Social learning across species - horses (*Equus caballus*) learn from humans by observation

Aurelia Schuetz[3] Kate Farmer[2], Konstanze Krueger[13]
[1]University of Regensburg, Biology 1, Universitätsstraße 31, 93053 Regensburg, Germany
[2]St Andrews University, School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife, KY16 9JP Scotland, United Kingdom
present address:
[3]University of Applied Sciences Nürtingen-Geislingen, Neckarsteige 6-10, 72622 Nürtingen, Germany
corresponding author: Konstanze Krueger: konstanze-krueger@equine-science.de

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Abstract

This study examines whether horses can learn by observing humans, given that they identify individual humans and orientate on the focus of human attention. We tested 24 horses aged between three and twelve. 12 horses were tested on whether they would learn to open a feeding apparatus by observing a familiar person. The other 12 were controls and received exactly the same experimental procedure, but without a demonstration of how to operate the apparatus. More horses from the group with demonstration reached the learning criterion (N = 8) of opening the feeder twenty times consecutively, than horses from the control group (N = 2), and younger horses seemed to reach the criterion more quickly. Horses not reaching the learning criteria approached the human experimenters more often than those that did. The results demonstrate that horses learn socially across species, in this case from humans.

Keywords

Social enhancement • Equus caballus • Human demonstrator • Interspecies specific learning • Social learning

Introduction

Animals acquire new behaviours through individual and social learning. Individual learning is triggered by the experience of an individual animal, while social learning occurs when an animal observes another animal's behaviour, or their visual, olfactory, and auditory cues, to achieve a goal. (Byrne and Whiten 1988). Social enhancement is said to be the simplest social learning mechanism and is common in animals (Mersmann et al. 2011). It can be either stimulus enhancement (i.e. focussing the oberver's attention on a demonstrator's action) or local enhancement (i.e. focussing the observer's attention on a demonstrator's presence). Furthermore, social learning can occur through observational conditioning (i.e. positive or negative associations with an object or event through observation) or through copying the behaviour of others (Whiten et al. 2004). Copying may be exact imitation or emulation of behaviour when the animals understood the observer's goal but used other techniques to achieve it (Tomasello 1990).

Complex social systems, as reported for horses, promote social information transfer (Byrne and Whiten 1988). Equids show elaborate social skills such as the formation of alliances between females for offspring protection (Cameron et al. 2009), interventions in affiliative and agonistic interactions of group members for bond protection (Schneider and Krueger 2012; Krueger et al. 2015), and conciliatory behaviour after conflict (Cozzi et al. 2010). So, it is not surprising that they copy the social behaviour of other horses (Krueger and Heinze 2008), adapt to the expectations of other horses when crossing a carpet (Rørvang et al. 2015), and learn to open a feeding apparatus by observing other horses (Krueger et al. 2014). Interestingly, horses learn from higher ranking, older horses in their social group (Krueger and Heinze 2008;

Krueger et al. 2014), and a mix of individual trial and error learning and social enhancement has been discussed to be the primary mechanism in horses (Krueger et al. 2014; Rørvang et al. 2015).

In addition, the domestication of horses 3000- 5000 years ago may have shaped inter-species communication abilities as in other domestic species. Geese, imprinted by humans, learned to open a feed box by observing their caretaker (Fritz et al. 2000) and dogs learned tasks, such as finding toys in a detour task and how to operate several types of experimental apparatus from humans (Pongrácz et al. 2001, 2004,2012; Mersmann et al. 2011). Dogs appeared to learn socially from familiar and unfamiliar persons (Pongrácz et al. 2001) and high and low ranking dogs learned from humans equally well (Pongrácz et al. 2008, 2012).

Domestic horses are able to use human pointing gestures to find food (Maros et al. 2008; Proops et al. 2013) and to orientate on the direction of human attention (Sankey et al. 2011; Krueger et al. 2011). They distinguish between familiar and unfamiliar persons (Sankey et al. 2011; Proops and McComb 2012), generalise positive and negative experiences from one human to others (Sankey et al. 2010) and infer emotional states from human photos (Smith et al. 2016). Some horses have expectations of human behaviour (Sankey et al. 2011) which may inhibit their performance in an experiment (Lesimple et al. 2012).

This study evaluates: a) whether horses would learn to open a feeding apparatus by observing a human demonstrator and b) whether horses choosing to stay in close contact with the experimenters would show behaviour indicating social learning to the same extent as the others.

