Invited review: Socio-cognitive capacities of goats and their impact on human-animal interactions

Christian Nawroth[1,2]

[1] Queen Mary University of London, Biological and Experimental Psychology, School of Biological and Chemical Sciences, London, UK

[2] Leibniz Institute for Farm Animal Biology, Institute of Behavioural Physiology, Dummerstorf, GER

Correspondence

Christian Nawroth

Email address: nawroth.christian@gmail.com

Abstract

A detailed understanding of how livestock animals perceive and communicate with stockpersons is crucial to improving their welfare by means of positive human-animal interactions. However, research regarding the cognitive underpinnings of these interactions in ungulate livestock is still limited. In this review article, I summarize recent advances on studies on the cognitive capacities of domestic goats (*Capra hircus*), with a special focus on human-animal interaction. Recent work has shown that goats respond to subtle behavioural changes by humans, but also highlighted some of their limitations in comprehending information directed towards them. Based on these findings, I outline how applied research can benefit from these findings and discuss how human behavioural changes can affect appetitive and aversive behaviour of livestock. Because goats' socio-cognitive capacities affect their ability to adapt to human handling, a better understanding of their cognitive capacities will improve their welfare in the long term.

Keywords: animal welfare; handler; human-animal communication; social cognition; stockperson

1. Introduction

In recent years, several welfare-related approaches have emerged, covering affective states (Désiré et al., 2002; Marchant-Forde et al., 2009; Mendl et al., 2010), motivation (Buijs et al., 2011; Kirkden and Pajor, 2006), coping behaviour (Forkman et al., 1995) and biological/cognitive functioning of livestock (Duncan and Petherick, 1991; Fraser et al., 1997; Wechsler and Lea, 2007). All approaches acknowledge that a detailed understanding of the perceptive and cognitive abilities of non-human animals is necessary in order to comprehend their normal behavioural expressions and to avoid exposing them to mental distress.

Socio-cognitive research in primates, as well as dogs, has skyrocketed over the last few decades (Call and Tomasello, 2008; Kaminski and Nitzschner, 2013; Miklósi and Soproni, 2006; Tomasello and Call, 1997). Yet, livestock species are still underrepresented in animal cognition research and the cognitive mechanisms involved in their behaviour and decision-making are not well understood (Broom, 2010; Duncan and Petherick, 1991; Wechsler and Lea, 2007).

Goats are comparatively small ruminants and live in fission-fusion societies, developing stable dominance hierarchies (de la Lama and Mattiello, 2010; Shank, 1972; Stanley and Dunbar, 2013). They are explorative and curious (Briefer et al., 2015; Langbein et al., 2009; Nawroth et al., 2017), traits that make them an excellent model species for cognitive and behavioural mechanisms in ungulate livestock. Previously, a range of test paradigms has been used to investigate learning and physical problem solving abilities of goats (Langbein et al., 2007; Meyer et al., 2012). This research has shown that goats possess an impressive long-term memory, allowing them to accurately discriminate between previously learned visual stimuli presented on a screen, even after several weeks (Langbein et al., 2008, 2004). Because farm settings involve frequent interactions with stockpersons, it is also of importance to know how goats mentally represent humans in order to improve their welfare.

This review article outlines recent advances in research on goat behaviour regarding their ability to discriminate between, and attributing attention to, humans, with an additional focus on human-goat communication and social learning. In addition, ways to integrate this basic research into various applied settings are proposed and future challenges in investigating goat cognitive capacities are discussed.

2. Discrimination between, and attributing attention to, humans

Negative perceptions of people by farm livestock can substantially reduce their welfare, subsequently impacting upon meat or milk production due to elevated stress levels (Brajon et al., 2015b; Breuer et al., 2000; Hemsworth, 2003). Therefore, an important theoretical consideration for these interactions is whether animals associate specific experiences with certain handlers. Domestic ungulates have indeed been shown to differentiate between conspecifics (Coulon et al., 2011; Hagen and Broom, 2003; Kendrick et al., 1995) and humans (Brajon et al., 2015a; Koba and Tanida, 2001; Stone, 2010). However, previous research on goats has focused mainly on the discrimination of conspecifics using visual (Keil et al., 2012), auditory (Briefer et al., 2012), or cross-modal cues (Pitcher et al., 2017). For example, Keil et al. (2012) showed that goats discriminate between familiar and unfamiliar conspecifics even when the target's head is hidden. Alongside visual cues, olfactory discrimination is likely to play an additional role in the process. To date, there have been no investigations to determine specifically how goats discriminate between humans. However, studies in cattle and pigs have shown that body height and/or general facial features can be sufficient for discrimination between humans (Koba and Tanida, 2001; Rybarczyk et al., 2001), and it is likely that the discrimination process in goats might operate in a similar manner (see Keil et al., 2012). In relation to potential long term recognition of humans, good memory capacities over several modalities can be presumed in this species, as research on mother-offspring recognition and problem-solving has shown (Briefer et al., 2014, 2012). When goats learned how to solve a 2-

step puzzle box in order to receive a reward, they were able to memorize this association for several months (Briefer et al., 2014). It is quite likely that learning processes associated with humans (e.g. receiving rewards) can be memorized for a similar period.

