„Zoophilologica. Polish Journal of Animal Studies"
Nr 2 (14)/2024, pp. 1–24
ISSN 2451-3849
DOI: https://doi.org/10.31261/ZOOPHILOLOGICA.2024.14.06

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Horses' Self-recognition in the Mirror Test New Approach

Самоузнавание лошадей в зеркальном тесте. Новый подход

Абстракт

Целью статьи является представление новой, модифицированной процедуры зеркального теста и ответ на вопрос, является ли домашняя лошадь (Equus caballus) самосознательным видом с точки зрения рефлексивного сознания. Новый подход к зеркальному тесту отличается сокращением времени воздействия зеркального отражения на животное, изменениями в маркере и введением контрольного условия, которое минимизирует вероятность получения ложноположительных результатов. Испытание включает 24 лошади, которые тестировались в двух условиях. Четверть лошадей смогли обнаружить невидимое для них лакомство, не видя себя в зеркале. Такое поведение интерпретировалось как самоузнавание. Эта доля оказалась статистически значимо отличной от доли,

Horses' Self-recognition in the Mirror Test New Approach

Abstract

This paper aims to present a new, modified mirror test procedure and to answer the question of whether the domestic horse (*Equus caballus*) is a self-conscious species in terms of reflexive consciousness. The new approach to the mirror test is characterised by a reduction in the animal's exposure time to the mirror image, changes in the marker, and introduction of a control condition, which minimises the likelihood of false positive results. The sample includes 24 horses tested in two conditions. A quarter of the horses tested were able to detect a treat that was invisible to them, without seeing themselves in the mirror. This behaviour was interpreted as self-recognition. This proportion turned out to be statistically significantly different from the proportion expected in the null hypothesis, as shown by the McNemar test. In the light of the above

ожидаемой в нулевой гипотезе, как показал тест Макнемара. В свете вышеприведенных результатов эксперимента и теоретического анализа характеристик вида мы пришли к выводу, что самоузнавание наблюдаемых лошадей, по-видимому, свидетельствует об их самосознании.

Ключевые слова: лошадь, домашняя лошадь, самоузнавание, самосознание

results of the experiment and theoretical analysis of the characteristics of the species we draw a conclusion that the observed horses' self-recognition is a likely mark of their self-consciousness.

Keywords: horse, *Equus caballus*, mirror test, self-recognition, self-consciousness, self-awareness

While horsemanship is an age-old art, it is only through recent scientific advancements that we have gained systematic and verified understanding of the workings of the equine mind. For example, developments in cognitive science and comparative psychology allow researchers to explore the field of animal psychology using quite-proven research methods.[1,2] It is therefore not surprising that researchers interested in equine psychology have begun to conduct research into the question of whether the domestic horse is a self-conscious species.[3,4] So far, this issue does not appear to have been resolved.

As herd animals, horses have developed specific herd behaviours and highly sophisticated inter-individual (as well as interspecies) communication, using mainly gestures and muzzle facial expressions.[5] Advanced social interactions involving the phenomena of care and rearing of offspring by mares, social behaviour reflecting care, and a wide range of playfulness differentiated by both sex and age of individuals[6] are indicative of high social intelligence in domestic horses.[7] There are also reports of a prevalent ability among horses to learn by imitating the behaviour of

[1] Susan D. Healy, "The face of animal cognition," *Integrative Zoology*, 14, no. 2 (2019): 132–144, https://doi.org/10.1111/1749-4877.12361.

[2] Jean Pierre Rossi, "Cognitive Sciences and the Mind of Animals," *International Journal of Comparative Psychology*, (1992), https://doi.org/10.46867/c4s88f.

[3] Paolo Baragli, Chiara Scopa, Veronica Maglieri, and Elisabetta Palagi, "If Horses Had Toes: Demonstrating Mirror Self Recognition at Group Level in Equus Caballus," *Animal Cognition*, 24, no. 5 (2021): 1099–1108, https://doi.org/10.1007/s10071-021-01502-7.

[4] Gordon G. Gallup and James M. Anderson, "Putting the Cart before the Horse: Claims for Mirror Self-Recognition in Horses Are Unfounded," *Animal Cognition*, 25, no. 1 (2021): 1–4, https://doi.org/10.1007/s10071-021-01538-9.

[5] Jen Wathan, Anne M. Burrows, Bridget M. Waller, and Karen McComb, "EquiFACS: The Equine Facial Action Coding System," *PLOS ONE*, 10, no. 8 (2015): e0131738, https://doi.org/10.1371/journal.pone.0131738.

[6] Sue M. McDonnell, "Reproductive Behavior of Stallions and Mares: Comparison of Free-Running and Domestic in-Hand Breeding," *Animal Reproduction Science*, 60–61 (2000): 211–19, https://doi.org/10.1016/s0378-4320(00)00136-6.

[7] Leanne Proops, "Social Cognition in Domestic Horses (Equus Caballus)," PhD diss., University of Sussex, 2011.

other individual horses. Animals are thought to use this ability according to social learning principles.[8]

Moreover, research shows that horses are able to communicate their preferences to humans using symbols, and that, at least some of them, are capable of solving problems based on conceptual understanding.[9] Furthermore, it is thought that horses may be characterised by possessing long-term categorical and conceptual memory.[10] Some researchers[11] report that horses may be characterised by some limited type of prospective memory (up to about 10 seconds), which appears to be trainable to slightly improve performance. Other studies indicate that for short-term spatial memory, horses seem to be able to encode and recover the existence of the target object and its location for up to 30 seconds.[12] Research on decision-making in horses focuses, among other things, on the ecological aspect. Observations of semi-free ranging population of Przewalski horses have shown that movement decisions might be made by herd consensus driven by ecological determinants.[13]

Results from other studies suggest that domestic horses may be capable of cross-modal recognition of faces of familiar people,[14] including correctly discriminating facial images of unrelated individuals, as well as monozygotic and dizygotic twins.[15] A study by Lansade et al.[16] allows us to conclude that horses recognise the human

[8] Konstanze Krueger, Kate Farmer, and Jürgen Heinze, "The Effects of Age, Rank and Neophobia on Social Learning in Horses," *Animal Cognition*, 17, no. 3 (2013): 645–55, https://doi.org/10.1007/s10071-013-0696-x.

