DOMESTIC GOATS (*capra hircus*) AS A MODEL LIVESTOCK SPECIES FOR ANIMAL WELFARE RESEARCH

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Editor Note: For this journal, the speaker has provided a summary of some of the relevant areas of his research – referenced at the end of the article.

Long-term memory of kid calls by mothers (1)
Parent–offspring recognition is crucial for offspring survival. At long distances, this recognition is mainly based on vocalizations. Because of maturation-related changes to the structure of vocalizations, parents have to learn successive call versions produced by their offspring throughout ontogeny in order to maintain recognition. However, because of the difficulties involved in following the same individuals over years, it is not clear how long this vocal memory persists. We investigated long-term vocal recognition in goats. We tested responses of mothers to their kids' calls 7–13 months after weaning. We then compared mothers' responses to calls of their previous kids with their responses to the same calls at five weeks postpartum. Subjects tended to respond more to their own kids at five weeks postpartum than 11–17 months later, but displayed stronger responses to their previous kids than to familiar kids from other females. Acoustic analyses showed that it is unlikely that mothers were responding to their previous kids simply because they confounded them with the new kids they were currently nursing. Therefore, our results provide evidence for strong, long-term vocal memory capacity in goats.

Goats recognise other goats but pay particular attention to close social partners or "friends" (2)
When identifying other individuals, animals may match current cues with stored information about that individual from the same sensory modality. Animals may also be able to combine current information with previously acquired information from other sensory modalities, indicating that they possess complex cognitive templates of individuals that are independent of modality. We investigated whether goats possess cross-modal representations (auditory–visual) of conspecifics. We presented subjects with recorded goat calls broadcast equidistant between two individuals, one of which was the caller. We found that, when presented with a stablemate and another herd member, goats looked towards the caller sooner and for longer than the non-caller, regardless of caller identity. By contrast, when choosing between two herd members, other than their stablemate, goats did not show a preference to look towards the caller. Goats show cross-modal recognition of close social partners, but not of less familiar herd members. Goats may employ inferential reasoning when identifying other goats, potentially facilitating individual identification based on incomplete information. Understanding the prevalence of cross-modal recognition and the degree to which different sensory modalities are integrated provides insights into how animals learn about other individuals, and the evolution of animal communication.

Goats learn how to solve complex physical cognition tasks quickly and retain long-term memory of the task (3)
The computational demands of social living (maintaining group cohesion, reducing conflict) and ecological problems (extractive foraging, memorizing resource locations) are the main drivers proposed to explain the evolution of cognition. Different predictions follow, about

whether animals would preferentially learn new tasks socially or not, but the prevalent view today is that intelligent species should excel at social learning. However, the predictions were originally used to explain primate cognition, and studies of species with relatively smaller brains are rare. By contrast, domestication has often led to a decrease in brain size, which could affect cognition. In domestic animals, the relaxed selection pressures compared to a wild environment could have led to reduced social and physical cognition. Goats possess several features commonly associated with advanced cognition, such as successful colonization of new environments and complex fission-fusion societies. We assessed goat social and physical cognition as well as long-term memory of a complex two-step foraging task (food box cognitive challenge), in order to investigate some of the main selection pressures thought to affect the evolution of ungulate cognition. The majority of trained goats (9/12) successfully learned the task quickly; on average, within 12 trials. After intervals of up to 10 months, they solved the task within two minutes, indicating excellent long-term memory. The goats did not learn the task faster after observing a demonstrator than if they did not have that opportunity. This indicates that they learned through individual rather than social learning. The individual learning abilities and long-term memory of goats highlighted in our study suggest that domestication has not affected goat physical cognition. However, these cognitive abilities contrast with the apparent lack of social learning, suggesting that relatively intelligent species do not always preferentially learn socially. We propose that goat cognition, and maybe more generally ungulate cognition, is mainly driven by the need to forage efficiently in harsh environments and feed on plants that are difficult to access and to process, more than by the computational demands of sociality.

Understanding indicators of goat emotions is key to improving welfare (4)
Emotions are important because they enable the selection of appropriate behavioural decisions in response to external or internal events. Techniques for understanding and assessing animal emotions, and particularly positive ones, are lacking. Emotions can be characterized by two dimensions: their arousal (body excitation) and their valence (negative or positive). Both dimensions can affect emotions in different ways. It is thus crucial to assess their effects on biological parameters simultaneously, so that accurate indicators of arousal and valence can be identified. To find convenient and non-invasive ways to assess emotions in goats, we measured physiological, behavioural and vocal responses of goats in four situations: (1) control (no external stimulus, neutral); (2) anticipation of a food reward (positive); (3) food-related frustration (negative); (4) brief isolation away from other goats (negative). These situations were characterized by different levels of arousal, assessed later by heart rates measured during the tests. We found several clear, reliable indicators of arousal and valence. For example, suring situations of higher arousal, goats had lower heart rate variability. They displayed more head movements, moved more, had their ears pointed forwards more often and on the side (horizontal) less often and produced more calls. They also produced calls with higher fundamental frequencies. In positive situations, goats had their ears oriented backwards less often and spent more time with their tails up than in negative situations. Furthermore, they produced calls in which the fundamental frequencies were less variable. Our methods for assessing the effects of emotional arousal and valence on biological parameters could lead to more effective monitoring and understanding of animal emotions and therefore welfare.

Goats communicate with people like other domestic animals, such as dogs and horses (5)
Domestication is an important factor driving changes in animal cognition and behaviour. In particular, the capacity of dogs to communicate in a referential and intentional way with humans is considered a key outcome of how domestication as a companion animal shaped the canid brain. However, the lack of comparison with other domestic animals makes general conclusions about how domestication has affected these important cognitive features difficult. We investigated human-directed behaviour in an ‘unsolvable problem’ task in a domestic, but non-companion species: goats. During the test, goats experienced a

forward-facing or an away-facing person. They gazed towards the forward-facing person earlier and for longer and showed more gaze alternations and a lower latency until the first gaze alternation when the person was forward-facing. Our results provide strong evidence for audience-dependent, human-directed visual orienting behaviour in a species that was domesticated primarily for production (meat, milk and fibre), and show similarities with the referential and intentional communicative behaviour exhibited by domestic companion animals such as dogs and horses.

(6) Goats can differentiate between human facial expressions and prefer to interact with happy people

Domestication has shaped the physiology and the behaviour of animals to better adapt to human environments. Therefore, human facial expressions may be highly informative for animals domesticated for working closely with people, such as dogs and horses. However, it is not known whether other animals, and particularly those domesticated primarily for production, such as goats, are capable of perceiving human emotional cues. We investigated whether goats can distinguish human facial expressions when simultaneously shown two images of an unfamiliar human with different emotional valences (positive/happy or negative/angry). Both images were vertically attached to a wall on one side of a test arena, 1.3 m apart, and goats were released from the opposite side of the arena (distance of 4.0 m) and were free to explore and interact with the stimuli during the trials. Each of four test trials lasted 30 seconds. We found that goats preferred to interact first with happy faces, meaning that they are sensitive to human facial emotional cues. Goats interacted first, more often and for longer duration with positive faces when they were positioned on the right side. However, no preference was found when the positive faces were placed on the left side. We show that animals domesticated for production can discriminate human facial expressions with different emotional valences and prefer to interact with positive ones. Therefore, the impact of domestication on animal cognitive abilities may be more far-reaching than previously believed.

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