Measuring cognition and emotion of animals to understand their welfare

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Abstract

The major knowledge gap in assessing animal welfare is our inability to measure how animals actually feel in the different situations in which we farm them. As animals are unable to speak, we must find ways of gaining insight into their minds. Our animal welfare research at CSIRO includes a focus on understanding the cognitive abilities of animals in order to gain insight into how they feel and to thereby enable us to improve their welfare.

Animals perform better in tests of learning that require skills related to their fitness and survival. For example, grazing animals, such as cattle and sheep perform well in maze tests, indicating they have good spatial memory, which allows them to graze with optimum efficiency. Species that wander across a territory searching for random food sources, such as chickens, pigs and dogs do not perform as well in tests of spatial learning. By understanding the cognitive abilities of different species we can use cognitive principles, based on human psychological theories, to develop scientific approaches for measuring emotive state in animals. An example of this is the assessment of cognitive bias. From the response of an animal to an ambiguous situation we can infer its emotional state. Thus, when an animal is content, it is more likely to assess the ambiguous scenario as potentially delivering a positive outcome. In contrast, when an animal is in an adverse mental state, it is more likely to assess the same scenario as delivering a negative outcome, and respond accordingly.

The paper will describe the application of a range of cognitive tests to sheep. If we understand how animals think and feel, we may be able to do a better job at optimising their welfare.

The Challenge of Measuring Animal Welfare

Society is increasingly concerned with the welfare of animals used for food production and this concern transfers into the product choices consumers make. The science of objective measurement of animal welfare is relatively new. There exist some methods of assessing animal welfare, such as measuring blood variables indicative of changes in physiology or immunology. Studies of animal behaviour have also been used to indicate obvious states such as pain or discomfort, or preferences for different environments, however, the information gained may be relatively limited.

The major knowledge gap in assessing animal welfare is our inability to measure how animals actually feel in the different situations in which we farm them. As animals are unable to speak, we must find ways of gaining insight into their minds. Our animal welfare research at CSIRO includes a focus on understanding the cognitive abilities of animals in order to gain insight into how they feel and to thereby enable us to improve their welfare. The challenge is to achieve this insight into animal mental states in a scientifically rigorous way. In order to measure animal welfare, we need to get animals to demonstrate to us how they feel, and to do this, we need to better measure and understand their cognitive abilities.

Understanding Animal Cognitive Abilities

Cognition is the mental process of knowing, thinking, learning and judging. Learning involves a modification in animal behaviour that occurs as a result of experience. Animals have evolved their cognitive abilities to increase their chance of survival. To highlight some of the concepts we wish to convey in this paper, we will use the sheep as an example. Sheep traditionally and unfairly have had a reputation as being “dumb”. This perception of sheep may have developed from the difficulties of handling individual sheep when conducting routine management practices due to their strong flocking instinct. Sheep have evolved this instinct to increase their chance of survival and help protect them from predators, basically, through safety in numbers.

The assessment of cognitive processes, such as spatial learning and memory has been commonly performed in rats using maze tests, such as the Morris water maze and the radial-arm maze (Hodges, 1996). To further our understanding of the cognitive and learning abilities of sheep, we developed a maze test for sheep. The maze test utilised conspecifics and the strong flocking instinct of sheep as motivation to move through the maze, thereby negating the need for prior training. An 18.4 x 8.2 m outdoor maze was constructed with 1.2 m high opaque external walls and a number of internal barriers (Figure 1). The inner walls were made of open-barred portable fence panels to enable animals to view conspecifics at the opposite end of the maze, thus providing motivation to traverse the maze and join their flock mates. The first time an animal navigates the maze indicates cognitive ability, whereas the improvement in completion time over successive testing indicates learning.

We validated that the maze was measuring spatial memory in sheep by administering scopolamine, a muscarinic receptor antagonist that has been shown to impair memory function (Ferreira et al., 2003). Sheep receiving scopolamine were unable to improve their time to navigate the maze over 3 consecutive days of testing, whereas control animals significantly improved over the 3 days (Lee et al., 2006).

