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EDITORIAL

Horse cognition and behavior from the perspective of primatology

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This article aims to show recent, novel approaches to the study of horses. It also describes why readers of the journal *Primates* would do well to start considering horses in relation to the study of human and nonhuman primates. In our recent research, my colleagues and I have advanced the study of horse cognition using a computer-controlled touch panel (Tomonaga et al. 2015) and also the behavioral study of wild horses, in the Serra D'Arga in Portugal (Ringhofer et al. 2017). A parallel approach using both laboratory work and fieldwork is intended to provide a better understanding of horses from a holistic perspective.

The primary motivation to study horses comes from the idea of understanding humans not just from a primate perspective, but from a broader mammalian perspective. In the classification of organisms, Primates is the order that includes *Homo sapiens*. Research has often been driven by questions about human evolution, such as where did we come from? How did we come to be as we are today? This is often the grand design or main unifying framework in the study of nonhuman primates. However, less attention has been given to the question of primate evolution in relation to other mammals. How did nonhuman primates come to be as they are? How did nonhuman primates evolve? We have to think more about primate evolution in relation to other mammals, not solely focus on human evolution relative to other primates. This is the key issue. It is also the main reason why I wrote the article "From four hands to two feet" (Matsuzawa 2016), to describe human evolution from a broader, mammalian perspective.

Mammal species number about 4000–6000, depending on the method of classification used. The common mammalian ancestor existed in the Mesozoic, 252–66 million years BC. This ancestor is believed to have been a small, nocturnal, terrestrial creature, similar in form to present-day rats and mice. The important point is that this common ancestor was a four-legged animal that walked on the ground.

Let us examine the history of planet Earth. A huge shift in climate took place on a global level 66 million years ago. A mass extinction occurred, and by the Mesozoic, dinosaurs were extinct. After the mass extinction, the common mammalian ancestor diverged into different environmental niches, adapted to a new environment and, thus, its morphology changed.

Let us consider bats, which fly through the air. Two of their four legs evolved into something similar to birds' wings. Not many people are aware that almost one quarter of all mammalian species are bats. Bats have been highly successful in terms of speciation, hence the high number of different bat species. This may be partly due to the fact that bats are the only mammal that can move through the air by powered flight. In this sense, bats monopolize a huge niche; they have no competing mammalian species except for other species of bat.

Let us consider whales and dolphins, which swim through water. Here, four legs evolved into something similar to the fins of fishes. Dolphins, whales and other aquatic mammals have been incredibly successful in the water, exploiting an unusual habitat and niche for mammals. Incidentally, not many people recognize that whale and dolphin species are the most successful species on this planet, by one measure, collectively occupying a larger surface area than other species of mammal, including humans. One might counter

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that there are more than 7 billion people crowded onto the planet, but it is important to remember that humans inhabit land. There are no humans living in the sea. The surface area of planet Earth is about 510,065,600 km^2, of which land occupies about 147,244,000 km^2 (28.9%) and sea 362,822,000 km^2 (71.1%). The ratio of land to sea can fluctuate slightly, but is ca. 29:71. Species of whales and dolphins are found everywhere in the oceans including the Arctic and Antarctic. Therefore, they occupy a larger surface area of the planet than humans.

Let us consider nonhuman primates, which evolved to live in the trees—an arboreal life! That is the crucial point. Not in the air, not in the water, not on the ground, but in the trees. We need to recognize different modes of life of nonhuman primates in different habitats and niches: avian, aquatic, and arboreal, as well as terrestrial. The trees provide an exceptional niche for primates; orangutans, the largest of all the arboreal animals, spend the majority of their lives in trees. Many other mammalian species continue to live on the ground, such as species of horse, wolf, lion, elephant, etc. During the process of speciation from the common mammalian ancestor, many species remained terrestrial, but others flew into the air, dove into the water or climbed into the trees. This is important to keep in mind when seeking to understand the origin of primates that live in trees. We can conclude that the four feet of primates turned into four hands in the course of primate evolution, which enabled efficient grasping of tree trunks and branches.

