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Commentary

Can studies of cognitive abilities and of life in the wild really help us to understand equine learning?

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The subject of equine learning has seen several reviews and well documented syntheses, in the form of papers (Nicol, 2002; Hanggi, 2005) and book chapters (Waring, 2002; McGreevy, 2004; Nicol, 2005). One therefore expects a new review to provide fresh insights and/or original approaches, and it is with curiosity and interest that one opens the review of Murphy and Arkins, especially as the abstract raises interesting issues, such as:

- a major methodological problem—that positive reinforcements are used quasi-systematically in experimental work, whereas equestrian practice (which such experiments could improve) is primarily based on the use of negative reinforcements;
- the interest of ethological studies of feral horses for understanding the domestic horse.

Though the review does not break new ground conceptually, it does point the way to some interesting areas where further work is urgently needed on horses. In the section on "Contemporary training schemes and equine learning", the authors quite rightly note that training is generally achieved through the use of negative reinforcements. The basic training of saddle horses can indeed be achieved by work in hand, which allows the use of positive reinforcements, nonetheless it is difficult to envisage how a rider in the saddle could do other than use principally negative reinforcements. The authors are quite right about the methodological problems posed by the fact that negative reinforcements are not used more often in experimental studies of training. The authors are also quite right that the question of sidedness and its influence on experimental results, which is seldom dealt with explicitly, needs much more attention (see also Larose et al., 2006). However, some of the points need deeper treatment than they receive.

The authors point out that the number of studies devoted to training in the horse is limited, but do not mention the crucial need for research to understand how the exact programmes of reinforcement affect the speed of acquisition, or the resistance to extinction of learning (e.g. continuous versus partial or intermittent reinforcement schedules, and fixed-ratio, variable-ratio, random-ratio schedules, etc.).

The deficit of studies on cognition could have been illustrated with concrete examples of the important questions which need to be addressed. Thus, for example, in the field of the cognition of their environment, the permanence of the object and its relation with the working memory must be important, particularly for learning. This question has been the subject of several studies in other domestic species such as the dog (Fiset et al., 2003), or the cat (Fiset and Doré, 2006), yet has received little attention in the horse (but see Grzimek, 1949; McLean, 2004). The same can be said about spatial representation: like all large grazers, horses move between patches of good grazing in their home ranges (Howery et al., 1999), and may travel 25 km to drink (Stoffel-Willame and Stoffel-Willame, 1999), and even show seasonal migrations when the ecological conditions require it (Olsen, 1996). This raises the question of how horses structure their home ranges, and how they learn to form cognitive maps (Tolman, 1948).

Nicol (2005) underlines the importance of understanding their capacity to form abstract concepts, for instance their representation of time, and the obvious practical utility of such knowledge. Indeed, the interaction between their perception of space and time represents an essential field of research if we are to understand the feeding strategies of horses, which influence the quality (fitness) of the individuals and their impact on the communities of plants they eat, and thus more generally on biodiversity. One of the major problems the animals must face is the spatial distribution of their food resources in variable

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environments. The capacity of the horses to return to rich patches in meadows is a key determinant of their success in foraging. It would seem that the horses choose the richest patches when the information of which they dispose is recent; on the other hand when they do not have recent information, they practise dynamic averaging, and choose their feeding sites according to the long-term average richness of the available sites (Devenport et al., 2005). It is urgent to test the generality of the conclusion that the horses use dynamic averaging, and even weight information received over variable time intervals in order to optimize their foraging. These questions are not mentioned at all in Murphy and Arkins' review.

With regard to social cognition, the issue of intraspecific individual recognition has so far been the subject only of two preliminary studies, which were done over 20 years ago (Wolski et al., 1980; Leblanc and Bouissou, 1981). The results of various ethological studies strongly suggest that such recognition occurs, such as the existence of dominance hierarchies in family groups (Tyler, 1972) and between stallions of different harems (Miller and Denniston, 1979), which can be non-linear, the existence of strong preferences for certain social partners within the groups (Feist and McCullough, 1976), and the selectivity of mares with respect to their own foal (Tyler, 1972). Further, recent work suggests that horses are also capable of discrimination between humans by using facial characteristics (Koba et al., 2004), and that they are able to transfer such discrimination to photographic representations of these humans (Tanida et al., 2005). Are these capabilities learned? And if so, what are the mechanisms? How long do the animals retain the information? Sheep can recognize the faces of 50 different other sheep, after more than 2 years (Kendrick et al., 2001), but field observations suggest stallions are no longer able to recognize young males from their family group after a separation of 18 months (Berger, 1986). These scientific issues also have obvious practical implications.