[9] Cecilie Marie Mejdell, Turid Buvik, Grete Helen Meisfjord Jørgensen, and Knut Egil Bøe, "Horses Can Learn to Use Symbols to Communicate Their Preferences," *Applied Animal Behaviour Science*, 184 (2016): 66–73, https://doi.org/10.1016/j.applanim.2016.07.014.

[10] Evelyn B. Hanggi and Jerry F. Ingersoll, "Long-Term Memory for Categories and Concepts in Horses (Equus Caballus)," *Animal Cognition*, 12, no. 3 (2009): 451–62, https://doi.org/10.1007/s10071-008-0205-9.

[11] Jack Murphy, "Assessing Equine Prospective Memory in a Y-maze Apparatus," *Veterinary Journal*, 181, no. 1 (2009): 24–8, https://doi.org/10.1016/j.tvjl.2009.03.028.

[12] Paolo Baragli, Valentina Vitale, Elisa Paoletti, Manuel Mengoli, and Claudio Sighieri, "Encoding the Object Position for Assessment of Short Term Spatial Memory in Horses (Equus caballus)," *International Journal of Comparative Psychology*, 24 (2011): 284–91, https://doi.org/10.46867/ijcp.2011.24.03.02.

[13] Marie Bourjade, Bernard Thierry, Myriam Maumy and Odile Petit, "Decision-Making in Przewalski Horses (Equus ferus przewalskii) is Driven by the Ecological Contexts of Collective Movements," *Ethology*, 115 (2009): 321–30, https://doi.org/10.1111/J.1439-0310.2009.01614.X.

[14] Jessica Frances Lampe, and Jeffrey Andre, "Cross-Modal Recognition of Human Individuals in Domestic Horses (Equus Caballus)," *Animal Cognition*, 15, no. 4 (2012): 623–30, https://doi.org/10.1007/s10071-012-0490-1.

[15] Sherril M. Stone, "Human Facial Discrimination in Horses: Can They Tell Us Apart?" *Animal Cognition*, 13, no. 1 (2009): 51–61, https://doi.org/10.1007/s10071-009-0244-x.

[16] Léa Lansade, Violaine Colson, Céline Parias, Fabrice Reigner, Aline Bertin, and Ludovic Calandreau, "Human Face Recognition in Horses: Data in Favor of a Holistic Process," *Frontiers in Psychology*, 11 (2020), https://doi.org/10.3389/fpsyg.2020.575808.

face based not on a single, specific facial feature, but by recognizing holistically the whole set of features. In addition, it seems that facial images are not processed by horses as abstract shapes, as faces first shown in photographs were subsequently also recognised by horses in direct contact between the human in question and the horse. In light of the above-mentioned research results, it is safe to state that horses have higher cognitive functions,[17] including the promising ability to recognise faces,[18] therefore questions have started to be asked about self-consciousness in horses.[19]

While self-consciousness is a construct that has been vastly studied in animals, progress in this area has been significantly hampered due to terminological disagreements and controversy over key concepts. Bekoff and Sherman[20] proposed that *self-cognizance* can be understood as a point on a continuum of complex social behaviour and conscious engagement. Those researchers detailed three degrees of self-cognizance in animals: (1) *self-referencing*: the ability to compare the characteristics of an object/individual (such as an individual's smell or appearance) with those learnt from their own phenotype, and then accepting or rejecting that object based on a degree of likelihood; (2) *self-awareness*: the ability to distinguish one's own body or other things from that of other individuals or their things; and (3) *self-consciousness*: the presence of such feelings as sympathy, empathy, and the presence of theory of mind (the ability to infer and understand another's mental states, such as intentions, feelings and beliefs and to use this information to explain and predict other's behaviour.[21] According to Bekoff and Sherman's[22] theory, passing the mirror self-recognition (MSR) test proves the presence of self-awareness in the animal.

The MSR test is a behavioural technique developed by Gordon G. Gallup[23] and first used to investigate the potential self-consciousness of chimpanzees. Its purpose is to attempt to determine whether the animal being tested has the ability to visually recognise itself. The test has been successfully conducted on a variety of

[17] Takimoto, Ayaka, Yusuke Hori, and Kazuo Fujita, "The Present Situation and Future Prospects of Studies on Horse Cognition," *Japanese Journal of Animal Psychology*, 61 (2011): 141–53, https://doi.org/10.2502/JANIP.61.2.2.

[18] Lansade et al., "Human Face Recognition in Horses: Data in Favor of a Holistic Process."

[19] Baragli et al., "If Horses Had Toes: Demonstrating Mirror Self Recognition at Group Level in Equus Caballus."

[20] Marc Bekoff, and Paul W. Sherman, "Reflections on Animal Selves," *Trends in Ecology and Evolution*, 19, no. 4 (2004): 176–80, https://doi.org/10.1016/j.tree.2003.12.010.

[21] Sarah Whittle, Katherine Bray and Elena Pozzi, "Toward a Social Brain," *Elsevier EBooks*, 2021, https://doi.org/10.1016/b978-0-12-819641-0.00136-5.

[22] Bekoff and Sherman, "Reflections on Animal Selves."