Methods

Locations, study periods and animals

Between January and April 2015, we tested horses in their home environments, as familiarity with the test area improves learning in mammals (Miklósi and Soproni 2006; Maros et al. 2008). They were kept in eight different locations with various housing conditions close to Stuttgart, Germany. The housing and management of the horses were in line with German horse management guidelines with at least three to four hours turn-out in social groups each day.

The 24 horses were semi randomly distributed over the experimental (N = 12) and control group (N = 12). The former comprised seven horses and five ponies of various breeds, with six mares, five geldings and one stallion, all aged between three and twelve (mean = 6.1 years, SD = 3.14). The control group was composed of five horses and seven ponies, with five mares and seven gelding, aged between four and twelve (mean = 8 years, SD = 2.97). It has been shown that animals with basic training from humans may be better at reading human cues (Miklósi and Soproni 2006), so we chose horses with at least 3 months of basic "ground training" (Deutsche Reiterliche Vereinigung e.V. 2014). All horses were mentally and physically sound and in good or very good feeding condition. During the 2 hours before the experiment they were not trained and received only hay.

Experimental area and apparatus

We used lunging circles or riding arenas with sand and/ or wood shavings on the ground. We fenced them to make experimental areas of about 15 m², with grass out of the horses' reach (Fig. 1). The experimental apparatus consisted of a feed box, and a switch which had to be pressed to open the feed box (Fig. 1). We separated the box and the switch by 1 meter, as learning can clearly be

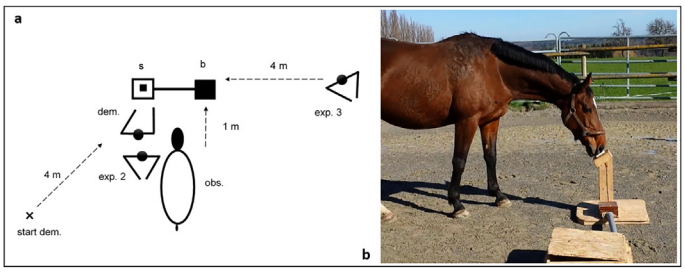

Fig. 1 Experimental setting: a positions of the horse (obs.), the demonstrating person (dem.) the starting position (start dem.) Experimenter 2 (exp. 2), and Experimenter 3 (exp. 3) b the observer horse pushes the switch to open the feed box.

demonstrated if animals have to memorise a particular manipulation to achieve a goal some distance away.

The wooden feed box was 50 cm long, 50 cm wide and 20 cm high, with a wooden lid. A removable plastic box for the feed was placed inside and cleaned after each test to avoid contamination. The switch was white, to contrast with the wood and be clearly visible to the horses. It was 8 x 8 cm and mounted on a 15 x 15 x 7 cm wooden container. Although horses discriminate objects and colours best at ground level (Hall et al. 2003), we placed the switch on the 35° sloped top of a 50 cm high and 15.5 cm thick pole for safety reasons. Pressing the switch opened the lid of the box electronically. An 8 volt battery, embedded in the wooden pole and secured with a wooden cover, powered the box and switch via a wire, which was protected by an 8cm grey, plastic tube.

Experimenters and their tasks

There were three experimenters, each with different tasks.

Experimenter 1 was the demonstrator. As horses orientate best on familiar persons (Krueger et al. 2011) and learn best from familiar conspecifics (Krueger and Heinze 2008) owners (N = 12) who had cared for their horse for at least one year were chosen. Experimenter 1 walked from the start (Fig. 1) to the switch (about 4 m) and raised her arm to hip height after about 2 m. She called the horse's name during the second half of the walk, to get its attention (Pongrácz et al. 2004). After pressing the switch, the demonstrator waited for the feed box to fully open, walked to the box, squatted down at the left side of the box so that horses could see the full procedure. She then took a piece of food out of the box, and ate it within 5 seconds. She then stood up and returned to the start, turning her back to the apparatus.

Experimenter 2 handled the horse, and was unknown to the horse. She led the horse to the start (Fig. 1), then stayed there, turning her back to the apparatus. She kept the horse on a loose rope, and did not touch the horse (Krueger et al. 2014) while it observed experimenter 1. Experimenter 2 released the horse at the starting position and led the horse back to the start after each trial.

Experimenter 3 recorded the results on a tablet pc, controlled the video camera and refilled the box. She placed herself at the fence, to the right of the apparatus and turned away to about 135° (Fig. 1). Refilling the feed box was done in full sight of the observing horse to reduce feature negative effects (Hopewell et al. 2010) which may lead some animals to think that the demonstrator left no food in the box.

