trained, two of which had not been used in experiment 1. The sheep took an average of 4·5 sessions (minimum 2, maximum 8) over a 3-week period to become fully trained. Figure 5 shows the percentage of sheep passing through the push-door at each weighting. Significantly fewer sheep went through the push-door for control 1 and control 2 than for the food deprivation treatments ($P < 0.05$). More sheep went through the push-door for control 2 than for control 1 ($P < 0.05$).

There was a significant difference in the rate at which sheep worked to push through the push-door at the different weightings, with the mean rate increasing as the weight on the push-door increased ($P < 0.0001$). There was no effect of the length of deprivation, and no interaction between deprivation length and weight on the push-door on the rate at which sheep worked to push through the push-door.

Table 1 shows the mean times taken to reach the race, the push-door, and the food and the mean times spent pushing the push-door for the six treatments. No effect of the weight on the push-door was found on these measurements. Sheep deprived of food were significantly quicker reaching the race ($P < 0.0001$) and the push-door ($P < 0.0001$) than non-deprived sheep. There was no effect of the length of the deprivation on the time taken to complete these tasks by food-deprived sheep. Sheep that had been deprived of food for 12h, 18h and 24h were significantly quicker reaching the food than non-deprived sheep ($P < 0.0001$). Sheep that had been deprived of food for 6h were significantly quicker reaching the food

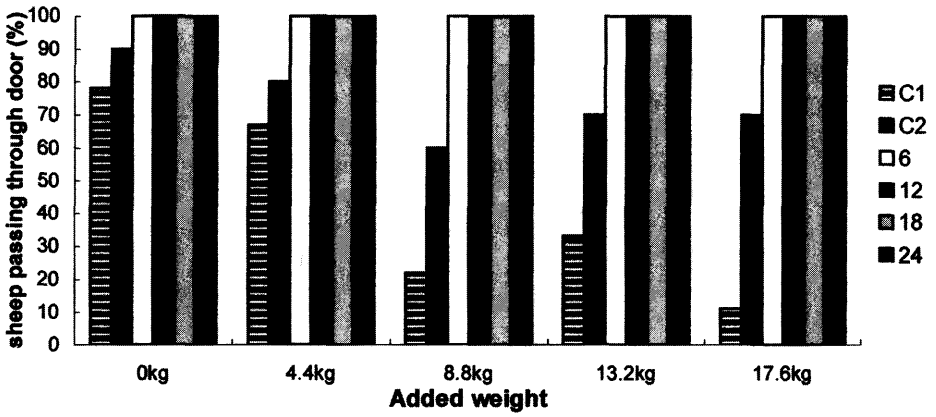

Figure 5 **Percentage of sheep passing through the push-door at each weighting of the push-door for each treatment. C1 – control 1; C2 – control 2; 6 – 6h food deprivation; 12 – 12h food deprivation; 18 – 18h food deprivation; 24 – 24h food deprivation.**

than after the control 2 treatment ($P < 0.0001$). Food-deprived sheep also spent less time pushing the door than non-deprived sheep ($P < 0.0001$). For non-deprived treatments, sheep were quicker to enter the race when there was food in the reward pen (control 2) than in the control 1 condition when there was no food in the reward pen ($P < 0.05$).

Table 1 **Mean (± SEM) times taken by sheep in experiment 2 to reach race, push-door and food, mean time spent pushing the push-door and the mean rates at which food-deprived sheep worked to push through the push-door.**

	Time to race (s)	Time to door (s)	Time to food (s)	Time pushing (s)	Rate of work (J s^{-1})
No food deprivation					
control 1	21.8^{a} (4.46)	12.1^{a} (2.63)	21.5^{ab} (6.34)	3.4^{a} (0.44)	-
control 2	11.7^{b} (2.82)	16.4^{a} (3.96)	30.2^{b} (6.25)	3.2^{a} (0.46)	-
Length of deprivation					
6h	2.9^{c} (0.17)	4.0^{b} (0.18)	12.2^{ac} (2.94)	1.7^{b} (0.07)	34.67 (4.44)
12h	2.5^{c} (0.17)	3.5^{b} (0.15)	5.6^{c} (0.22)	1.4^{b} (0.07)	42.42 (5.10)
18h	2.5^{c} (0.12)	3.6^{b} (0.14)	6.2^{c} (0.29)	1.5^{b} (0.10)	38.62 (4.61)
24h	2.4^{c} (0.08)	3.5^{b} (0.10)	6.9^{c} (1.37)	1.6^{b} (0.18)	42.50 (5.86)

Means in the same column with different lettered superscripts are significantly different ($P < 0.05$).