Primates are the mammals that favored living in the trees. They are characterized by four hands pitted against the four feet of mammals that continued to live on the ground. Having four hands was an adaptation to the new niche in the trees. During the course of human evolution, our ancestors started to spend more time down on the ground. Thus, we evolved two feet from two of our ancestor's four hands: the evolutionary scenario of humans evolving from four-handed animals. This is in contrast to the popular understanding of "four feet to two hands", i.e., the idea that four-legged animals instead started to stand up over the course of human evolution during which hands were created that are unique to humans. This is definitely not the case! We humans have hands because we are also primates, previously adapted to an arboreal life. Humans evolved two feet as an adaption to allow them to run and walk, and for stamina over long distances. This is the story depicted by the four hands to two feet hypothesis (Matsuzawa 2016). The key point is the divergence from the common ancestors of all mammals, the original form of which was an adaptation to the terrestrial environment. Then terrestrial life diverged to include mammals adapted to avian, aquatic and arboreal life.

Having studied nonhuman primates for the past four decades, I wanted to find out more about the descendants of the earlier types of four-legged animals that have remained terrestrial. An understanding of four-legged animals may provide us with a better understanding of primate evolution in the context of all other mammals. I selected the horse as the model animal.

Horses were selected for three main reasons. Firstly, many people are captivated by horses, thus the study of horses is likely to reach a wide audience. Secondly, there are long-established groups of feral horses (*Equus caballus*) now living in the wild, unlike domestic cats and dogs. Although there are relatively few sites where wild horses can be observed throughout the world, I wanted to understand the way of life of these animals in their natural habitat. Thirdly, I wanted to investigate the mind of the horse. As with the chimpanzee, I wanted to come to know the perceptual world of horses. The episode of the infamous horse "Clever Hans" comes to mind in relation to horse cognition. Unfortunately, this fraudulent demonstration of horse cognitive capability has largely inhibited researchers from attempting serious scientific study of the intellectual capacity of horses. One only has to consider the current situation in the academic world to see this: there are lots of papers on the minds of nonhuman primates, elephants, dogs, cats, birds, fishes, octopuses, yet very few on the minds of horses. Horses are used for riding and racing; riders command horses to walk, canter, gallop and give tactile and/or auditory commands to get them to jump obstacles, turn right, stop etc. (Fig. 1), yet very few scholars have paid attention to questions such as how do horses perceive the world?

My research interest in horses developed following my encounter with Carlos Pereira at the Sorbonne, who is an expert in horse training. The story is as follows. Carlos expressed a wish to know more about horses from a variety of different angles. He met my former student Claudia Sousa (1975–2014), who was also Portuguese, at a conference (Fig. 2) where Claudia introduced our computer-controlled touch panel experiment. She received her Ph.D. from Kyoto University through following my approach to comparative cognitive science to understand the chimpanzee mind holistically. She pursued both fieldwork (Sousa et al. 2009) and laboratory work (Sousa et al. 2003), and became a bridge between Carlos and me. Near the end of 2013, Carlos approached me after I had delivered a talk at the Musée de l'Homme in Paris. Upon listening carefully to what he had to say, I recognized immediately the importance of studying the horse mind. So, I made a purchase at the beginning of 2014 and was suddenly the owner of two horses here in Japan.

My colleague, Masaki Tomonaga, and I carried out the first study of horse cognition in which a computer touch panel was used (Tomonaga et al. 2015). Amazingly, the horses were very good at learning to touch the panel with their noses, and the research went very well. We were the first to succeed in demonstrating horse cognition through

Fig. 1 Horses are used by humans for riding and races. People communicate commands to horses to walk, run, gallop or command them to jump over obstacles, turn right, stop etc. (photograph by Carlos Pereira)

Fig. 2 Claudia Sousa (1975–2014) (photograph provided by Claudia Sousa)

computer-mediated tasks. The horses discriminated between various shapes such as different letters of the alphabet (Fig. 3). Their perception is somewhat similar to that of humans, chimpanzees and also dolphins, thus providing evidence that there might be common characteristics shared across mammalian species in terms of shape perception. We also tested their ability to estimate the number of dots appearing in an array on a screen (Fig. 4). The horses were good at making relative judgements, i.e., which side has "many" dots relative to "few." The experimental paradigm for horses as described here is exactly the same as that used for chimpanzees (Fig. 5; Matsuzawa et al. 2006).