Experimental procedure

Habituation phase

A maximum of ten habituation trials per horse were conducted on the first day. The habituation criteria were reached when the horse approached the open feeding box unprompted, and ate all the food inside, twice in a row. Horses in the experimental group needed a mean of 6.42 (SD = 2.1) and horses in the control group a mean of 5.1 (SD = 0.79) habituation trials.

Procedure for the experimental group

The 12 test horses received a maximum of 120 demonstrations, 10 – 20 per day, spread over one to two weeks, depending on their motivation (Krueger et al. 2014). To increase motivation, horses were allowed to eat once from the box before the experiments started each test day. If horses hesitated to approach the box they received a motivation feeding between the 8th and the 9th trial on each test day. If they kept approaching the experimental apparatus but failed to operate it, they received a motivation feeding at the latest between the 11th and the 12th trial.

The horse was positioned with its front feet one meter away from the apparatus, to ensure it could closely observe the procedure. It was then free to investigate the apparatus for 3 minutes during each trial (Fig. 1). After 3 minutes the horse was led back to the start. When horses pressed the switch and opened the feed box they were allowed to eat all the food inside before the next trial.

Learning criteria were reached and the experiment finished when the horse opened the feed box 20 times in succession, ten with demonstration and 10 without demonstration (Krueger et al. 2014). If horses did not reach learning criteria within 120 trials, or if they lost interest and did not touch the feeding apparatus for 10 trials in a row, they received one further motivation feeding. If the horse still did not touch the feeding apparatus (apart from one possible approach directly after the motivation feeding) the experiment was terminated for this particular horse

The apparatus was counted as touched when a horse sniffed, licked, bit, or pushed it with its muzzle, or if the horse pushed it with its hoof. Touches were recorded on the tablet PC, and the technique used was analysed from the video recordings.

Procedure for the control group

The experimental procedure for the control group was basically the same as for the test horses, but without any demonstration of how to open the apparatus.

The horse owners stayed at the starting position with their backs turned towards the feeding apparatus.If a control horse was successful, it was allowed to eat the food and was led back to the starting position for the observer horses. If it was not successful the food was still in the box. The box had to be emptied to start a complete, new trial. Therefore, the control horse was turned around, led away, and positioned with its back, slightly transvers to the experimental apparatus. Experimenter 2 covered the corner of horse's eye nearest the apparatus with her hand, so it could not see experimenter 3, who opened and emptied the feed box. Then the horse was turned around led to the starting position and another trial was started.

Data analysis

We calculated the number of trials in which each horse showed a certain behaviour as a percentage of its overall number of trials.

We also calculated a "Touch Order Index", to indicate whether horses touched the switch or the feed box first, as follows: number of trials switch touched first – number of trials box touched first / number of trials switch touched first + number of trials box touched. If the box was touched first more often, the value was closer to -1, and if the switch was touched first more often, the value was closer to 1.

The statistical analysis was done with the R-Project statistical environment (R Development Core Team, 2016). Figures were made with Microsoft Word 2013 and GIMP 2.8. We used non-parametric tests because the data of some samples were not normally distributed (Shapiro Wilk test). Multifactorial comparisons were tested with Generalized Linear Models (GzLMs). To compare medians we used Wilcoxon signed rank exact tests for dependent data. A one Sample Wilcoxon signed rank exact test was used to calculate deviations from the mean within a sample. To analyse correlations of data sets with $N < 10$, we applied Kendall's rank correlation tau tests. All tests were two-tailed and the significance level was set at 0.05.

Ethic statement

All the horse owners offered their horses and their own participation in the experiment of their own free will. They were informed about the test procedure and the publication of the anonymous data before testing, and agreed with both. The tests did not cause the horses any pain, suffering or damage. The experiments were in agreement with the German animal welfare regulations and no permit by the animal welfare board of the test region was needed.