Discussion

'Buddy' sheep were used in both experiments as isolation is known to be stressful to sheep (Parrott *et al* 1988), and isolation was found to be a problem when training the sheep in these experiments. In experiment 1, leaving the crate open, so that the sheep could enter and leave as they wished, presented them with a choice: remain in visual and partial physical contact with another sheep, or obtain food in the crate. In experiment 2, the 'buddy' was penned next to the reward pen. Fewer sheep went through the push-door when there was no food reward

(sheep could see into the reward pen over the push-door) which indicated that the sheep which pushed through the push-door were working for the food rather than the company of their pen mate.

There were also problems attracting sheep to the panels in experiment 1. Attempts to increase the attractiveness and visibility of the switches did not increase the number of sheep that became fully trained. It has been suggested that incompatibilities between response and reinforcer make it difficult to train animals to make operant responses to obtain rewards (Breland & Breland 1961; Dawkins 1990), and this may explain the lack of success in training the sheep and the large individual variation in responses.

The method used in experiment 2 attempted to overcome this incompatibility between response and reinforcer by using a response more closely related to the feeding behaviour of sheep. More sheep learned the task over a shorter period of time (in less than 1 month as compared with 2 months), and while the three sheep trained to use the crate were also trained to use the push-door, five sheep which had not learned to use the crate were successfully trained to use the push-door. This increase in the ease of training may be a result of the sheep being more accustomed to both the handler and the surroundings, having been trained for the previous experiment. However, two of the four sheep which had not been used in experiment 1 learnt to use the push-door, which would suggest that it was a more appropriate response than pressing panels, as a larger proportion of the population learnt to use the push-door.

Food deprivation resulted in an increase in the number of animals completing the task, and an increase in the speed at which they did so, suggesting an increased motivation to feed exists after only 6h without food. Increasing the length of the deprivation was found to have no effect on the time taken to enter the race, go through the push-door or reach the food. Petherick and Rutter (1990) found hens deprived of food for 12h and 43h also spent the same amount of time pushing to gain access to food, but hens in that experiment were quicker to get through the door after 43h of food deprivation. The door used in that study differed from the one we used in that it was held shut by computer until a required force was reached, then it was released. Those authors felt that this 'unnatural' behaviour of the door could have been mildly aversive to the hens. While the forces exerted upon the push-door used in experiment 2 were less accurately calculated, it behaved more naturally, opening as the sheep pushed against it. This also overcame the problems found by Duncan and Kite (1987) in their hen experiments, in that the force required by the sheep to push the door did not increase as the push-door opened due to the use of bearings.

As increasing the length of deprivation had no effect on any of the measurements taken, this could mean that the motivation of sheep to feed immediately after a period of deprivation is the same after 6h, 12h, 18h and 24h. Alternatively, as it took only a few seconds for the sheep to complete the task, the push-door may not have been sensitive enough to differentiate between the deprivation lengths.

The consumer-demand theory of motivation put forward by Dawkins (1983) suggests that a demonstration of need requires the animal to be willing to experience some cost for the consummatory goal of its motivation. Lawrence *et al* (1989) found the level of food restriction affected how willing pigs were to work for food. In experiment 2, the lower percentage of sheep passing through the push-door in the control treatments than in the food-deprived treatments would suggest that any reward obtained by passing through the push-door did not outweigh the cost of pushing against it. This is consistent with the consumer-demand theory of motivation, as when they were deprived of food all sheep went through the push-door.

In both experiments, the motivation to feed was only measured immediately following a period of deprivation. It was possible that the sheep were equally motivated to feed immediately after the periods of deprivation, but any change in motivation as time proceeds after regaining access to feed may differ depending on the length of deprivation. This temporal aspect of motivation has formed the basis of subsequent investigations.

Animal welfare implications

In both experiments, the sheep were familiar with the experimental conditions. Commercial transportation will involve sheep being fed in novel environments, with food which may be novel. As sheep have been found to be neophobic regarding food in novel environments (Done-Currie *et al* 1984; Burritt & Provenza 1997), if they are not provided with food that they will readily consume during breaks in a journey or post-transport, they may be unable to reduce the increased feeding motivation that has been demonstrated in this study. This may have implications for the welfare of sheep both during and post-transport, as freedom from hunger (and thirst) is one of the Farm Animal Welfare Council's 'five freedoms' (Farm Animal Welfare Council 1994).

The second experiment demonstrated an increase in the motivation of sheep to feed after just 6h without food, but no further increases in the motivation as measured here were seen after deprivations of up to 24h. As transport of sheep may involve periods without food considerably longer than 6h, it is important that the welfare implications of this increased motivation are considered when formulating legal requirements for feeding intervals.

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