



Goats learn socially from humans in a spatial problem-solving task



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ARTICLE INFO

Article history:

Received 8 April 2016

Initial acceptance 3 May 2016

Final acceptance 8 August 2016

MS. number: 16-00312R

Keywords:

detour task
domestication
social cognition
social learning
spatial cognition

Domestication drives changes in animal cognition and behaviour. In particular, the capacity of dogs to socially learn from humans is considered a key outcome of how domestication shaped the canid brain. However, systematic evidence for social learning from humans in other domestic species is lacking and makes general conclusions about how domestication has affected cognitive abilities difficult. We assessed spatial and social problem-solving abilities in goats, *Capra hircus*, using a detour task, in which food was placed behind an inward or outward V-shaped hurdle. Goats performed better in the outward than in the inward detour without human demonstration. Importantly, a single presentation by a human solving the inward detour resulted in goats solving the task faster compared to the inward detour without demonstration. Furthermore, eight of nine subjects that received a demonstration used the same route as the demonstrator in the subsequent trial. Thus, goats learn socially from humans. This provides strong evidence for social learning from humans in a domestic species other than dogs.

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Animals may acquire new behaviours by individual and/or social learning. Individual learning occurs through an individual's own experience, but if the environment is unpredictable, it can lead to costly mistakes. By contrast, social learning occurs when the acquisition of behaviour is influenced by observing or interacting with other individuals (Galef & Laland, 2005; Heyes, 1994), and social animals should have plenty of opportunities to learn from conspecifics. Social learning allows the acquisition of locally adaptive information from conspecifics without having to pay some of the costs associated with individual learning, such as a higher risk of predation (Galef & Laland, 2005). Animals use a diversity of mechanisms to learn from others, including social facilitation, stimulus and local enhancement, or observational conditioning (Heyes, 1994; Laland, 2004) and social learning is evident in many taxa, including primates (Whiten, 2000), birds, reptiles (Kis, Huber, & Wilkinson, 2014; Wilkinson, Kuenstner, Mueller, & Huber, 2010) and fish (Duffy, Pike, & Laland, 2009).

Research on social learning often focuses on information transfer between conspecifics (Laland, 2004; Whiten, Horner, Litchfield, & Marshall-Pescini, 2004), but social learning between members of different species also occurs and may be

particularly relevant in human–animal interactions. For example, the ability of canids to solve a task in which they have to go around an obstacle in order to reach a food reward (also known as a 'detour task') has been widely investigated (Mersmann, Tomasello, Call, Kaminski, & Taborsky, 2011; Pongrácz et al., 2001). Interestingly, dogs, *Canis lupus familiaris*, but not dingoes, *Canis lupus dingo*, were quicker to find food in a detour task after watching a human demonstrator (Pongrácz et al., 2001; Smith & Litchfield, 2010). This has led to the assumption that the ability of dogs to learn socially from humans in a detour task is linked to their specific domestication history as companion animals, which led to an increased inclination to interact with humans and to pay attention to their communicative cues (Hare, Brown, Williamson, & Tomasello, 2002). However, others have suggested that the ability of dogs to gain information from humans is more closely associated with ontogeny, e.g. being raised by humans (Udell, Dorey, & Wynne, 2008).

In general, detour tasks can be used to investigate social learning abilities between conspecifics and heterospecifics (Pongrácz et al., 2001; Rørvang, Ahrendt, & Christensen, 2015; Wilkinson et al., 2010). However, to date, the effect of a human demonstrator during detour tasks has only been assessed for canids (Mersmann et al., 2011; Pongrácz et al., 2001; Pongrácz, Miklósi, Timár-Geng, & Csányi, 2003; Smith & Litchfield, 2010), and therefore broad conclusions about the mechanism that resulted in this ability are not possible. Research on other species, particularly domesticated ones, is crucial in order to evaluate which species perceive and use information provided by humans.

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In ungulate livestock, vertical information transfer between individuals (e.g. social learning by offspring from mothers) is important for the development of foraging skills (Glasser et al., 2009; Oostindjer et al., 2011). Still, evidence for horizontal information transfer is scarce. For example, there is no consensus as to whether horses, *Equus caballus*, are capable of social learning from conspecifics or heterospecifics (Baer, Potter, Friend, & Beaver, 1983; Clarke, Nicol, Jones, & McGreevy, 1996; Krueger, Farmer, & Heinze, 2014). Horses that observed a demonstrator horse manipulating an apparatus to receive a reward also spent more time near the test apparatus. However, observer horses did not learn to manipulate the apparatus more quickly than control horses (Ahrendt, Christensen, & Ladewig, 2012), indicating that they relied on stimulus and/or local enhancement cues from the demonstrators. In another task, observer horses copied specific following behaviours towards humans if the demonstrator was a dominant conspecific, whereas this was not the case if the demonstrator horse was subordinate or unknown to the observer (Krueger & Heinze, 2008).

