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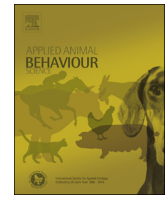

Visual attention and cognitive performance in sheep

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ABSTRACT

Cognitive probes are increasingly being used as an inferred measure of the emotional (and thus welfare) status of the animal. This reflects the bidirectional and interactive nature of emotional and cognitive systems. To date, cognitive paradigms have focused on how the emotional system biases expected outcome of prospective actions within goal-orientated scenarios. Evidence, however, suggests that negative affective state can also modulate attentional mechanisms. Measuring attention alongside other current tests of cognitive bias may provide greater resolution in the measurement of animal welfare. As a starting point for developing cognitive tasks of attentional control, we decided to assess the basic relationship between visual attention and cognitive performance in a farm animal species (sheep).

Variation in visual attention and cognitive performance was sought through testing of four different breeds of upland and lowland sheep (Beulah, Bluefaced Leicester, Texel and Suffolk; n = 15/breed) on a visual attention task and a two-choice visual discrimination task (to measure cognitive performance).

Cognitive performance and visual attention differed significantly between breeds ($F_{3,46} = 4.70$, $p = 0.006$ and $F_{3,5o} = 6.05$, $p < 0.001$ respectively). The least visually attentive breed of sheep (Blue face Leicester) had the lowest level of cognitive performance and the most visually attentive breed (Suffolk) had the highest level of cognitive performance. A weak but significant relationship between vigilance/fearfulness and visual attention was also observed ($t_{44} = 3.91$, $p = < 0.001$; $r^2 = 0.23$) that appeared to adhere to the Yerkes-Dodson law, with both high and low levels of vigilance/fearfulness having a negative effect on visual attention. These results demonstrate a discernible relationship between visual attention and cognitive performance. This provides a basis for further exploring attention systems in the context of changes in animal affective state and thus animal welfare.

1. Introduction

Cognitive probes are increasingly being used as an inferred measure of the emotional and thus welfare status of the animal (Harding et al., 2004; Burman et al., 2011; Gygax, 2014; Hales et al., 2014; Baciadonna and McElligott, 2015; Roelofs et al., 2017). This reflects the bidirectional and interactive nature of emotional and cognitive systems (Banich et al., 2009) where the emotional system is considered to bias the expected outcome of prospective actions within goal-orientated scenarios. Emotional state biases can however affect cognition in ways other than shifts in expected outcome. For example, substantial evidence suggests that attentional mechanisms (and thus cognition) are also highly affected by negative affective state (Eysenck and Derakshan, 2011). Referred to as attentional control theory, bias can occur due to an imbalance between goal-directed and stimulus–driven attentional systems where a negative affective state weakens the former and strengthens the latter to produce a lack of attentional control (Richards et al., 2012). The lateral intraparietal region of the brain appears to be central to these competing attentional mechanisms and is often described as the brain's multimodal priority map (Gottlieb, 2007). Frontoparietal networks have the ability to steer attention towards current executive goals, but the parietal region is highly influenced by the emotional state of the subject (Viviani, 2013). For example, individuals with depression, anxiety and negative mood state focus significantly more on negative or threatening stimuli in their environment, supporting the idea that attention is guided not only by the external context but also by the internal state of the individual (Joormann and Arditte, 2013). Attentional bias can thus have a detrimental effect on accurate and efficient cognitive processing and tests that can monitor this type of cognitive disturbance are thus potentially pertinent measures of affective state (Joormann and Siemer, 2011). It follows, therefore, that cognitive tests of judgement bias may in fact be measures in shifts of attention or, there may be a complex and integrated effect of judgement and attention bias on cognitive performance. From

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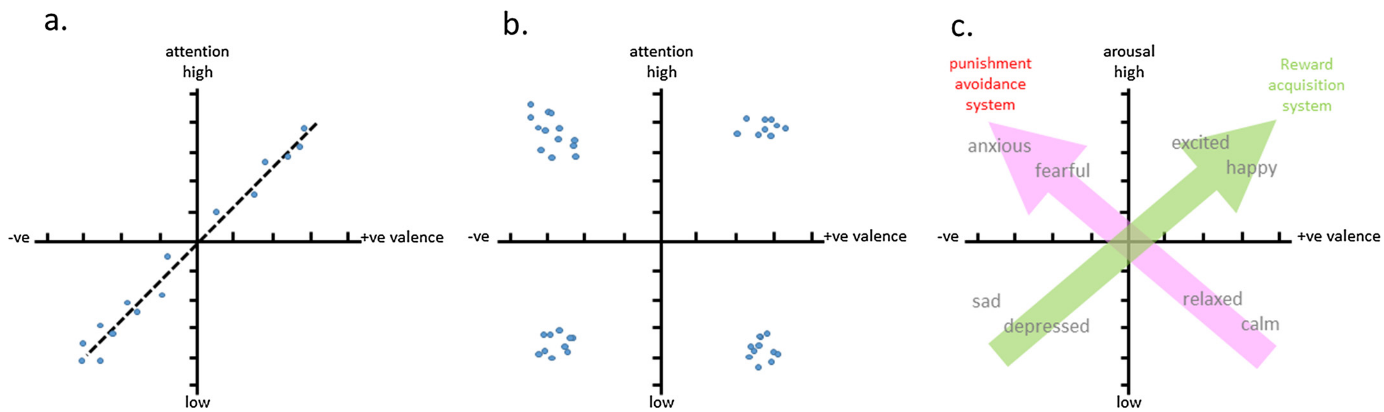