[23] Gordon G. Gallup, "Chimpanzees: Self-Recognition," *Science*, 167, no. 3914 (1970): 86–87, https://doi.org/10.1126/science.167.3914.86.

animal species, including bottlenose dolphins,[24] magpies,[25] and gorillas.[26] A positive result on the MSR test was also reported for the Asian elephant.[27] Despite the many reports that not only primates, but also bird, marine mammal, or fish are able to pass the MSR test, Gallup[28] claims that methodological errors and over-interpretations in some publications do not allow for conclusive confirmation of the veracity of this information. Nevertheless, much of the scientific community is in favour of interpreting the behaviour of some of these species as an expression of self-consciousness.[29]

Due to a multitude of methodological errors, as well as problems with the mirror test itself, a large wave of criticism fell on this technique.[30] First of all, for many of the species tested, sight is not the dominant sense. For example, the original mirror test gave negative results for dogs, which use hearing and smell far more frequently than sight.[31] These results may be considered false negatives, since dogs can pass the olfactory mirror test, which is based on the sense of smell.[32] Furthermore, for many animal species, direct eye contact with another individual is an expression of aggression, which discriminates against dogs and some gorillas, among others, from being able to pass the mirror test.[33] Gorillas also react sensitively if they feel they are being watched, which is an additional factor supporting the lack of validity of this type of test in these animals. Most animals react quite intensively when

[24] Kenneth Marten, and Suchi Psarakos, "Evidence of Self-Awareness in the Bottlenose Dolphin (*Tursiops Truncatus*)," in *Cambridge University Press EBooks*, (1994), 361–79, https://doi.org/10.1017/cbo9780511565526.026.

[25] Helmut Prior, Ariane Schwarz, and Onur Güntürkün, "Mirror-Induced Behavior in the Magpie (Pica Pica): Evidence of Self-Recognition," *PLOS Biology*, 6, no. 8 (2008): 202, https://doi.org/10.1371/journal.pbio.0060202.

[26] Francine G. Patterson, and Ronald D. Cohn, *Self-Recognition and Self-Awareness in Lowland Gorillas* (Cambridge: Cambridge University Press, 1994), 273–90, https://doi.org/10.1017/cbo9780511565526.019.

[27] Joshua M. Plotnik, Frans B. M. De Waal, and Diana Reiss, "Self-Recognition in an Asian Elephant," *Proceedings of the National Academy of Sciences of the United States of America*, 103, no. 45 (2006): 17053–57, https://doi.org/10.1073/pnas.0608062103.

[28] Gordon G. Gallup, "Self-Awareness and the Emergence of Mind in Primates," *American Journal of Primatology*, 2, no. 3 (1982): 237–48, https://doi.org/10.1002/ajp.1350020302.

[29] Sébastien Derégnaucourt and Dalila Bovet, "The Perception of Self in Birds," *Neuroscience & Biobehavioral Reviews*, 69 (2016): 1–14, https://doi.org/10.1016/j.neubiorev.2016.06.039.

[30] Bekoff and Sherman, "Reflections on Animal Selves."

[31] Roberto Cazzolla Gatti, "Self-Consciousness: Beyond the Looking-Glass and What Dogs Found There," *Ethology Ecology & Evolution*, vol. 28, no. 2 (2016): 232–240, https://doi.org/10.1080/03949370.2015.1102777.

[32] Alexandra Horowitz, "Smelling Themselves: Dogs Investigate Their Own Odours Longer When Modified in an 'Olfactory Mirror' Test," *Behavioural Processes*, 143 (2017): 17–24, https://doi.org/10.1016/j.beproc.2017.08.001.

[33] Bekoff and Sherman, "Reflections on Animal Selves."

noticing another individual in the mirror, and their reaction (usually to flee, caused by a sense of threat) often prevents them from taking a longer look at the reflection. Given these constraints, particular attention should be paid to the characteristics of the species under study. For some of them, the standard version of the mirror test will almost always give false results even if the animal may be capable of self-recognition.

To date, not many attempts have been made to test the ability of horses to recognise themselves in a mirror. As we have mentioned above, researchers often turn out to be overly optimistic about the results of the mirror test, although in the case of the study of horses, the expectation does not seem over-inflated. A study by Baragli et al.[34] was highly circulated in the scientific community. The results of this study were published on a number of popular science websites, so that the hypothesis of equine self-consciousness began to permeate the wider public. That same year, however, an article was published by the author of the MSR test himself, who heavily criticised the aforementioned study and pointed out the multitude of methodological errors committed by Baragli et al.[35] Among other things, the researchers did not include a properly conducted control sample in the study, and the recorded footage turned out to be inconclusive evidence of horses passing the mirror test. Due to criticism and significant oversights in the research procedure and interpretation of the results, the question of horses' potential self-consciousness has not been resolved.

Given the ambiguity of the results from the previous study through methodological confusion, and taking into account the theory of Bekoff and Sherman[36] allowing for this to occur, in this study we hypothesise that horses are capable of self-recognition in mirrors, which makes it possible to put forward a thesis of the existence of self-consciousness in horses. The test used in this study was designed to see if the domestic horse can both recognise itself in a mirror image and use this ability to locate a treat placed at the animal's legs.

In this study we mainly follow the Bekoff and Sherman[37] theory of self-cognizance, but we will also compare our results with the perspectives in the studies by Gallup.[38] For example, Gallup's self-consciousness would be considered self-awareness in the Bekoff and Sherman's theory.

[34] Baragli et al., "If Horses Had Toes: Demonstrating Mirror Self Recognition at Group Level in Equus Caballus."

[35] Gallup and Anderson, "Putting the Cart before the Horse: Claims for Mirror Self-Recognition in Horses Are Unfounded."

[36] Bekoff and Sherman, "Reflections on Animal Selves."