Less attention has been paid to investigating heterospecific learning in domestic ungulates, e.g. from humans. Held, Mendl, Devereux, and Byrne (2001) reported that pigs, *Sus scrofa*, directly trained by a human experimenter to find food (in one of several corridors) learned to locate the reward. Although pigs learned to visit the correct location, this can only be considered as nonsystematic evidence, because data for the training trials were not analysed in detail. More importantly, no control group without a human demonstrator was tested. In addition, there is no evidence for horizontal information transfer or heterospecific social learning in other ungulate livestock species, e.g. goats and sheep (Baciadonna, McElligott, & Briefer, 2013; Briefer, Haque, Baciadonna, & McElligott, 2014). Some of the negative findings might be explained by test subjects not approaching higher-ranking conspecifics or by potential food depletion when a conspecific moves to a rewarded position first (Baciadonna et al., 2013; Rørvang et al., 2015). Methodological constraints are an alternative explanation for the lack of positive results. The test set-ups may have been too difficult to master for the subjects after only a limited amount of exposure to a demonstrator, e.g. by using a two-step puzzle box (Briefer et al., 2014). Furthermore, the ability of subjects to pay attention to demonstrators may have been reduced because presentation times were too long or the actions performed by the demonstrator may not have been ecologically meaningful to the observer, e.g. pulling a string (Briefer et al., 2014). To solve some of these issues, one solution would be to use attention-getting behaviours during the task as this has already been shown to improve dogs' detour performance (Pongrácz, Miklósi, Timár-Geng, & Csányi, 2004).

In previous research, detour tasks with ungulate livestock have focused mostly on the effects of laterality (Versace, Morgante, Pulina, & Vallortigara, 2007) and/or spatial learning (Osthaus, Proops, Hocking, & Burden, 2013; see Rørvang et al., 2015 for lack of social learning in horses using a detour task). In our study, we investigated the effect of a human demonstrator on the performance of goats, *Capra hircus*, in a detour task and addressed potential shortcomings in previous research. We implemented attention-getting behaviours (i.e. rattling sound of food rewards) to attract the attention of subjects towards the human demonstration of the task (Pongrácz et al., 2004). Furthermore, we examined their flexibility in generalizing learned solutions in the spatial problem-solving task. To accomplish this, we presented goats with a series of trials of either inward or outward detour tasks before reversing the detour in a final trial (see Fig. 1). Canids solved the outward configuration faster than the inward configuration, probably because of an avoidance of corners (Pongrácz et al., 2001;

Smith & Litchfield, 2010). In a similar manner, we expected goats to perform better in the outward than the inward task. For this reason, we only gave them a human demonstration in the inward but not outward detour configuration. This is because we expected a floor effect for their latencies in the outward detour that would have hampered our ability to detect performance improvements after prior human demonstration. Importantly, we expected them to improve in their detour performance once they had observed a human solving the inward task (Pongrácz et al., 2001; Pongrácz, Miklósi, Vida, & Csányi, 2005).

METHODS

Subjects and Housing

The study was carried out at a goat sanctuary (Buttercups Sanctuary for Goats, <http://www.buttercups.org.uk>) in the U.K. Initially, we tested 42 adult goats (14 females and 28 castrated males, Table 1), which were fully habituated to human presence because of previous research (Baciadonna et al., 2013; Briefer & McElligott, 2013). They were aged 3–16 years and of various breeds. Routine care of the animals was provided by sanctuary employees and volunteers. The goats had ad libitum access to hay and were not food restricted before testing.

Procedure

The experiment was carried out in a temporary enclosure (700 × 500 cm), which we set up within the normal daytime range of the goats. Subjects were tested from 1200 to 1600 hours during September 2015. The test subjects were visually isolated from other goats, but remained in auditory and olfactory contact with them. Two transparent metal hurdles (height: 120 cm; length: 200 cm) were positioned in the middle of the test arena according to the different test conditions (Fig. 1a). Before the start of each training and test trial, the test subjects were kept on a leash by one experimenter to standardize its starting position during the trials.

Training

The initial training period consisted of three trials for every subject before testing. An experimenter baited a transparent plastic box (10 × 20 cm) with a piece of dry pasta visible to the subject, positioned the box in front of the hurdles and shook the box once. The subject was then released and was free to explore the arena and the box. After the subject obtained the reward from the box, the subject was brought back to the starting point and a new training trial started. Subjects that went reliably towards the box after three trials were included in the test. Subjects were assigned to one of the following three experimental groups.

Inward detour group (no demonstrator)

This inward detour group with no demonstrator consisted of 13 goats. Three goats were excluded because they did not approach the box reliably in the training trials. A second experimenter remained with the goat at the starting pen and prevented it from seeing inside the test arena by using opaque livestock fencing. The first experimenter placed the baited box through the V-shaped hurdles on the inner side of the intersecting angle, not visible to the test animal (Fig. 1b), and shook the box once to draw the subject's auditory attention towards it. When the first experimenter returned to the starting pen, the second experimenter released the goat and started the trial. Both experimenters remained in the starting pen. If the goat was not able to obtain the reward within

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