The ability to attribute attentive states to conspecifics or heterospecifics might have severe impacts on decision-making and stress responses in livestock animals. For example, gaze directed to an individual might be considered as threat and elicit an anti-predator response (Clucas et al., 2013; von Bayern and Emery, 2009). Beausoleil et al. (2006) investigated whether human staring altered the behaviour of domestic sheep (*Ovis aries*) in comparison to no human eye contact. They found that sheep glanced at the staring human more often and showed higher levels of locomotor activity. However, they did not find a difference in fear-related behaviour. Body, head and gaze orientation of individuals might also influence livestock behaviour to maximize gains and minimize effort competitive situations with conspecifics (Held et al., 2002, 2001) and cooperative situations with handlers. As evidence for the former, Kaminski et al. (2006) presented two goats who were facing each other, with two rewards in the middle of an arena – one that was visible to both, while the second was only visible to one goat. They demonstrated that the behaviour of individual goats in this food monopolization task depended on their previous agonistic experience with a competing subject, but not on whether the competing goat could see the reward. When investigating goat-handler interactions, Nawroth et al. (2016b, 2015) found that goats differed in their anticipatory behaviour depending on an experimenter's attentive state. In the experiments, an inaccessible reward was positioned in front of the goat, and over an interval of 30s, the experimenter engaged in different postures that resembled different levels of attention directed towards the test subject (e.g. the experimenter turned his back to the subject or closed his eyes). Anticipatory behaviour was highest when the experimenter paid more attention to the subject, while 'standing alert' behaviour was most prominent when the experimenter was present but did not pay attention. These results indicate that goats adapted their behaviour to the head and body orientation, but not eye visibility, of an experimenter as a means for reward delivery. In an attempt to crossvalidate these findings, Nawroth & McElligott (2017) found that goats adapted their approach and choice behaviour depending on whether a human was forward-facing or turned its back to them and thus partially replicated the previous results using an anticipation paradigm. However, in contrast to the earlier findings (Nawroth et al., 2015), goats in the later experiment did not change their behaviour according to human head orientation alone, highlighting the potential impact of previous interactions with humans, and other confounding factors in test designs, on the outcome of these tasks. Future research has the potential to clarify further ontogenetic factors and confirm whether goats, and other livestock animals, can mentally represent the perspective of humans (and conspecifics).

Figure 1. Images of test setups designed to investigate goats' socio-cognitive capacities. A) Goat detours obstacle (metal hurdles) after receiving a demonstration of a human experimenter; from Nawroth et al., 2016a. B) Goat makes a choice in a 2-way object choice task; from Nawroth et al., 2015. C) Goat gazes at a human experimenter when confronted with an unsolvable problem (sealed container in front of subject); from Nawroth et al., 2016c

3. Communication with humans

Communication with conspecifics or heterospecifics is crucial in acquiring information from the environment (Bradbury and Vehrencamp, 1998). Cognitive studies conducted with dogs highlight their ability to follow human pointing gestures and similar human-given cues, such as gaze or voice, from a very young age (Agnetta et al., 2000; Riedel et al., 2008; Rossano et al., 2014). Recent research has demonstrated that horses can perform some of the communicative skills normally associated with dogs (Proops et al., 2010; Proops and McComb, 2010), indicating these may be general domestication traits. Indeed, horses, like dogs, are (at least partly) domesticated for companionship or working purposes, which would be expected to generate selection pressures for advanced skills of human-animal communication and interaction. By contrast, goats were domesticated for meat, milk and hair products (MacHugh and Bradley, 2001), and thus might not share these advanced socio-cognitive capacities with dogs and horses. To investigate this, Nawroth et al. (2015, see Figure 1b) and Kaminski et al. (2005) tested goats' ability to follow various human-given cues in an object-choice task. In these tasks, two opaque containers are positioned to the left and right of an experimenter, with only one of the containers being baited with a reward. Both studies found that goats utilized human pointing gestures, but not the human head direction or gaze to locate a hidden reward. However, the experiments did not control for the effect of local/stimulus enhancement, i.e. the pointing finger was always closer to the rewarded container than to the non-rewarded one. Thus, the movement and presence of the outreached arm and finger alone might have guided the choice behaviour of the goats. Additionally, it is unclear whether a conditioned response or comprehension of the referential nature of the pointing gesture accounts for their performance.