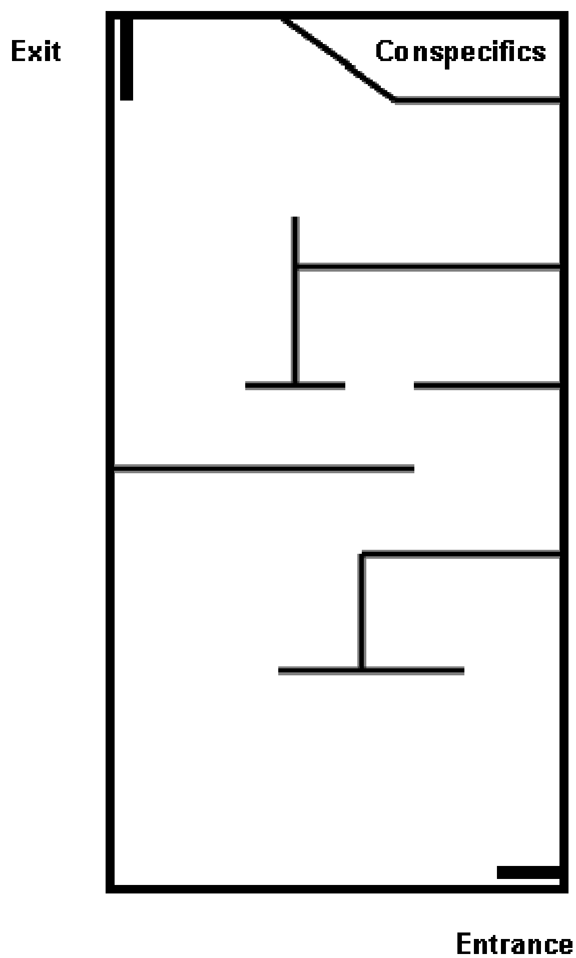
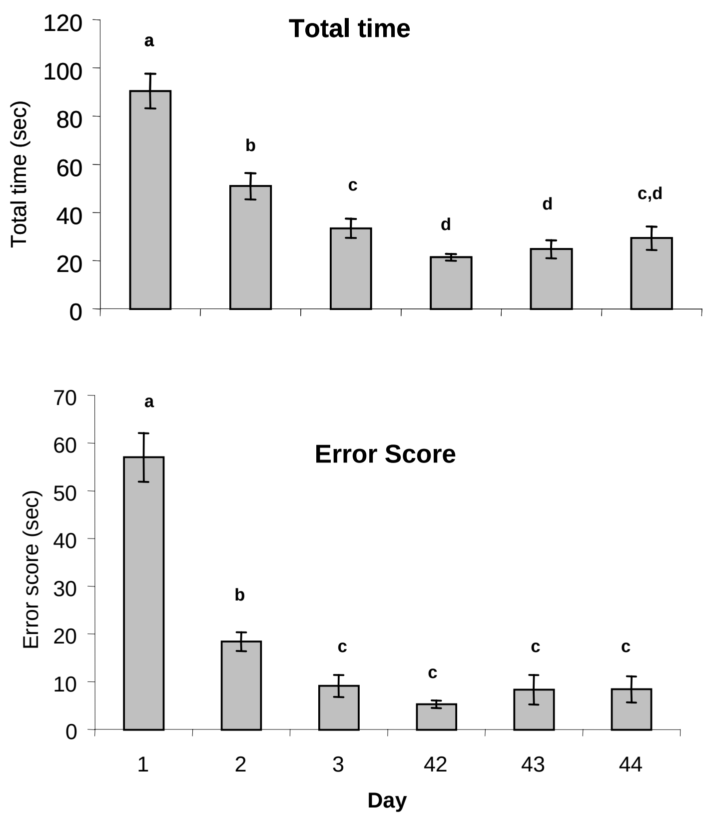


Figure 1. Maze layout

We studied the learning profile of Merino sheep (Figure 2) and found that sheep significantly reduced the total times taken to complete the maze over 3 consecutive days. When sheep were tested 6 weeks later (Days 42, 43 and 44), they improved further and were faster than on Day 3. With experience, the sheep committed fewer errors (the time spent in blind compartments of the maze), improving from Day 1 to Day 3. There was no further improvement in error times when sheep were tested 6 weeks later, with no differences shown between these days or Day 3. In a separate study, when sheep were tested one year later, they were significantly faster to complete the maze, indicating that they did not only retain the memory of the maze but had improved in their performance.



[a,b,c,d] Different superscripts between day are significantly different (P<0.05)

Figure 2. The mean total time to complete the maze and error time (±SEM) for sheep tested on day 1, 2, 3, 42, 43 and 44.

These results show that sheep have the ability to learn and improve their spatial memory of a relatively complex maze, and retain this information for at least a 1 year period. Sheep have excellent spatial memory ability and this can be explained by the Darwinian theory that cognitive ability is related to survival needs. Sheep may have evolved this spatial memory ability to enable them to graze efficiently over wide areas and remember where they had been previously to maximize their feed intake, a necessary skill for their fitness and survival.

