Comparative Intelligence of the Llama (*Lama glama*): Implications for Welfare

By

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Figure 1. Two llamas: a baby llama, cria (less than one year old) on the left and a yearling on the right (Courtesy of Bluecaps Farm)

Introduction

Llamas, as shown in figure 1, have been domesticated in South America for many years and over the last couple of decades they have become much more common in the UK where they are kept primarily either as pets or commercially as trekking or breeding animals. Despite their long association with man, little research has been carried out regarding their cognitive abilities. The purpose of this study was, therefore, to investigate the intelligence of the llama in order to make informed decisions to address or improve their level of welfare.

The study first looked at the comparative neuroanatomy of the llama in relation to other species as a potential indicator of relative intelligence. Secondly, their level of awareness and their ability to learn was investigated by carrying out an experiment to determine if they could learn to use a mirror to find a bucket associated as a food source. The results of these findings on the implications of welfare were then discussed.

The Llama (*Lama glama*)

Llamas are one member of four New World or South American Camelid species. The others are the alpaca: *Vicugna pacos*, the vicuna: *Vicugna vicugna*, and the guanaco: *Lama guanicoe*. Llamas are believed to have evolved from the guanaco around 5,500 years ago and since then have typically been used as beasts of burden, but their fibre, leather, meat and manure is also utilised. Llamas are growing increasingly common in Europe, North America, New Zealand and Australia where they are typically kept as companion animals, as 'lawn mowers', as guard animals, in zoos and farms or in commercial trekking groups. Husbandry procedures, other human-animal interactions and housing facilities all provide ample opportunity for a potentially low level of welfare to be inflicted.

Predicting the Intelligence of the Llama

Brain size has long been thought to give an indication of the level of intelligence of a species. The measure is the relative size of the brain to the body. Figure 2 depicts a graphical method comparing brain and body sizes on a log scale, of 116 ungulates and some additional species. Animals with points above the trendline have a larger than average brain for their body size and therefore potentially show a higher than average level of intelligence.

In addition, a numerical method compares relative brain to body sizes. This is referred to as the Encephalization Quotient (EQ). The EQ is a ratio between the observed and expected brain mass for a species of a certain size. The majority of animals are expected to have an EQ of 1, and so a value higher than this may suggest higher than average intelligence. Table 1 gives some examples of EQs for a range of species.
The data came either from Shoshani, *et al.*, (2006), Roth & Dicke, (2005), Mace, *et al.*, (1980), or was calculated from the data in Pérez-Barbería & Gordon, (2005) using the same EQ formula as that used in Shoshani, *et al.* (2006):

$$EQ = \frac{Brain\ Mass}{0.12\ X\ Body\ Weight^{2/3}}$$

(Jerison, 1977)

Animal	EQ
Pig (Mace, *et al.*, 1980)	0.6
Sheep	0.6
Giraffe	0.7
Bactrian Camel	0.8
Rat (Shoshani, *et al.*, 2006)	0.8
Llama	0.9
Guanaco	0.9
European cat (Shoshani, *et al.*, 2006)	1.1
Dog (Roth & Dicke, 2005)	1.2
Vicuna	1.4
Ring-tailed lemur (Shoshani, *et al.*, 2006)	1.5
Gorilla (Shoshani, *et al.*, 2006)	1.4-1.7
Fox (Roth & Dicke, 2005)	1.6
Asian elephant	2.3
Chimpanzee (Shoshani, *et al.*, 2006)	2.2-2.5
Human (Shoshani, *et al.*, 2006)	7.3-7.7