Table 1 Test horses of the experimental and the control group

name	age	sex	size	LC / NLC*	# trials till learn	# trials till loss of interest
Experimental						
Sorana	3	Mare	Horse	LC	3	-
Willi	3,5	Gelding	Pony	LC	9	-
Stjarni	3,5	Gelding	Pony	LC	14	-
Bandit	4	Gelding	Pony	NLC	-	57
Campino	4	Mare	Horse	LC	2	-
Plume	4	Mare	Horse	LC	5	-
Cheyenne	5	Mare	Horse	LC	5	-
Venus	6	Gelding	Pony	NLC	-	83
Charly	8	Stallion	Pony	LC	26	-
Camilla	9	Mare	Horse	LC	52	-
Anni	11	Mare	Horse	LC	26	-
Brunka	12	mare	Pony	NLC	-	56
Median					**11,5**	**68**
Controll						
Jpy	4	mare	Pony	NLC	-	41
Naskur	4,5	Gelding	Pony	NLC	-	37
Glaenefor	5	Gelding	Pony	NLC	-	38
Kahila	5	Mare	Horse	NLC	-	40
Avalon	7	Gelding	Pony	NLC	-	38
Estelle	8	Mare	Pony	NLC	-	13
Enamorado	8	Gelding	Horse	NLC	-	70
Mijall	8	Gelding	Pony	LC	13	-
Askaban	11	Gelding	Horse	NLC	-	25

* LC = horses reached the learning criteria, NLC = horse did not reach the learning criteria

Results

More horses of the experimental group (N = 8) reached the learning criterion than horses from the control group (N = 2) (GzLM N = 24, z = 2.33, p = 0.02; Table 1). One horse in the experimental group and 5 horses in the control group opened the feed box between 1 and 5 times, but never reached the learning criteria. Horses that reached the learning criterion took fewer trials than those that lost interest when they did not reach learning criterion (GzLM: N = 24, t = 4.43, p < 0.001; Table 1). Also, horses in the test group (with demonstrations) took fewer trials than horses in the control group (without demonstration) (GzLM: N = 24, t = 2.6, p = 0.02; Table 1). The younger the horses, the fewer the demonstrations they needed to open the box for the first time (Kendall's rank correlation tau: N = 8, τ = 0.69, p = 0.02) and they tended to need fewer trials to reach the learning criteria (Kendall's rank correlation tau: N = 8, τ = 0.52, p = 0.08, Table 1.

Order of touching the feed box and the switch

In most trials the horses touched the feed box before they touched the switch (One Sample Wilcoxon signed rank exact test: N = 24, V = 0, p < 0.001), with no difference between horses that reached the criterion and those that did not, or experimental and control horses (GzLM: all p > 0.05).

Criterion reaching horses changed to touching the switch before approaching the feed box at a median of 6 trials (min = 1 trial, max. = 12 trials) within the 20 trials of the learning criteria, irrespective of their age (Kendall's rank correlation tau: N = 10, τ = -0.05, p = 0.85) and irrespective of the frequency with which they touched any part of the apparatus (Kendall's rank correlation tau: N = 10, τ = 0.07, p = 0.78). Horses that needed more trials before changing to operating the switch before going to the feed box were more inconsistent in approaching the switch before the feed box. (Kendall's rank correlation tau: N = 10, τ = -0.68, p = 0.01).

Manipulation techniques of successful observer horses

The eight observer horses that reached the criterion used five techniques to manipulate the switch: they bit it, pressed it with their upper lip, played with it with the upper lip, licked it, and pressed it with their hoof (Fig. ESM_2, Online Resource 2). Three horses used only one technique. Five horses used two or three techniques, of which four horses used a mix of several techniques throughout the test, and one used only one technique after trial ten. The two control horses that reached the learning criterion used only one technique: pressing the switch with their upper lip.

Approaches to human experimenters

Horses that reached the criterion approached the human experimenters less frequently than those that didn't

(GzLM: N = 24, t = 2.97, p = 0.007) and horses of the experimental group approached the experimenters less frequently than control horses (GzLM: N = 24, t = -3.181, p = 0.004; Fig.2).

Discussion

In this study, more horses operated a feeding apparatus after observing a human demonstrator, than horses that did not receive a demonstration. Domestication may have shaped the horses' ability and motivation to use human given cues (Maros et al. 2008; Proops et al. 2013; Sankey et al. 2011; Krueger et al. 2011), as discussed for dogs (Hare et al. 2002; Miklósi and Soproni 2006). As previously shown for individual and social learning in horses, young horses tended to reach the learning criteria more quickly than older horses (Nicol 2002; Krueger et al. 2014). Some horses may have used individual trial and error to open the feed box (Krueger et al. 2014), as two control horses learned how to open the feed box without any demonstration, and all the horses started manipulating the feed box before manipulating the switch. Individual learning at the feed box is very likely to have been triggered by finding feed there during the habituation phase and motivation feedings. It may have been socially enhanced by the presence of the recording experimenter close to the feed box.