Notably, communication can also be directed to humans. Dogs use gazing behaviour as a form of referential and intentional communication when interacting with humans (Miklósi et al., 2003; Savalli et al., 2014). This specific behaviour is often tested using a so-called 'unsolvable problem' paradigm in which subjects are confronted with an inaccessible food reward (Miklósi et al., 2003). During an initial training phase, the reward is typically positioned in a container and the tested subject is able to access the reward e.g. by removing the lid. After successful training, the reward is rendered inaccessible e.g. by attaching the lid to the container, and the human-directed behaviours of the subjects during the test are recorded. Like dogs, goats showed frequent gazes, gaze alternations, and physical interactions to a human experimenter who was positioned next to the unsolvable problem (Nawroth et al., 2016b, see Figure 1c). In addition, goats took into account the attentional stance of the human, highlighting the communicative nature of the human-animal interactions in this task (for dogs see Marshall-Pescini et al., 2013). When the experimenter was facing the problem (compared to an experimenter with its back turned to the problem), goats showed an increased use of gazes and gaze alternations to the experimenter, but not physical interactions, during this 'unsolvable problem' task. It is not clear yet, if and how ontogenetic factors (e.g. amount of previous interactions with humans) impact upon this behaviour in goats (for dogs see Passalacqua et al., 2011). Taken together, the human-directed behaviour of goats shows strong similarities with the communicative behaviour exhibited by domestic companion animals such as dogs and horses.

4. Social learning from humans

Social learning occurs when the acquisition of own behaviour is influenced by observing other individuals, and it should most likely take place when individual learning can be costly, e.g. in terms of predation risk or offspring foraging behaviour (Galef and Laland, 2005; Heyes, 1994). Although many natural threats are non-existent for livestock animals kept under husbandry conditions, we would expect animals to still be able to learn from others, e.g. in the domain of food acquisition. In addition, highly social animals, like goats, should also experience numerous opportunities to learn from others. However, some research has shown that goats appear to predominantly rely on personal rather than social information in various food-related tasks. Baciadonna et al. (2013) tested goats in their use of conflicting personal versus social information in a foraging task, where goats had the opportunity to follow another goat in a T-maze. Goats were found to predominantly rely on personal rather than social information when both types of information were available and in conflict. Briefer et al. (2014) investigated goats physical and social problem-solving ability in a complex two-step foraging task, where subjects first had to pull a rope and then lift a lever in order to receive access to food. Goats quickly learned the task on an individual basis. However, subjects did not learn the task faster after observing a demonstrator compared to the group that received no demonstration. This indicates that they, again, relied on individual rather than social experience in this task.

It has been speculated that goats, as selective browsers, should preferentially employ personal rather than social information from conspecifics because this might be the most efficient way to locate patchily distributed resources in highly variable environments (Briefer et al., 2014). However, methodological constraints might also be an alternative explanation for the lack of positive results. For example, negative findings could be explained by an expected food depletion when a conspecific moves to a rewarded position first (Baciadonna et al., 2013; see for horses Rørvang et al., 2015). Test setups may also have been too difficult for the subjects to master after a relatively limited exposure to the skilled demonstrator, e.g. by using a 2-step puzzle box (Briefer et al., 2014). Furthermore, the actions performed by the demonstrator may not have been ecologically meaningful to the observer, e.g. pulling a string (Briefer et al., 2014). More recently, domestic ungulate spatial and social problem-solving abilities have been assessed using a detour task where goats were required to detour a V-shaped hurdle in order to receive a reward. Goats that experienced a human solving the task prior to their own test trial were faster to solve the task themselves compared to goats that did not receive a demonstration (Nawroth et al., 2016a, see Figure 1a). It is up to future research to investigate by what mechanisms, e.g. imitation, social facilitation, stimulus and local enhancement, or observational conditioning (Heyes, 1994; Laland, 2004), goats, and other ungulate livestock, are able to use information from conspecifics and/or humans.

5. Applied Implications

A detailed understanding of how goats perceive and deal with their physical and social environment is of high importance in our attempts to provide them with good welfare. For example, knowledge about an individual´s learning mechanisms and its understanding of the physical environment can provide valuable information for designing high-standard husbandry conditions (Laughlin and Mendl, 2000; Mendl et al., 1997) or to develop more adequate cognitive enrichment items for goats and other livestock species (Kalbe and Puppe, 2010; Meyer et al., 2010; Puppe et al., 2007; Zebunke et al., 2011).