Table 1. Encephalization quotients of various species

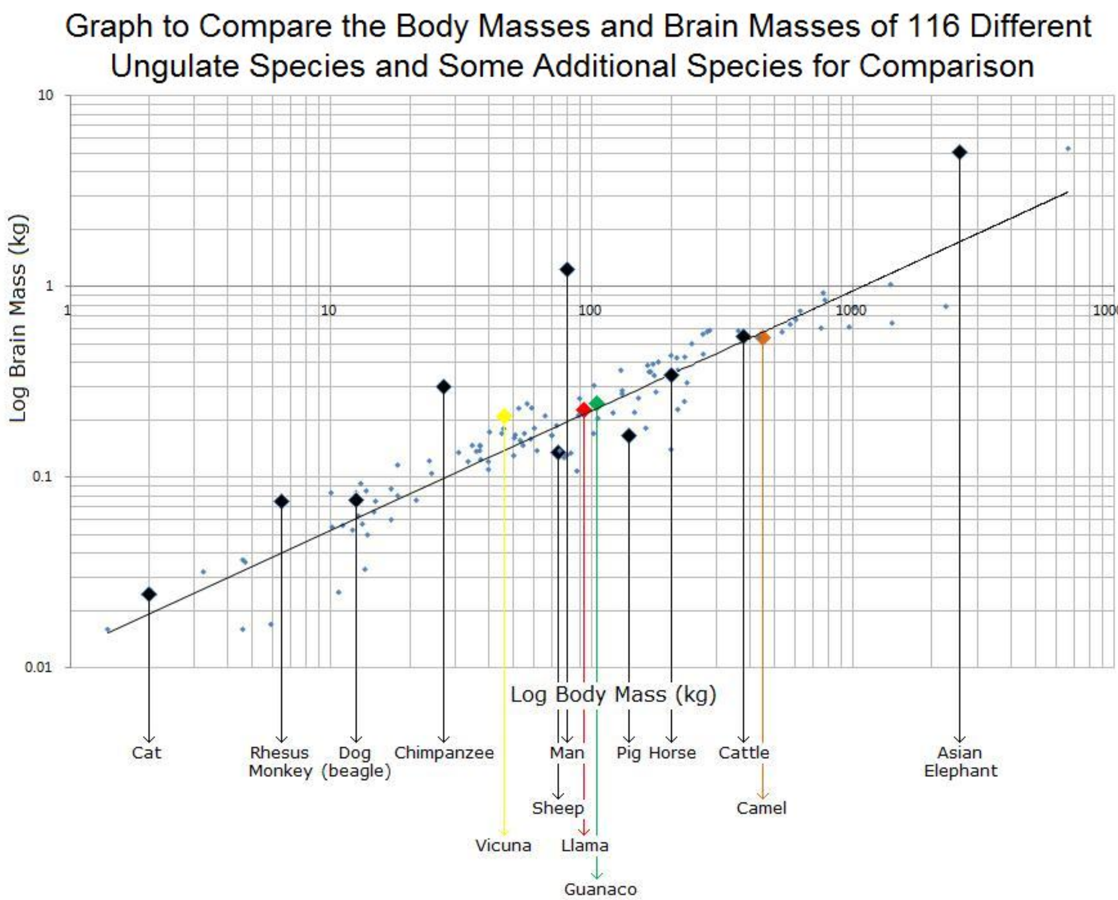

Figure 2. Graph to compare the log brain mass against the log body mass for 116 ungulate species and some non-unglulate species. The trendline is calculated from only the ungulate data.

Intelligence, Learning, Awareness and Welfare

Intelligence and learning are closely related, with an animal's level of intelligence often based upon its ability to learn. Higher levels of intelligence are also likely to raise the level of awareness. Gallup Jr, (1998) proposed that self-aware animals should be able to make deductions about the mental states of other animals, which is classified as a form of complex learning by Emery & Clayton, (2004). This suggests that higher levels of awareness equate to a higher level of intelligence. Looking at an animal's level of intelligence can be useful when assessing how much an animal might be affected by an environment or situation, and so can lead to a form of measure of its welfare.

Learning

Learning allows an animal to modify its behaviour in relation to an experience so it behaves differently in the future. Learning can be broadly divided into three forms: simple, associative and complex.

Simple learning is where an animal changes its behaviour over time in response to one or more stimuli. It is thought to incorporate habituation, dishabituation and sensitisation.

Associative learning refers to an animal's ability to relate cause and effect and make an association between the two. Associative learning includes: classical or Pavlovian conditioning, operant conditioning in which the animal initiates cause and effect, and imprinting.

Complex learning involves a range of behaviours. Emery & Clayton, (2004) have defined four cognitive tools which together construct nonverbal complex cognition: causal reasoning, flexibility, imagination, and prospection. Latent learning has also been proposed to be a form of complex learning. In causal reasoning an animal is believed to show an understanding of the relationship between a tool and its resulting outcome. This can include actual physical tool use and also tactical deception. Flexibility is based on the ability of an animal to learn generalised rules that can be used in novel situations and changing circumstances. Abstraction, innovation, object and social play are all thought to be flexible behaviours. Imagination allows an individual to form scenarios and situations in the mind that are not actually happening. Insight, cognitive maps and experience projection have all been proposed to indicate the use of imagination. Prospection is the ability of an animal to use past experiences to anticipate events that are going to happen in the future. Latent learning is described by Stouffer, (2010) as 'the acquisition of neutral information with no immediate effects on behaviour'. For example, a rat exposed to a laboratory maze will learn to navigate that maze quicker when set a task, than a naïve animal.

Awareness

Awareness has been defined by Sommerville & Broom, (1998), as 'a state in which complex brain analysis is used to process sensory stimuli or constructs based on memory'. Sommerville & Broom, (1998) also described five states of awareness. The first two of these can be broadly categorised as unconscious involving automatic responses. The remainder require conscious thought, in which flexible responses depend upon memory and the consequences of actions are understood in both the short and long term.

