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The intelligence of sheep

Commentary on **Marino & Merskin** on *Sheep Complexity*

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Abstract: This commentary suggests how recent theories about the predictive brain could help us understand the evidence put forward by Marino & Merskin for intelligence in sheep. I contrast predictive intelligence in sheep with automatic behaviors that do not require intelligence, and I consider the flexibility of sheep intelligence.

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In the first part of this commentary, I suggest that some of the sheep behaviors discussed by Marino & Merskin (2019) (M&M) could be executed automatically with little or no intelligence. I then argue that intelligence is linked to an animal's ability to make predictions, and I examine the evidence for predictive intelligence in sheep. The commentary closes with a discussion of the flexibility of sheep intelligence.

1. Automatic Sheep Behaviors. Many behaviors are simple reflexes or motor programs that are executed in response to input patterns. Some are hardwired in the spinal cord; others are hardwired in the brain – for example, a fear reaction is often triggered when people see something small and fast moving, such as a mouse or spider. Automatic behaviors can be learnt through conscious intelligent processes, and then they can be invoked without conscious control or intelligence. For example, when I am learning to drive, I pay great attention to the road, other cars, and so on, and consciously control the movements of my hands on the steering wheel. Experienced drivers can drive without conscious awareness of what they are doing.

People often misinterpret automatic behaviors as evidence for complex cognitive processes. For example, **Vonk** (2019) highlights several ways in which M&M overinterpret simple behaviors as more complex psychological traits. In humans many personality traits, including political orientation, are likely to depend on simple feedback loops between environmental stimuli and emotional responses (Haidt 2013), which have a substantial genetic component (Alford et al. 2005). In sheep, shyness/boldness and gregariousness could be linked to simple feedback loops between the perceived distance from other sheep and an emotional response – longer distances triggering feelings of fear; shorter distances triggering aversion. Sheep's ability to recognize faces and discriminate tastes are also likely to be basic automatic responses. Biological neurons cultivated in a Petri dish have been shown to be capable of classification and control tasks (Demarse et al. 2001; Heard et al. 2018; Ruaro et al. 2005), so the

neurons in a sheep's brain could learn relationships between input patterns and motor output without the need for intelligence or consciousness.

2. Predictive Intelligence in Sheep. In recent years, many have argued that the core function of the brain is prediction (Clark 2016). This hypothesis ties together many aspects of the brain's functionality and is supported by an increasing amount of experimental evidence. Intelligence is a complex multifaceted term, and many overlapping definitions have been put forward. These include cognitive ability, rational thinking, problem solving and goal-directed adaptive behavior (Bartholomew 2004). My current working hypothesis is that intelligence is closely linked to the ability of a system to make predictions. If brains are intelligent and the core function of the brain is prediction, then brains that are better predictors will be more intelligent. The recent successes of artificial intelligence have largely been based on the ability of machine learning algorithms to generate predictions.

M&M's work supports the idea that sheep have a variety of forms of predictive intelligence. They can make predictions about social interactions, predators and the physical effects of plants. Sheep can carry out spatial navigation and have a limited ability to predict how the face of another sheep will appear from different perspectives (Ferreira et al. 2004). However, sheep (and other ungulates and ruminants) have very limited effectors – just a mouth and hooves – so they cannot learn about objects in the ways that primates, birds and cephalopods can. We can hold an object in our hands and learn what happens when we rotate and deform it. Sheep can only explore objects with their mouths and walk around them. This suggests that the predictive intelligence of sheep might be less than that of animals who use complex effectors to manipulate their environments. However, the observation of tool use in wild dolphins (Krützen et al. 2005) shows that complex effectors might not be essential for the development of a rich understanding of the world. M&M do not discuss tool use in sheep, and it would be interesting to see if the experimental setup that has been used to probe imitation and intelligence in bumblebees (Loukola et al. 2017) could be adapted to explore predictive intelligence and tool use in sheep.

3. Flexibility of Intelligence. Suppose an organism has a high level of predictive intelligence and complete knowledge of the consequences of every state. This knowledge becomes useless if the environment changes — for example, if the climate shifts or a new species of plant or animal is introduced. To cope with change, animals have to adjust predictions that are no longer supported by evidence from the environment. One way of measuring the flexibility of intelligence is to pair a stimulus with a reward, change the relationship between stimulus and reward, and then measure how long the animal takes to learn the new relationship. There are more complex variations of this type of test in which the reward is initially linked with one feature of the stimulus, such as color, and then linked with a different feature, such as shape. M&M's discussion of the experiments carried out by Morton and Avanzo (2011) suggests that the predictive intelligence of sheep has some flexibility: sheep can learn rules connecting stimuli and rewards, and adapt to changes in these rules over time.

4. Conclusion. This commentary has suggested that some of the sheep behaviors discussed by M&M such as face recognition and personality traits could be the result of fairly simple mechanisms that do not require much intelligence, but some of the other research discussed by M&M demonstrates that sheep do have more predictive intelligence than many people think and that sheep intelligence has a significant amount of flexibility.

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