Similarly, in order to implement better handling practices, it is crucial to know how goats perceive and interact with humans. Based on this knowledge, applied research can be better adjusted to measure how subtle human behavioural change might have rewarding or aversive effects on goat behaviour. Studies of human-animal interactions (e.g. interspecific communication) have already shown the potential to identify relevant stress-reducing behaviour by stock people during handling and transport (Waiblinger et al., 2006). For example, early direct interactions between calves/heifers and their handlers (e.g. stroking) led to less stress and fear of humans (Boissy and Bouissou, 1988; Stewart et al., 2013); factors that are linked to negative effects on welfare (de la Lama and Mattiello, 2010; Rushen et al., 1999). Non-tactile interactions, such as those through visual and auditory cues, also play a key role (Hemsworth, 2003). Thus, knowledge on how and under what circumstances goats perceive and direct communication towards humans (Kaminski et al., 2005; Nawroth et al., 2016c, 2015) is of great importance to align interactions according to species-specific needs and capabilities.

Research in a number of livestock species has also highlighted that fear-related stress levels induced by routine handling practices of stockpersons can limit farm productivity in terms of not only decreasing meat and milk production, but also due to e.g. lower reproduction rates (Hemsworth, 2003). For example, on farms where milk yield was low, cows approached the experimenter less in a standard fear test than cows from farms with a higher milk yield (Breuer et al., 2000), indicating avoidance of humans due to previous aversive associations with them. Similar effects might be expected for dairy goats. Here again, non-tactile interactions could play a crucial role. Because goats differ in their food-anticipating and choice behaviour dependent upon humans attentional stance (Nawroth et al., 2015; Nawroth and McElligott, 2017), it is likely that this factor also affects goat behaviour during routine handling in industrial settings. Identification of the components of approach behaviour that elicit the lowest stress response during management practices is thus of relevance for both productivity and goat welfare improvements. It is thus not only crucial to know how negative impact can be minimized by reducing aversive handling practices, but also to recognise and implement positive human-animal interactions (i.e. to provide positive associations during handling practices, Hemsworth, 2003; Nawroth et al., 2016c, 2015).

Furthermore, by identifying mechanisms of social learning in goats, insights will be gained on how to better accustom farm animals to new environments or feeding devices, such as food dispensers. Additionally, knowledge regarding how goats adapt their behaviour to variations in humans body or head orientation (Nawroth et al., 2016b, 2015) will also affect outcomes in established test paradigms, such as human approach tasks (Hemsworth et al., 1996; Jago et al., 1999).

Finally, an increasing number of cognitive studies conducted on goats will likely have effects on public perception and therefore consumer behaviour (Bastian et al., 2012; Serpell, 2004) – leading to an increase in awareness of how goats are housed and how these housing conditions may potentially inhibit their full behavioural repertoire.

6. Future Directions

As it is increasingly apparent from the existing literature, relatively little is known about how goats differentiate, memorize and recall humans. Greater insight into how goats mentally represent stockpersons has huge potential to improve animal management and handling practices through the reduction of unnecessary stress that animals are exposed to. We would expect to find that goats, like horses (Lampe and Andre, 2012; Proops and McComb, 2012), represent humans in a cross-modal manner, i.e. forming a mental image across sensory modalities.

Indeed, the fact that goats use human pointing gestures to locate food (Kaminski et al., 2005; Nawroth et al., 2015) and are able to communicate in a referential and intentional way with humans when faced with an unsolvable problem (Nawroth et al., 2016c) indicates sophisticated skills in interspecific communication. However, it is unclear whether they are able to utilise referential and intentional communication from humans (for dogs see Kaminski et al., 2012), a skill useful for adapting to new environments and a significant area of future exploration.

Similarly, more empirical research is also needed on goats abilities to perceive human emotional cues, such as body postures or facial expressions (for dogs see Albuquerque et al., 2016; Müller et al., 2015) and how these cues might help them to guide their own behaviour. In dogs, test subjects have been shown to use human emotional facial and vocal information to adapt their behaviour towards an unfamiliar and potentially frightening object (Merola et al., 2012), while horses show a functionally relevant response (e.g. an increase in heart rate) to images of human faces with different emotional valence (Smith et al., 2016). Future advances in this field will also facilitate the development of experiments investigating these and other complex socio-cognitive phenomena in goats, such as prosocial behaviour and empathy (de Waal and Suchak, 2010; Preston and de Waal, 2002).

7. Concluding Remarks

Farm animal cognition is a relatively new, but growing, field of research. Improved implementation of test designs from animal cognition research is highly recommended in order to increase knowledge on how goats perceive and interact with their environment. Because socio-cognitive capacities of goats can affect their ability to adapt to human handling, gaining a deeper understanding of their cognitive abilities will ultimately decrease stress levels and increase productivity, and thus should be a major focus for improving animal welfare in the long term.

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