[37] Bekoff and Sherman, "Reflections on Animal Selves."

[38] Gordon G. Gallup, "Can animals empathize? Yes," *Scientific American*, 9 (1998): 66–71.

Method

Ethical Statements

This study was carried out in accordance with the recommendations of the directive 2010/63/EU of the European Parliament. The owners gave written consent to the use of their horses in this experiment.

Test Location

The study was conducted in two locations in the permanent residence of the horses involved in the research. The first location was a fenced-in lunging area (a circular square used, by design, for lunging horses) with a diameter of 15 meters, located on the premises of the Perrin Horse Riding Centre in Rudawa, Poland. The 45 by 150-centimeter safe mirror used in the study was placed in the northwestern part of the lunging area so that the sunlight would not interfere with the horse's ability to see it during the test.[39]

Due to health problems of three horses originally qualified for the study, three other horses were tested in a different location (the Santos Stable in Zabierzów, Poland). The study was conducted in an enclosed 20 by 40-meter hall, and the mirror was placed halfway along the long wall.

Materials

After reviewing the test procedure, the owners certified that they agreed to conduct the experiment. To analyse the results of the experiment, we used the author's *mirror interest questionnaire* (see Supplementary Materials). It was completed for each horse, based on the recordings made during the experiment.

[39] The mirror was placed at an angle of approximately 85 degrees – it has been noted that horses perform better in visual discrimination tasks when the stimulus is close to ground level (Hall et al., 2003). An animal approaching a mirror at a distance of 3–6 meters is able to perceive the image of its legs in the mirror image with both eyes (Carol Saslow, "Understanding the Perceptual World of Horses," *Applied Animal Behaviour Science*, 78 (2002): 209–42). The difference in the distance at which the horse will clearly see the reflection of its legs is dependent on the height of the location of the eyes, which depends on the length of the neck and the height of the horse, therefore during the experiment the horses could decide for themselves the distance from which they observed the reflection, since horses adjust body and head alignment for optimal visual acuity (L. Knill, R. Eagleton and E. Harver, "Physical Optics of the Equine Eye," *American Journal of Veterinary Research*, 38, no. 6 (1977): 735–7.

The standard version of the MSR test was modified in our research in order to prevent animals from learning how mirroring works, which made it very difficult for horses to pass the test. For this reason, the animals' exposure time to the mirror image was significantly reduced in this study. At the same time, the marker used in the standard test conditions was replaced by a treat that was invisible and not perceptible by a sense of touch. In the wild, horses are not often concerned about the cleanliness of their coat, whereas the presence of a treat as a marker will ensure that a horse capable of self-recognition in a mirror reflection will certainly not give up trying to get it. The following (Table 1) illustrates the differences between Gallup's original mirror test[40] and our approach.

Table 1

Difference between Gallup's mirror test procedure and our mirror test procedure

Factor	Gallups' procedure	Our procedure
Species	Chimpanzee (*Pan troglodytes*)	Horse (*Equus caballus*)
Time to familiarise with the mirror	80 h	None
The marker	Red dye on the uppermost portion of an eyebrow	The carrot located near the object's legs
Total time in control trial	30 minutes	120 seconds
Experimental trial duration	30 minutes	120 seconds
Distraction of the animal during marker placement	Anesthesia	Redirecting attention to food

When conducting the test, we abandoned the use of the standard marker used in conventional mirror testing. Instead of marking the horse's body with a visible substance, we placed a treat near the horse's legs. For this purpose, protectors were used to secure the tendons of the horse's front legs at the level of the cannons[41] used on a daily basis in the training of each of the test horses, and then we attached carrots to them (see Figure 1). Carrots were attached to each of the protectors by slipping them between the plastic part of the protector and the rubber part used to fasten the protector in such a way that the carrot did not exert direct pressure on the horse's leg.

[40] Gallup, "Chimpanzees: Self-Recognition."

[41] Cannon bone, known also as large metatarsal bone is the anatomical structure located between the horse's fetlock and carpal joint.

Figure 1. Legs of the horse prepared for the experiment.

Non-cut carrots were chosen because of the relatively small amount of odour emitted, and also because of their highly visible color (with correction for the dichromatic vision found in horses[42]).[43]

The argument for using carrot markers is that the front legs are not in the horse's field of vision with natural head positioning (i.e., at rest, horses keep their head at a height between the shoulder joint and the withers and when experiencing stress/fear/dynamic social behaviour, their head rises above the height of the withers).

[42] Evelyn B. Hanggi, Jerry F. Ingersoll, and Terrace L. Waggoner, "Color Vision in Horses (Equus Caballus): Deficiencies Identified Using a Pseudoisochromatic Plate Test," *Journal of Comparative Psychology*, 121, no. 1 (2007): 65–72, https://doi.org/10.1037/0735-7036.121.1.65.

[43] Carrots were used also because of their shape, allowing them to be seamlessly attached to the protectors without having to cut them open (which would intensify their smell). In addition, it is a treat that is mostly liked by horses and, according to vet reports, rarely causes allergic reactions from the horse's digestive system. The use of the treat as a marker was an important part of the study, avoiding false negative results due to the motivational aspect of the marker.

During the placement of the marker, the horse was given a treat-lick; Horslyx lick was used for approx. 2–3 minutes before the start of the procedure. The product is characterised by a sweet-herbal aroma. Due to its stickiness, when the treat is taken by the horse, it remains on the animal's tongue and muzzle until the animal consumes other food or drinks water. When licked, the sticky substance was spread further around the horse's nostrils by gently applying and rubbing the product onto the said area. We assumed that by the time the smell of the lick is still perceptible by human, it is many times more perceptible by the horse, which temporarily impairs its sense of smell. This treatment was intended to both distract a potentially curious horse from the activities at its legs and prevent it from recognising the faint odour of the carrot.