Fig. 1. Hypothetical relationship of visual attention with valence state. **a.** a simple linear relationship between attention and emotional state (positive and negative valence) suggesting a joint underlying mechanism; **b.** a more complex relationship between attention and emotional state controlled by independent mechanisms that may interact; **c.** core affect represented in two-dimensional space.
(adapted from Mendl et al. (2010))

a practical perspective, the relationship between judgement bias and attention may be important. If these attributes correlate, then one measure is will be as useful as the other in measuring the affective state (Fig. 1a). However, there may also be a more complex relationship between affective state and attention which has the potential to identify additional affect phenotypes (Fig. 1b). For example, animals experiencing emotions of negative valence may be in different affect states that can only be discriminated by also assessing the level of visual attention (Fig. 1b). These states may be similar to what has previously been proposed by Mendl et al. (2010) e.g. anxiety versus behavioural depression (Fig. 1c). Thus, measuring attention alongside other current tests of cognitive bias may provide greater resolution in the measurement of animal welfare.

As a starting point for developing cognitive tasks of attentional control (as inferred measures of affective state), we decided to assess the basic relationship between visual attention and cognitive performance in a farm animal species, sheep. Domestic selection has led to reasonable interbreed variation in vigilance/fearfulness between sheep breeds and thus potentially visual attention. For example, upland sheep are more prone to predation and need to be capable of locating areas of shelter as well as grazing and water sources, thus may be more vigilant and attentive to changes in their environment, particularly in the context of protecting young (see Dwyer and Lawrence, 2005, for review). By contrast, lowland breeds tend to be managed more intensively in a way that actively deters natural predators with shelter food and water being consistently provided. Consequently, lowland breeds may have lower fearfulness/vigilance levels by comparison and be less visually attentive. The aim of the study, therefore, was to examine the relationship between visual attention and cognitive performance (in a two-choice discrimination task) using four different upland and lowland breeds of sheep.

2. Experimental procedures

2.1. Animals

Four different types of female lowland and upland sheep (Bluefaced Leicester [lowland] N = 15), Texel (lowland, island) (N = 14), Suffolk (lowland) (N = 14) Beulah (upland) (N = 14) Table 1) randomly selected from pure-bred flocks were used in the study. All animals were 9 months old and born and maintained within the same lowland husbandry system at Aberystwyth University. Prior to the study, all animals lived outdoors and each had received the same amount of handling as part of the routine husbandry. During the study, all animals were kept indoors in a university stock barn with *ad libitum* water and hay. Animals were kept in their new group composition and indoor housing for seven days before training and testing commenced. All animals were given a daily feed supplement in the form of a standard ration of 400 g cereal-based pelleted concentrate per day (Wynstay Lamb Finishing nuts, Wynstay, UK). On testing days, these pellets were provided as the food reward within the operant task (see below). Studies were carried out in accordance with the UK Animals (Scientific Procedures) Act, 1986. All animals came from permanent stock flocks held at Aberystwyth University where the experimental work was carried out. Animals were returned to the stock flocks on completion of the study.

2.2. Vigilance/fearfulness testing

The four breeds were initially group-tested to confirm general variation in vigilance/fearfulness and thus potentially visual attention. Both tests were carried out once a day at 09:00 h for 6 days. This time point was the first of two normal feeding times for all sheep. The first test (Trough test) involved placing food in a 3 m food trough within the animals' normal husbandry enclosure whilst the human observer stood at the mid-point of the trough (Fig. 2a). Over the course of 5 min the number of animals that ate from the trough was recorded. The secondtest (Chair test) involved the human observer seated on a blue fold-up chair within the animals' normal husbandry enclosure. A bucket (yellow), from which animals were normally fed, was placed between the observer's legs (Fig. 2b). Over the course of 5 min, the number of animals that ate from the bucket was recorded.

2.3. Operant system

We used a purpose-built semi-automated operant system for the cognitive testing (McBride et al., 2016). This system consists of an ambulatory one-way circuit within an arena (8.7 × 3.1 m) in which animals engage and then disengage with the visual stimuli during each trial (Fig. 3). The semi-automated nature of the system is controlled via diffuse-reflective photo-electric sensors (Omron, Nufringen, Germany), Matlab R2015a (Mathworks, UK) in conjunction with Psychtoolbox (Psyctoolbox.org) and a 12 bit USB data acquisition device (DAQ; MCC 1208 fs; Measurement Computing, Norton, USA). Visual stimuli are presented via liquid crystal display (LCD) screens (1280 × 1024 pixel resolution, 250 cd/m2 Brightness)(Dell, UK) and the reward (5 g of normal sheep ration in the form of pellets) is delivered into a trough directly underneath the screens via an in-house designed feed dispenser (Quality Equipment, Woolpit, UK).

2.4. Acclimation and training in the operant testing system

In the acclimation phase, animals were habituated to the operant