Measuring Emotional States using Animal Cognition

By understanding the cognitive abilities of animals we can get them to demonstrate to us how they feel and thereby gain insight into their emotional state. We can use cognitive principles, based on human psychological theories, to develop scientific approaches for measuring emotive state in animals. One such approach, cognitive bias, is the alteration in the interpretation of information due to an individual's mental state. When influenced by a cognitive bias, neutral stimuli will be categorised according to an individual's mental state valence. A positive association is more likely to be generated if a positively valanced mental state is present such as happiness. Similarly a negative association is more likely to be generated from a negative or "depressed" affective state. Current measures of welfare like physiology and behaviour are dependent on the animal's response to a situation. Measuring the cognitive bias of an animal can help to predict how they will respond to a situation or how a situation has altered their mental state

In humans, cognitive bias is measured by providing the subject with an ambiguous stimulus and having them respond verbally using descriptive words or ranking emotions provided to them (Cohen et al. 2003; Paul et al. 2005). This is impossible to do in animals and so innovative methods to deduce the same information need to be developed. Experiments in rats (Harding et al. 2004) and in European starlings (Bateson and Matheson 2007; Matheson et al. 2008) have successfully measured cognitive bias. In all of these experiments, cognitive biases were tested by training the animals to perform different operant tasks and then measuring the behavioural responses to ambiguous cues. These experiments generated different mental states by either enriching the animal's environment (Matheson et al. 2008) or making it unpredictable (Harding et al. 2004; Bateson and Matheson 2007) which generated positively valanced and negatively valanced responses respectively.

Developing a Method of Measuring Emotional State in Sheep

Building on the concept of measuring cognitive bias in rats and starlings, our group took on the challenge of measuring cognitive bias for the first time in a livestock species – sheep. The aim of the study was to develop a method to measure cognitive bias and identify a difference in cognitive bias between control and stressed sheep. Developing a method for sheep proved to be more challenging than we at first envisaged. Initially, we planned to use a similar method to that used in rats using audio cue discrimination (Harding et al., 2004). This involved sheep learning an association between a high frequency audio cue and pressing a panel to receive a food reward, and a low frequency audio cue and pressing a panel to prevent the administration of an aversive white noise. However, we quickly found that rats are very different to sheep in their ability to distinguish audio cues and associate them with events, so we had to think of a sheep-specific method that builds on their specific cognitive abilities.

As discussed in a previous section, we have shown that sheep have well developed spatial memories, so our method used the spatial positioning of a bucket to indicate positive and negative events. To facilitate learning the association between visual cues and a positive and negative event, we used the evolutionary relevant events of a feed reward as the positive event, and their fear of predators as the negative event. The ambiguous cue was a bucket placed at positions between the locations delivering the positive and negative events. In order to test for cognitive bias, we aimed to induce an altered mental state in the sheep by using a previously validated stressor model (Minton and Blecha, 1990). Since a significant amount of the measurement of welfare in farm animals focuses on issues associated with negative welfare this is an important place to start with the research. Minton and Blecha (1990) generated physiological changes associated with acute and chronic stress in lambs by subjecting them to a restraint and isolation stressor (RIS).

Our hypothesis was that the stressed sheep would have a more negatively valanced mental state and therefore their cognitive bias would reflect a more negative interpretation of the ambiguous situation presented to them than unstressed sheep.

Experiment: Cognitive Bias in Sheep

A 2 x 3 x 1.5m wooden box was constructed in order to test for cognitive bias in sheep Figure 3). Twenty ewes were trained to associate the placement of a feed bucket in one corner of a pen with a positive reward on approach; however, when the bucket was in the alternative corner, a negative reinforcer (sight of a dog) was presented. Once animals reached the learning criterion, they were assigned to treatment or control groups. Treatment involved a restraint and isolation stressor for 6 h per day on three consecutive days.

Putative stress-induced cognitive bias was tested by providing ambiguous “probe” buckets in three positions between the positive and negative buckets. The approach behaviour of sheep to the five bucket positions was recorded. Animals were tested 5 times: before RIS, on 3 the consecutive days of treatment and the day after treatment. To avoid directional bias, half the sheep received the positive probe on the left side and the negative probe on the right side each day, and this was reversed for the other half of each group. Cognitive bias responses, plasma cortisol, haematology and behavioural responses in an arena were measured. The arena test is a measure of exploratory behaviour and involved placing an individual sheep in a novel 3 x 8 m yard (divided into 8 zones) and measuring the number of vocalisations and zones crossed in 3 minutes.