Sample Selection

Twenty-six horses stationed at the stable of the Perrin Riding Centre in Rudawa and three horses stationed at the Santos Stable in Zabierzów took part in the experiment. Among 29 horses selected for the study, one individual was excluded due to a health condition and four were excluded due to their anxiety behaviour in the research area (probably caused by separation anxiety).[44] The remaining sample of 24 horses consisted of seven mares and 17 geldings, aged from three to 14 years old (mean = 8.17, SD = 3.74). Twenty-one of them were hot- or warm-bloods, whereas three were cold-bloods or ponies. One-third of the horses participated in recreational riding, while the remaining were involved in sport riding. Two-thirds were farmed in stables, while one-third were kept on an open range.

Among the horses qualified for the experiment, 43% of the animals were in stableless husbandry – they were in a suitably adapted paddock throughout the day – while 46% (n = 13) of the horses were in stabled husbandry, spending on average half of their days in a paddock. Horses were paddocked in herds of two (two herds), three (three herds), and 11 (one herd) individuals. One horse was paddocked alone. Three horses (11%) were in stabled husbandry, spending an average of four hours a day in the paddock alone or with another horse. At the start of the study, all horses appeared in optimal mental and physical health.[45]

[44] The excluded horses were three mares and one gelding, aged 4, 10, 13, and 19 years old, all cold-bloods from the Perrin Horse Riding Centre.

[45] The mental wellbeing of the horses was assessed by both the horse owners and trainers – no previous behaviours suggesting impaired mental health were reported.

Procedure

In addition to the mirror test, a control trial was conducted. The purpose of a control trial used in this study was to see if the horses would not find the treat without the use of a mirror. In the control trial, the horse was introduced to the lunging area where there was a mirror covered with a black cloth (in the colour of the tape marking the walls of the lunging area). After the horse was introduced to the test area, it was guided around the test area on both the left and right sides because of the difference of transmission of stimuli between the hemispheres in horses.[46]

The control trial period began when the lead line was unhooked and the human experimenter exited the test area. During the 120-second period, the horse was allowed to freely explore the area, also approaching the covered mirror. If the horse did not find the marker at the end of the control trial and did not show any behaviour that would indicate a poor mental state (separation anxiety, panic, visible discomfort that could indicate pain), the animal qualified for the test trial. In the case of horses tested in the arena, due to the owners' request, they were led on a lunge throughout the study. The minimum length of the lunge counted from the halter to the hand was at least three meters to ensure that the horse could move its head and neck freely.

After a positive completion of the test trial, a human experimenter entered the lunging area and removed the cloth from the previously covered mirror and hung the mirror on the wall of the test area, and then left the area. For the next 120 seconds the horse was allowed to interact with the mirror. For the horses tested in the hall, the length of the lunge was not changed after the mirror was uncovered, and even more attention was paid to the lack of physical/verbal contact with the horse to counteract the animal's distraction. Horses' behaviour was observed and assigned to one of four categories (see Statistical Analysis). Movies depicting examples of horses passing and failing the test are available in Supplementary Materials.

In the case of a lack of interest in the mirror caused by the horse's failure to respond to the start of the control trial, there was an opportunity to bring the horse to the mirror a maximum two times in a way that allowed the horse to see its own reflection. For safety reasons, the maximum distance the horse could be walked to the mirror was three metres – the so-called *escape distance*,[47] beyond which there was a possibility of a strong emotional response of the horse to a new potential threat. In this case, the time for the control trial began to count only from the moment of the horse's first contact with the mirror image.

[46] Nicole Austin and Lesley J. Rogers, "Asymmetry of Flight and Escape Turning Responses in Horses," *Asymmetries of Brain, Behaviour, and Cognition*, 12, no. 5 (2007): 464–74, https://doi.org/10.1080/1357650070149530.

[47] Austin and Rogers, "Asymmetry of Flight and Escape Turning Responses in Horses."

The test trial was terminated when 120 seconds had elapsed after the start of the trial and also in cases of an earlier detection of the treat or at the appearance of signs of a deteriorated mental state (separation anxiety, panic, or visible discomfort that could indicate pain complaints). Upon completion of the test, the horse was rewarded regardless of the result and rejoined the herd or returned to the stall. Both the control sample and the test sample were recorded for later analysis. For a detailed overview of the interpretation of the mirror test results, see Supplementary Materials.

Statistical Analysis

Our analysis had two goals: first, to see if horses pass the mirror test at all, and second, to determine what factors are associated with an increased likelihood of recognising themselves in the mirror. In the first part of the analysis, we compared the horses' detection of the snack between the control and experimental conditions. Since each horse took part in the control trial and then (if it failed in the control trial) in the experimental trial, there were four possible outcomes: (1) the horse exhibited behaviour which precluded the possibility of a reliable test; (2) the horse detected the snack in the control trial; (3) the horse did not detect the snack in the control trial, but it succeeded in the experimental trial; or (4) the horse failed to detect the snack in both trials. The detailed description of the criteria of passing the test are provided in Supplementary Materials. Since we employed a two-staged test-passing experimental plan, we used the McNemar's[48] test to verify the hypothesis that the experimental manipulation (the presence of the mirror) significantly increases the possibility of the detection of the snack. McNemar's test is a version of the Chi-squared test that is used in cases of sequentially applying a threshold evaluation in situations where subjects who had passed a first evaluation are expected to pass a second evaluation, too.