However, social enhancement, triggered through the demonstrators' action, may have reinforced the horses' interest in the manipulation of the switch, as more horses from the experimental group reached the learning criterion than from the control group. Experimental group horses that reached learning criterion tried more manipulation techniques than those from the control group, but it should be noted that only two control horses learned the task. Furthermore, the experimental group horses, especially those that did not reach learning criterion, participated in the test for much longer than the control horses. Local enhancement may have attracted attention to the feeding apparatus itself, and especially the feed box, where demonstrators spent most of their time. Stimulus enhancement by the demonstrator's manipulation of the switch may have guided the horses' attention to some degree (Byrne and Whiten 1988; Whiten et al. 2004). The process of horses changing from manipulating the feed box first to operating the switch first could be the result of observational conditioning. Observing that pushing the switch is followed by a food reward from the feed box may have established an operant response (Whiten et al. 2004), as in elephants (Greco et al. 2013).

Whether horses consciously copied demonstrators (Tomasello 1990; Whiten et al. 2004) can not be inferred from this study. The position of the switch on top of a 50 cm pole made copying the technique of the demonstrator difficult. Furthermore, the delicate movement of the person pushing the switch may have been difficult to see by the observer horses.

Interaction with human experimenters

As in dogs and horses, the horses in this study that did not reach the learning criterion appeared to have expectations of the human experimenters (Sankey et al. 2011; Lesimple et al. 2012). They approached the experimenter more often than horses that reached the criterion. This appears to be comparable to dogs with a strong relationship with their owners (Topál et al 1997), and horses which showed frequent eye to eye contact and exploration behaviour towards humans performing poorly in learning tests (Lesimple et al. 2012). They could have been frustrated by the experiment and therefore may have searched for more contact with the persons. This is consistent with the observation that the control horses which received no demonstration searched for more contact with the experimenters than horses of the experimental group. Alternatively, the horses' behaviour may have been affected by previous experiences in which persons may have solved problems for them, and may have expected the person to provide the solution (Topál et al. 1997). Some of the horses that did not reach the learning criterion may simply have been demotivated and may have understood the task but did not demonstrate it. Moreover, some control horses may have orientated on their owners focus of attention rather than on the apparatus (Krueger et al. 2011). The influence of familiarity and posture should be controlled for in a follow up experiment.

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Supplementary material

Table A1, ESM_1, Learner horses touched the switch less often the more trials they completed (Fisher combination test: N = 10, $\chi^2_9 = 86.96$, $p < 0.001$).

Spearman-Rank-Correlation tests: trial # of learning criteria versus frequency of touches at switch			
Pferd	**N**	**τ**	**p**
Sorana	20	-0,689	<0,001
Willi	20	-0,652	0,002
Stjarni	20	-0,632	0,003
Plume	20	-0,613	0,004
Cheyenne	20	0,377	0,102
Charly	20	-0,205	0,386
Camilla	20	-0,174	0,462
Anni	20	-0,831	<0,001

Figure ESM_2

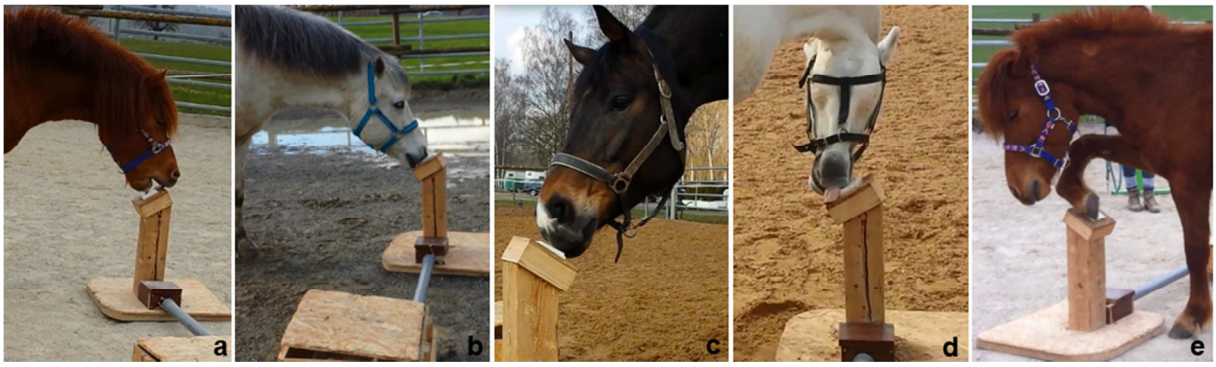

Fig. A1 Manipulation techniques, horses **a** bit the switch, **b** pressed the switch with their upper lip, **c** played at the switch with the upper lip, **d** licked the switch, and **e** pressed the switch with their hoof.