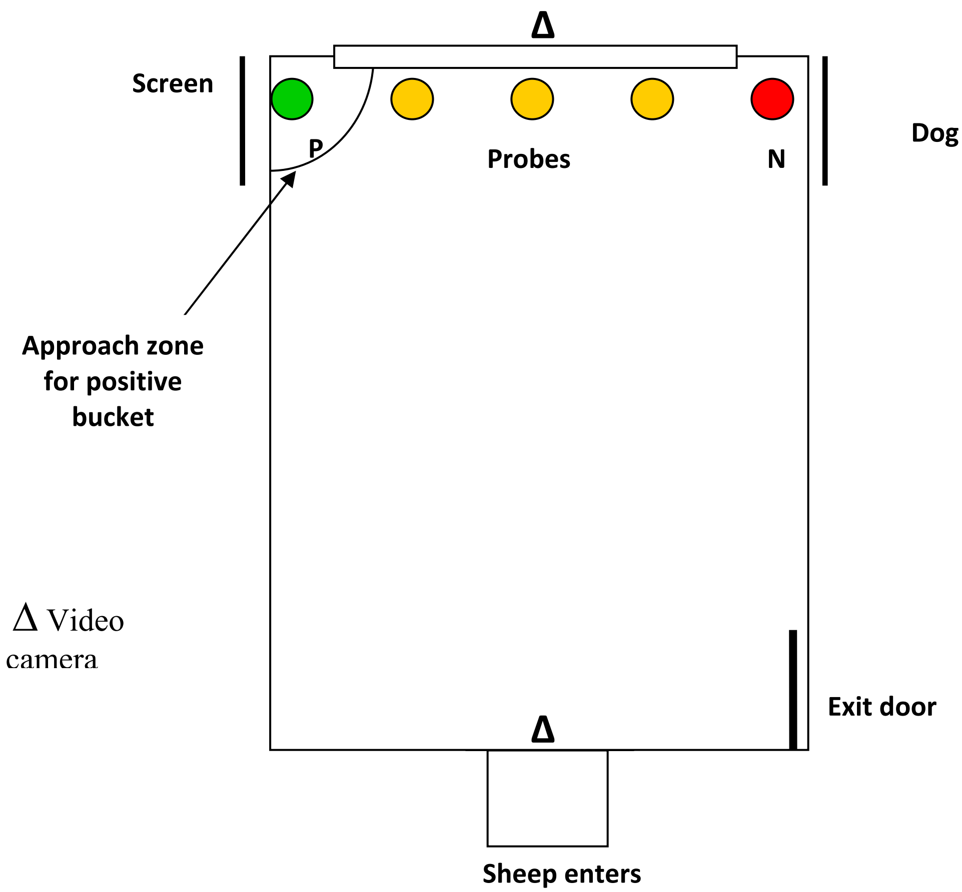


Figure 3. Cognition box showing bucket positions: P = positive (green), probe buckets (yellow), N = negative (red). The approach zone for the positive bucket is an example and an approach arc with the same radius was marked for each bucket position.

The results show that there was a highly significant difference in the time to approach each of the five different bucket positions. This indicates that the sheep had learnt the difference between the positive and negative buckets and that the animals were assessing the three probe bucket positions and responding according to their judgment of the situation. This graduated response provides strong evidence that this method has the potential to measure cognitive bias in sheep. Cortisol concentrations were elevated in RIS sheep compared with Controls ($P<0.05$). Significant treatment differences were seen in the concentrations of white blood cells, neutrophils, lymphocytes and eosinophils. There was a tendency for RIS sheep to vocalize less (2.1) than control sheep (3.5) in the arena test ($P=0.08$). Despite these effects, there was no effect of treatment on the frequency with which sheep approached buckets in any position.

While the stressor model successfully induced a physiological stress response in the sheep, it did not appear to lead to the sheep demonstrating a cognitive bias as measured by our method. A possible explanation could be that as sheep have evolved as a prey species, they are resistant to exhibiting behavioural responses to chronic stressors, as outward displays of weakness may increase their chances of being targeted by a predator. Therefore it could be possible that since sheep hide physical pain and illness they also hide responses to psychologically stressors and do not manifest their cognitive biases through behaviours.

Conclusions

We are only just beginning to develop the scientific basis of assessing animal mental states. If we understand how animals think and feel, we can do a better job at optimising their welfare and improving animal management. This will enable us to farm animals in an ethical way that meets public and consumer expectations. Further research into understanding the cognitive abilities of animals will enable the wider public to gain a greater appreciation and respect for the sentient capacities of our familiar farm animals.

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