In the second part of our analysis, we examined which variables were related to the horses' behaviour during the mirror test. The dependent variable was the subject's behaviour in the presence of the mirror, but, contrary to our first analysis, we distinguished four categories of behaviour, instead of just two (passing or failing the test). The four categories were (1) a lack of interest in the mirror image, (2) a fear of the reflection, (3) a seeming identification of the image in the mirror image as a different horse, and (4) behaviour as expected if mirror self-recognition occurred. We placed these categories in an ascending order, since each subse-

[48] Quinn McNemar, "Note on the Sampling Error of the Difference between Correlated Proportions or Percentages," *Psychometrika*, 12, no. 2 (1947): 153–57, https://doi.org/10.1007/bf02295996.

quent category requires a more specific interpretation of the mirrored-image than the previous one.

Furthermore, we decided to check if the result of the mirror test could be related to the age, sex (mares vs. geldings), and conformation type (hot-bloods and warm-bloods vs. cold-bloods and ponies) of the horse.[49] In addition, we took into account the frequency of trips outside the stable and therefore the multitude of new stimuli experienced by the horses due to the type of work performed (sport vs. recreational riding). Due to tentative reports on a correlation between the animal's coat and temperament,[50,51] as well as the potential influence of husbandry and contact with the herd on animal welfare and personality,[52] we also decided to take these two factors into account (gray, chestnut, bay, and black and stable vs. free-range respectively). Since the dependent variable was ordinal, we used the cumulative link model,[53] a model that uses a latent variable to predict ordinal value of the dependent variable from the values of a set of predictors. Both analyses were performed using R (version 4.2.1; R Core Team 2022).

[49] Research suggests that hot-blooded horses are characterised by heightened emotionality and reactivity, which can hinder the habituation process compared to cold-blooded horses, which are characterised by their ability to accept a stressor relatively more quickly (Zoe Braybrook, "The Use of a Startle Test to Determine the Differences Between Hot-Blooded and Cold-Blooded Equines – Is the Stereotype True?," *Journal of Animal Science and Technology. Forthcoming*, (2023)). Significant gender differences in character are also noted among horses – it is believed that mares are characterised by higher levels of aggressiveness, general tension and excitability, and it has been noted that they panic more easily compared with geldings, which, on the other hand, go through the habituation process more quickly and are characterised by faster learning ability and a greater ability to remember and use learnt concepts (Kylee J. Duberstein and Jenna A. Gilkeson, "Determination of sex differences in personality and trainability of yearling horses utilizing a handler questionnaire," *Applied Animal Behaviour Science*, 128 (2010): 57–63).

[50] Emma Brunberg, Sanna Gille, Sofia Mikko, Gabriella Lindgren, and Linda J. Keeling, "Icelandic Horses with the Silver Coat Colour Show Altered Behaviour in a Fear Reaction Test," *Applied Animal Behaviour Science*, 146, no. 1–4 (2013): 72–8, https://doi.org/10.1016/j.applanim.2013.04.005.

[51] Lauren Jacobs, Samantha A. Brooks, Julia W. Albright, and Samantha J. Brooks, "The *MC1R* and *ASIP* Coat Color Loci May Impact Behavior in the Horse," *Journal of Heredity*, 107, no. 3 (2016): 214–19, https://doi.org/10.1093/jhered/esw007.

[52] Jill E. Sackman and Katherine A. Houpt, "Equine Personality: Association With Breed, Use, and Husbandry Factors," *Journal of Equine Veterinary Science*, 72 (2019): 47–55, https://doi.org/10.1016/j.jevs.2018.10.018.

[53] Alan Agresti, "Categorical Data Analysis," *Technometrics*, 33, no. 2 (1991): 241, https://doi.org/10.1080/00401706.1991.10484817.

Results

Age was linked to type of work (t[16.547] = 2.96, p = .009), and farming was linked to conformation type (X^2[1] = 3.8571, p = .0495) and to coat (X^2[3] = 14.5, p = .0023). No other links between factors were observed. Specifically, the stable did not differentiate age, type, sex, coat, type of work, or farming.

Five of the 24 horses passed the test in the control condition. Accordingly, after the application of McNemar's test, none of the five horses took part in the experimental condition, as they were expected to pass it as well. Six of the horses that failed the test in the control condition passed the test when given the chance to observe themselves in the mirror. Thirteen horses did not pass the test in any of the conditions. The McNemar's test gave a positive result (X^2[1] = 4.17, p = .041).

Four horses were not interested in mirror reflection (1); five horses exhibited fear of the reflection (2); eight subjects appeared to identify the image in the mirror as a different horse (3); and six appeared to recognise themselves in the mirror (4). The cumulative link model (R^2 = .74, AIC = 59.3) revealed that none of the independent variables was linked to the behaviour in the presence of the mirror. See Table 2 for the complete list of coefficients.

Table 2

Coefficients of the ANOVA Table for the Cumulative Link Model Fit. The Response Variable is Behavior in the Presence of a Mirror

Factor	χ^2	*df*	*p*
Age	0.27	1	.6
Conformation type	0.1	1	.75
Sex	0.03	1	.86
Coat	0.92	3	.82
Work type	0.2	1	.89
Farming	0.16	1	.69
Stable	0.17	1	.69

Discussion

The statistical results indicate that the presence of a mirror significantly increased the probability of finding a treat. It might seem to be a far-reaching conclusion to state that in the light of these results horses are self-aware, but we will argue that this outcome in fact validates the hypothesis about horses' self-consciousness.