Visual perception has received most attention in the horse, but "senses probably of more crucial importance to the horse Umwelt have been neglected" (Saslow, 2002). Olfaction, in particular, which clearly plays an essential role in the interactions between horses, at short or long distances, has been the subject of very few studies, and the learning of olfactory differences seems virtually to have been ignored (or addressed very indirectly, Cairns et al., 2002). The same can be said for tactile perception, in spite of its being essential in the practice of horsemanship and in particular in the use of "aids", whose finesse is well illustrated in classical equitation by the action of "souffle de la botte" (energising the horse with the boot).

Finally, the authors state in the Abstract that "More detailed comparative investigations of feral or free-ranging and domestic horses may provide useful evidence of attention, stress and motivational issues affecting behavioural and learning processes in the horse". Learning is a key adaptive process, and if work on natural societies of equids clarifies the functions of equine behaviours (in evolutionary terms) and the mechanisms (behavioural, physiological) involved in their expression, this should improve our understanding of learning in equids. Virtually all the work cited in the review concerns domestic horses (e.g. Houpt et al., 1978, 1982; Wolff and Hausberger, 1994) and artificial groups with geldings and without stallions (van Dierendonck et al., 2004), rather than feral animals with natural social systems. Does this mean that the work done on feral horses so far sheds little light on learning? Our (very likely personal) view is that the results of the interesting research on feral horses which is described in a rich scientific literature since the seventies (reviewed in Waring, 2002), deserves more than the rather brief treatment it receives. In any case, it would have been very interesting to have the authors' view on priorities for future research on feral horses.

The issue of memory is crucial, since there can obviously be no learning without memory. Though the organization and the functioning of memory is far from fully understood, contrary to what the authors suggest ("no universally agreed model of how memory specifically works") there is a broadly accepted general model of memory (Tulving, 1995; Squire and Zola, 1996; Gazzaniga et al., 1998), and the behavioural and neurobiological dimensions of this model are gradually becoming clear. Within this general framework, the conclusions of Wolff and Hausberger (1996) that learning and memorising tasks of instrumental learning on the one hand and spatial learning on the other hand may involve different processes are coherent with the fact that they involve different parts of the brain. In this connection, it is highly relevant that our knowledge of the specific nature of the spatial memory of mammals, which we now know depends on two populations of neurons, of place (O'Keefe and Dostrovsky, 1971; Muller, 1996) and of orientation (Ranck, 1985; Muller et al., 1996) within the hippocampus, in relation to the prefrontal cortex where the goal to attain is encoded (Poucet et al., 2004), provide the neuronal basis for much experimental work on the representation of space by mammals, at different spatial scales. As mentioned before, it is urgent that such studies are carried out on horses, as movements between patches of "good quality grazing" are a crucial part of foraging strategies, and this raises the question of the role of the spatial memory, which has been studied in sheep (Rook et al., 2005), but not in the horse. Finally, the papers of Giebel (1958) and Dixon (1970), and the work of Voith (1975) too, on pattern discrimination learning, are also relevant to a consideration of long-term memory in the horse.

The section on "Social and observational learning" would have perhaps gained in clarity and rigour if a clear distinction had been made between social facilitation or enhancement, local or stimulus enhancement and observational learning of new behaviours (Galef, 1988; Nicol, 1995, 2006). This would have allowed the discussion to have been structured on the basis of processes which require differentiated cognitive capacities. We also feel that the authors' suggestion, based on Clark et al. (1996), that an individual's social status is an important determinant of the interest shown by other horses towards its actions, and of their motivation to learn them, is interesting if highly speculative. It is a pity that they assume that dominant horses are also leaders, which goes against what is known about horses (Miller, 1980).

When dealing with the question of evaluating higher cognition in the horse, the authors refer exclusively to the hierarchy of learning skills proposed by Thomas (1986). It seems to us that the