Welfare

A knowledge of learning and awareness in an animal is useful to assess how new situations may affect their welfare. The ability to learn leads to expectations of what might happen. This can either result in lowered welfare due to disappointment from something positive being expected but not occurring, or from expecting something negative to happen. Similarly the awareness an animal has can affect how they are treated. If an animal is believed to be unaware then it may be treated in a worse manner than if it is believed to be aware of what is happening. Determining these two capabilities of the llama might therefore aid in producing housing environments and husbandry techniques that provide an improved level of welfare.

Preliminary experiment: Can llamas learn to use a mirror as a tool to obtain information?

The aims of this experiment were to discover whether llamas were capable of learning to understand what a mirror image represents, and what level of awareness llamas display in response to their mirror image. The method was based on an experiment carried out by Broom, *et al.*, (2009) in pigs.

Method

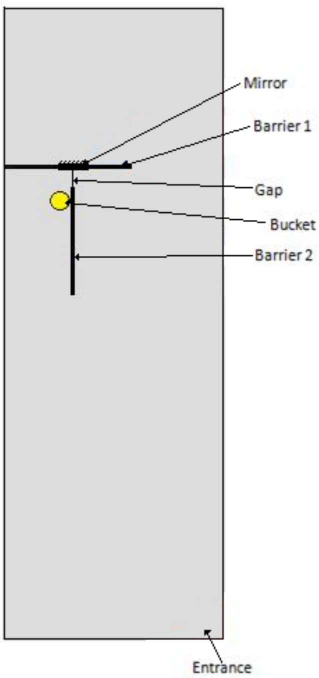

Figure 3. A scale drawing showing a plan of the enclosure.

A group of llamas were exposed to a mirror in the enclosure shown in figure 3 for four hours, and the response to their reflection was observed. A different group of llamas were then contained in the same enclosure, for four hours but <u>without</u> the mirror. Each animal was then tested to see if they could use the mirror image (as shown in figure 4) to find a bucket hidden behind a barrier, its true location is shown in figure 5.

Figure 4. Mirror image of the bucket.

Figure 5. The true location of the bucket.

Results

In general when exposed to the mirror all of the llamas responded to their own reflection as if it were a conspecific, for example one llama spat at its mirror image and all of the llamas went behind the mirror to find the apparently new animal. Four out of five of the mirror-experienced llamas successfully found the bucket whereas none of the four mirror-naive llamas managed to find it. A Fisher's Exact Test concluded that there is significant evidence at the 5% level to show that exposure to a mirror allows a llama to learn to use it to find a bucket recognised as a food container.

In addition, individual llamas left with a mirror were calmer than those without.

Discussion

Predicting intelligence using comparative neuroanatomy

Figure 2, which compares the log brain mass and body mass of different species shows that the llama's brain mass is above average, suggesting an above average level of intelligence for an ungulate species. Table 1 show that the llama has an EQ of 0.9, which is just below average. Using the log brain mass to body mass and the EQ it could be suggested that the llama has an about average level of intelligence for an ungulate species.

The values demonstrate and interesting trend between species but the figures should not be considered as absolute. This is due to factors such as variation in non-neuronal components in the brain between species and variation in body weights due to factors such as fleece mass.

Assessing learning and awareness from the preliminary experiment

The test performed is thought to show a few different forms of complex learning. Latent learning is thought to have been shown as investigation of the mirror image without any obvious form of reinforcement seemed to allow them to learn to understand the spatial information which it portrayed. The use of a cognitive map seems to be apparent as the llamas were able to navigate around the barriers in order to find the believed location of the bucket.
It could also be suggested that the llamas showed insight. They learned what the mirror image represented and were able to use this information to find the correct location of the bucket without using trial and error.

Being able to find the bucket in the mirror test was proposed by Broom, *et al*., (2009) to show a level of awareness referred to as "assessment awareness". To be able to find the bucket they must have been able to examine features of the current surroundings, remember certain past experiences, deduce new relationships between old and new information, and then act accordingly to try to produce a positive outcome.

Welfare implications of the present findings

The preliminary experiment showed that llamas are able to learn and so anticipate and expect. They also appear to display a high level of awareness. This information can be taken into account when designing husbandry practices to try and improve their level of welfare.
In addition, individual llamas housed with a mirror appeared calmer. This suggests that a mirror could potentially be used as a tool to improve the welfare of animals that have to be kept alone.

Conclusions

The study found that llamas seem to have a roughly average level of intelligence for an ungulate species. From the preliminary experiment it was determined that llamas are able to learn to understand and use a mirror. It was suggested that the successful completion of the experiment showed insight, the use of a cognitive map, the ability of latent learning and also the level of assessment awareness. These findings may be useful to modify husbandry practices to improve the welfare of the llama and other camelids.

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Author Profile

"Abi is 21 years old and studied in the School of Biosciences, graduating in 2011 with a first class degree in Animal Science BSc Hons. Abi is now studying for a Masters in Applied Animal Behaviour and Animal Welfare at the University Of Edinburgh and will be carrying out her research project on the effects the presence of playmates have on the amount and type of play behaviour performed by llama crias.