On the one hand, the test results were far from consistent. That is, some horses found the treat in the control trial, while other horses failed to find the treat in the presence of the mirror. On the other hand, 100% consistency is rarely observed with MSR tests, even in species whose self-consciousness is widely acknowledged. For example, in bonobo apes 57% of the individuals exhibited behaviours that indicated self-recognition in Walraven et al.;[54] 26% to 75% of chimpanzees in de Veer et al.;[55] and 60% of dolphins in Marten and Psarakos.[56] So, despite the fact that some horses found the treat in the control condition and others did not find it even when confronted with the mirror's reflection, the significant difference in behaviour in the mirror's presence leads us to conclude that it was the recognition of their reflection that enabled the horses to find the treat. After all, there are virtually no alternative explanations for how else the mirror could help. If anything, the presence of an object providing an image of the "other" horse should be rather distracting and draw attention to the object instead of the subject's legs. Thus, whether it indicates self-awareness or not, horses are probably able to recognise themselves in mirrors.

Nevertheless, Gallup,[57] among others, believes that passing the mirror test indicates an individual's *self-consciousness*, understood as the ability to become the object of one's own attention. Mirror recognition involves coordinating a primary representation (i.e., a mirror image) with a secondary representation (one's own representation of oneself). This requires a prior assumption that the individual being tested has some kind of self-concept. On this basis, passing the mirror test would be expected to reflect an individual's theory of mind, autobiographical memory, and empathy.

Bekoff and Sherman,[58] on the other hand, note that determining self-consciousness on the basis of a mirror test result may not be accurate and not necessarily suggest that such a result indicates that the animal in question is capable of self-awareness. The study points out that social behaviour should be taken into account to determine an animal's self-consciousness – self-conscious species should be characterised by their ability to compete or cooperate with individuals of their own herd.

[54] Vera Walraven, Linda Van Elsacker, and Rudolf F. Verheyen, "Reactions of a Group of Pygmy Chimpanzees (Pan Paniscus) to Their Mirror-Images: Evidence of Self-Recognition," *Primates*, 36, no. 1 (1995): 145–50, https://doi.org/10.1007/bf02381922.

[55] Monique W. de Veer, Gordon G. Gallup, Laura A. Theall, Ruud Van Den Bos, and Daniel J. Povinelli, "An 8-Year Longitudinal Study of Mirror Self-Recognition in Chimpanzees (Pan Troglodytes)," *Neuropsychologia*, 41, no. 2 (2003): 229–34, https://doi.org/10.1016/s0028-3932(02)00153-7.

[56] Marten and Psarakos, "Evidence of Self-Awareness in the Bottlenose Dolphin (*Tursiops Truncatus*)."

[57] Gallup, "Self-Awareness and the Emergence of Mind in Primates."

[58] Bekoff and Sherman, "Reflections on Animal Selves."

This view of the problem largely coincides with the results of a mirror test in which the most-social monkey species scored the best.[59,60]

Confronting these two different views, one might still lean toward the conclusion that a domestic horse can be self-conscious. This is supported not only by the results of our study, but also by the more conservative assumptions put forward by Bekoff and Sherman:[61] horses form complex herds characterised by a multitude of inter-individual behaviours, and they use these behaviours to their advantage.

However, a behavioural technique such as the mirror test is not without its weaknesses, which are likely to be reflected in this study as well. Some studies report that in the standard version of the mirror test some animals may pass the test by accident.[62] However, we believe that excluding from the study the animals who found the carrot without the aid of a mirror image allows us to avoid such a conclusion. Ultimately, there is also the possibility that even if animals recognise themselves in the mirror, the chosen body marking may be too uninteresting for them to intensify interactions with their own reflection. We also refute the potential allegation of a false negative test result due to the non-standard marker we used. The possibility of acquiring food is one of the best motivations used in instrumental/operant conditioning,[63] so we argue that if the animals had been able to accurately locate the marker, they would certainly have proceeded. Our main objection to the standard version of the mirror test is that animals with a relatively high level of intelligence are able to learn to recognise their reflection after a period of time needed to understand how the mirror works. The question then arises as to whether this indicates a real lack of self-recognition, and whether the interaction occurring is not a chance result of the learning process. However, due to the rather drastically reduced time of the test trial, we believe that the horses tested were not relying on learning ability, but on actual self-recognition. The horses that passed the test found the marker usually after their first interaction with the mirror image.

[59] Dorothy L. Cheney, and Robert M. Seyfarth, *How Monkeys See the World* (Chicago: University of Chicago Press, 1990), https://doi.org/10.7208/chicago/9780226218526.001.0001.

[60] Despite the wide disparity between species, we endeavour to emphasise noteworthy parallels observed in self-consciousness studies across diverse animals. These parallels may uncover fundamental, enduring features inherent to the studied process.

[61] Bekoff and Sherman, "Reflections on Animal Selves."

[62] Manuel Soler, Tomás Pérez-Contreras, and Juan Manuel Peralta-Sánchez, "Mirror-Mark Tests Performed on Jackdaws Reveal Potential Methodological Problems in the Use of Stickers in Avian Mark-Test Studies," *PLOS ONE*, 9, no. 1 (2014): e86193, https://doi.org/10.1371/journal.pone.0086193.

[63] Laura H. Corbit, and Bernard W. Balleine, "The Role of the Hippocampus in Instrumental Conditioning," *The Journal of Neuroscience*, 20, no. 11 (2000): 4233–39, https://doi.org/10.1523/jneurosci.20-11-04233.2000.

In light of current research, knowledge of the location of the marker does not affect the ability to self-recognise in the mirror in any way,[64] therefore we believe that in the case of the five horses that found the marker before the start of the test trial, mistakes may have been made in preparing them for the test.[65] We hypothesise that these horses may have had an insufficiently impaired sense of smell (through the use of a strong-smelling licking treat) and thus may have recognised the faint odour of the marker, or that they may have managed to notice the treat during the examination of the ground in the control trial.

While this study yields some insights, it is essential to acknowledge certain methodological limitations. Although these limitations do not undermine the credibility of the results, they warrant attention for the sake of methodological rigour and scientific integrity. Identifying and addressing these shortcomings not only ensures the robustness of future studies but also offers practical insights for refining methodologies in similar research endeavours.