Similarly, we have carried out fieldwork on wild horses based on the same paradigm of comparative cognitive science. For this purpose, Renata Mendonça, my Portuguese Ph.D. student, Carlos, and I first went to Portugal in May 2015 to search for the best research field site. While attending the University of Coimbra in Portugal, Renata was one of Claudia's students. Claudia recommended that Renata go to Japan, and Renata carried out her Ph.D. on wild orangutans in Borneo under my supervision at Kyoto University, just as Claudia did (Mendonça et al. 2017). Renata is now

Fig. 3 Horses can discriminate between different shapes such as letters of the alphabet (photograph provided by Masaki Tomonaga)

one of the pioneers exploring non-primate mammals with a background in the accumulated knowledge of nonhuman primate research. We first went to Peneda-Gêres National Park,

Fig. 4 We tested the ability of horses to estimate the number of dots appearing on screen in an array (photograph provided by Masaki Tomonaga)

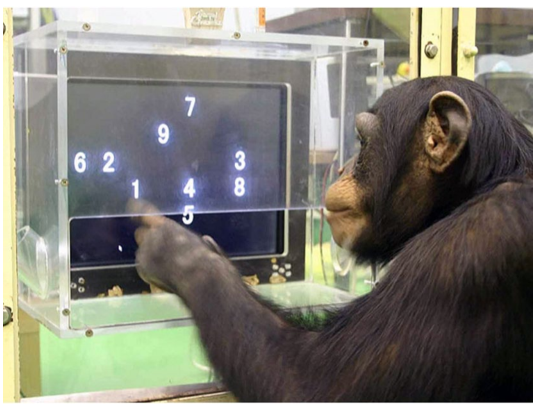

Fig. 5 The experimental paradigm for horses is exactly the same as that for chimpanzees (photograph taken by Tetsuro Matsuzawa)

then, on my next trip to Portugal, in October 2015, I went to look for a new site, one that was not within a national park. I was accompanied by Carlos and Satoshi Hirata, a former student of mine. Based on these two reconnaissance trips to Portugal, both in 2015, we finally chose the Serra D'Arga to be our long-term research site. There are wild horses called "garrano" there, which range freely in the mountains (Fig. 6). The field site is now run by Satoshi Hirata and his team: Shinya Yamamoto, Monamie Ringhofer, Renata Mendonça and Sota Inoue. The first research paper on these horses came out recently in *Primates* (Ringhofer et al. 2017).

The Serra D'Arga is particularly interesting because the wild horses there are predated upon by wild wolves (Fig. 7). The villagers allow the wolves to eat the horses to maintain their precious livestock, such as cows, sheep and goats, which are kept within the village. I find this manner of co-existence between wildlife and humans very interesting, and it was one of the major reasons for picking the Serra D'Arga as our field site.

Fig. 6 On the basis of two reconnaissance trips to Portugal in 2015, we eventually chose the Serra D'Arga as our long-term research site. The garrano range freely in the mountains there (photograph taken by Tetsuro Matsuzawa)

Fig. 7 The Serra D'Arga is particularly interesting because the wild horses here are predated on by wild wolves (photograph taken by Tetsuro Matsuzawa)

The use of drones applied to the study of horses represents a unique, novel research technique (Fig. 8). As in the study of Yunnan snub-nosed monkeys (Matsuzawa 2017), the drone is very effective for locating groups of garrano. There is a clear advantage to using drone surveys on horses in comparison with this particular species of monkey, as the latter lives in trees in mountainous habitat, whereas the horses live on relatively flat ground without many obstacles, and one can easily observe entire groups from the sky, remotely.

I joined the field survey in May 2017. Ringhofer et al. (2017) report that there are currently 208 individuals in 26 groups at the site, and each individual horse has been identified by the research team. The follow-up study this year clearly showed two major factors. First, a high mortality rate for foals aged less than 1 year, some of which are presumably eaten by wolves. Indeed, I observed a foal with

Fig. 8 The use of drones represents a unique, novel research technique applied to the study of horses (photograph taken by Tetsuro Matsuzawa)

characteristic wounds inflicted by attacking wolves. Second, a high frequency of female emigration from one group of garrano to another. The stability of groups of horses may be different to that of nonhuman primates, and continued long-term fieldwork on horses will elucidate the evolution of their social life in comparison with that of nonhuman primates.

The opportunity to examine the life of wild horses parallels that of nonhuman primates in their natural habitats. So far, it has proved very difficult to understand inter-community encounters and relationships in nonhuman primates. However, in the case of the horse, inter–community interactions can be measured and evaluated easily, thanks to the use of drones. Using this novel technique, the spatial distribution of every individual in each group of horses is easy to observe and record. Group decision-making for movement can also be quantified, based on precise data. Thus, the study of horses is likely to complement the study of nonhuman primates in some aspects of behavioral and social studies. The study of horses may open up new horizons in understanding the evolution of the human mind and society, from the perspective of mammalian evolution.

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