Firstly, one may argue that our sample size was too small. However, we aim to counter this potential criticism. Comparable studies involving larger animals often utilised similar or even smaller sample sizes. For instance, Gallup[66] examined only four chimpanzees, while Baragli et al.[67] assessed merely 14 horses. Although our sample size may pose some challenges, particularly in the context of the second analysis focused on testing potential correlates of self-recognition, it is essential to note the trade-off between the number of variables tested and our moderate sample size, resulting in reduced statistical power. While this is not an ideal scenario, considering the exploratory nature of the second analysis, it remains acceptable. In this context, our primary concern lies in detecting potential spurious effects rather than overlooking the existing ones.

Secondly, in order to prevent carrots from being found accidentally, another way of placing them can be considered. Perhaps the horses that found the carrots during the control trial showed higher tactile sensitivity compared to the other animals, so that they sensed increased pressure in the leg area associated with the

[64] Kim A. Bard, Brenda K. Todd, Chris Bernier, Jennifer M. Love, and David A. Leavens, "Self-Awareness in Human and Chimpanzee Infants: What Is Measured and What Is Meant by the Mark and Mirror Test?" *Infancy*, 9, no. 2 (2006): 191–219, https://doi.org/10.1207/s15327078in0902_6.

[65] Due to methodological assumptions, we do not anticipate that horses that pass the mirror test will do so by chance. In order to qualify the test as passed, a cause-and-effect sequence had to occur in which the horse first showed mirror-oriented behaviour and then found the treat. There may or may not have been an endogenous or exogenous distraction between the interaction with the mirror and finding the treat; however, finding the treat without a prior interaction with the mirror was not considered a passed trial.

[66] Gallup, "Chimpanzees: Self-Recognition."

[67] Baragli et al., "If Horses Had Toes: Demonstrating Mirror Self Recognition at Group Level in Equus Caballus."

appearance of a new object. Such a possibility has not been foreseen, but it does not appear to be impossible, so it should not be ruled out if attempts are made to repeat the procedure.

Finally, for future studies, it is useful to know the exact psychophysical state of the animals when selecting a study group. Diseases such as monthly blindness or mental disorders can potentially affect studies that rely on the visual modality or cognitive abilities of the animals. In our study, a detailed interview with the owners was not conducted. In order to be able to determine the traits and abilities of an entire species, it is necessary to select individuals for study groups so that they are psychophysically capable of participating in the study in the same way as is done in human studies. Currently, the problem of selecting non-representative groups with including incapable individuals seems to be a methodological problem for all animal studies with limited animal numbers. Further animal welfare research is needed to address the standards.

This study neither ends the discussion on potential self-consciousness in horses, nor was it intended to do so, but it does provide evidence in favour of the hypothesis that horses are self-conscious. Some horses succeeded in passing the mirror test, the rules of which were changed in a conservative direction, and the conditions for passing the test trial were difficult, compared to prior studies. We believe that in order to be able to talk about the self-consciousness of non-human primates, we should subject them to tests that leave no room for over-interpretation of the behaviour under investigation. We hope that our modified tool will find its way into future research on this topic.

Data availability statement

The complete dataset and statistical analysis procedures are publicly available at https://doi.org/10.17605/OSF.IO/57VSN.

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Supplementary Materials

Mirror Interest Questionnaire
Interpretation of the Mirror Test Results

Based on the recordings, a group of repetitive behaviours was observed among the horses as a reaction to the presence of a mirror image in the test trial. The following component behaviours formed the basis for the interpretation of the four total responses with which the polynomial model analysis was performed. The method of classifying these behaviours was based on whether or not a particular activity was observed, and in addition, the duration of each behaviour was taken into account if it occurred. Among the *component behaviours* were:

1. looking toward the mirror, suggesting interest in one's own mirror image (during the course of this behaviour, the horse either did not change its position relative to the mirror or approached it);
2. sniffing the mirror, a direct interaction with the object;
3. looking behind the mirror, occurring most often after behaviours 1 and 2, interpreted as a situation in which part of the horse's head crossed the line of the mirror;
4. attention directed to the ground in front of its own legs, indicating a redirection of the focus of attention toward the ground, but without pointing the nostrils towards the front hooves;
5. attention directed to one's own legs, or redirecting the focus of attention toward the ground directly in front of one's legs (with the line of the nasal bone crossing the line perpendicular to the ground), and locating carrots; and

6. A temporary or long-term loss of interest in the mirror caused by exogenous (more common) or endogenous factors.

Due to the possibility of distinguishing specific, recurring types of horse reactions by means of interpreting component behaviours, it was decided to specify the following types of holistic behaviours:

1. mirror self-recognition distinguished on the basis of frequently repeated and consecutive behaviours of the 1st, 4th, and 5th of the former component behaviours, which ultimately resulted in finding the carrot (behaviours 2 and 6 may have occurred with reduced frequency);
2. recognition in the mirror image of another horse, as distinguished on the basis of frequently repeated and consecutive component behaviours 1, 2, and 3, followed by behaviour 6, which resulted in the horse completely losing interest in the study (during behaviour 2, the animal's frequent response was regular, gentle bumps against the mirror with its muzzle, specific to inter-personal behaviour when meeting a new individual; in some cases, low-pitched voice signals, interpretable as greetings, were also observed);
3. fear of mirror reflection, as distinguished on the basis of component behaviour 1, with the co-occurring characteristic of anxiety-specific auditory signals and/or whole-body tensing, ultimately culminating in behaviour 6 and/or decisively walking away from the mirror; and
4. lack of interest in the mirror reflection, as distinguished on the basis of a short exhibition of the 1st component behaviour, followed by a prolonged enactment of the 6th.

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