Second Edition

Equitation Science

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with website

WILEY Blackwell

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Preface

This is a book for horse-industry personnel, and indeed everyone who spends time with horses and ponies. It will help to ensure that humane, proficient horsemanship becomes more prevalent.

Many equine scientists, veterinarians, ethologists and behaviour therapists share the view that the current lack of science in equitation contributes to the prevalence of undesirable equine behaviours with human-related causes. The number of horses worldwide is large and growing. As a consequence, there are increasing numbers of horse-owners, many of whom are new to horse-keeping, with little knowledge of how to train their animals. This has led to a rise in the number of associated horse-welfare problems culminating in high wastage rates. Such problems reflect the uninformed practices, poor training techniques, inappropriate use of training equipment and, in some cases, inhumane handling of horses. In addition, horse-related injuries are a major public-health concern, with most fatal injuries occurring while the rider is mounted. Death rates from horse-related injuries are in the vicinity of one death per million head of population and in terms of injuries, horse-riding is more dangerous than motorcycle riding. Improving riders' understanding of horse behaviour and subsequently reducing the number of 'conflict behaviours' horses develop will reduce the prevalence of such accidents. Furthermore, the increasing profile of 'Natural Horsemanship' and 'horse whisperers' has made horse-industry personnel question some traditional practices, prompting them to consider how novel techniques operate and to question how the language relating to horse-training and riding relates to what is known through psychology, ethology and veterinary science. This book will help them in these endeavours.

This second edition contains updated information on research results that have emerged since the publication of the first version. Since publication of the first edition, equitation science has become an established scientific discipline that aims to provide an understanding of the behavioural mechanisms that underpin the human–horse interface. Equitation science is the measurement and interpretation of interactions between horses and their riders. While many horse-training systems focus on a purely ethological approach with scant attention paid to learning processes, we have attempted to redress this to give a full account of the interactions of both ethological and learning processes (known in behavioural science as learning theory). Compared to the first edition, the focus of this book has shifted to include a broader description of the range of training systems that variously align with learning theory. Because horse-training relies so heavily on the use of tactile pressures, our book attempts to describe the optimal use and pitfalls of these interactions and the relative potential of combined reinforcement through the inclusion of positive reinforcement.

The objective measurement of variables is important, so this book explains, from first principles, traditional and novel techniques to reveal what works, what does not, and why. Most importantly, it also explores the welfare consequences of training and competing with horses under different disciplines.

Equitation science has an extremely promising future since it is more humble, global, accessible and accurate, and less denominational, commercial, open to interpretation and misinterpretation than traditional interpretations of horse-training. Because of this, it has the potential to be the most enduring framework to inform every facet of horse–human interactions.

The authors offer unique perspectives by being able to combine tertiary qualifications in veterinary medicine (PM), ethology (PM, JWC, UvB), zoology (AM & JWC), comparative cognition (AM), animal welfare (PM, JWC, UvB), animal breeding and genetics (UvB), and stress biology (JWC & UvB), with significant experience in animal-training (AM, PM, UvB), elite equestrian competition (AM), clinical behaviour modification (AM & PM) and coaching (AM & PM).

Acknowledgements

We wish to acknowledge the tremendous support we have received over many years from our colleagues in academe and the horse industry. Early attempts to apply learning theory to horse training were made by AM (Horse Training the McLean Way) and PM (Why does my horse…?). Since then, the emerging discipline of equitation science developed rapidly following discussions between Debbie Goodwin, Natalie Waran and PM at the Havemeyer Foundation Workshop on Horse Behaviour and Welfare in Iceland in 2002.

The first workshop on equitation science was held at the Royal (Dick) School of Veterinary Studies, University of Edinburgh in 2004, where AM gave practical demonstrations of the application of 'learning theory' in-hand and under-saddle. As a result of the interest of approximately 30 equine scientists at this workshop, it was decided to launch the first symposium in equitation science at the Australian Equine Behaviour Centre the following year. Since then, the annual conferences of the International Society of Equitation Science (ISES) have attracted an increasing number of delegates from all over the world.

The formation of the ISES is a great step forward for horses and is a direct result of the growing worldwide interest in this area by equine scientists and equestrian professionals alike. The equestrians we wish to acknowledge include Portland Jones, Manuela McLean, Jody Hartstone, Anjanette Harten, Warwick McLean and Nicki Stuart.

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This book is accompanied by a companion website:

www.wiley.com/go/mcgreevy/equitation

The website includes:

- Powerpoint slides with downloadable figures

1

Introduction – The Fascination with Horses and Learning

Introduction

Everyone who spends time with horses will from time-to-time become fascinated by their behaviour and learning abilities. One does not have to search for long to find reports of extraordinary learning performance in individual horses; examples range from 'Clever Hans', the horse that appeared to be able to count and read but, even more interestingly, was responding to very subtle cues from human bystanders; to reports of horses being able to open box doors and gates (Figure 1.1), to everyday accounts of circus and sports horses performing precise movements in response to small cues from their trainers or riders (Figure 1.2).

Humans have been fascinated by animal learning for centuries and, since the 1800s, scientists from various fields have investigated the mammalian and avian brain to understand how animals of different species learn and adapt to their environments. The best-studied species are rodents and birds, primarily because these species are easy to study and to keep in a laboratory. Despite the evolutionary differences between these species, remarkable similarities exist in the way they learn. This has resulted in the development of 'learning theory', a set of principles that apply to all animals and explain how animals learn. Learning theory has revolutionised the way humans think about animal training, and learning theories are applied with great success in the training of, for example, dogs, marine and other zoo animals (Figure 1.3). Indeed, it is difficult to find a modern training manual for these animals that does not use learning theory as a basis. Learning theory establishes clear guidelines and training protocols for correct training practices and methods of behaviour modification. It is truly fascinating, easy to relate to and simple to understand. Throughout this book, we will repeatedly refer to 'learning theory' as simply a comprehensive term for 'the ways in which animals learn.'

Similarly, more and more horse-trainers use and teach learning theory and understand the opportunities it can offer trainers in every discipline. Like all other animals, horses learn in predictable and straightforward ways. However, traditional horse-training differs fundamentally from the food-based training methods used for marine mammals, exotic carnivores and most companion animals, because it largely relies on what is termed 'negative (subtraction) reinforcement.' During their early training, horses learn that the correct response results in the reduction of pressure from the bit via the reins when they *stop* or *slow*. Pressure from the rider's legs or spurs is reduced when the horse moves forward. To be effective and humane, the application of pressure must be subtle and its removal immediate once the horse complies. This reliance on pressure and the release of pressure underlines the need to ensure that training programmes are effective and humane. Science can and

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Figure 1.1 'Horses on the run': In 2013, the story about Mariska hit the world press after her owner posted a YouTube video showing how Mariska could open not only her own box door but also make her way to open the doors of the other horses' boxes. (Photo courtesy of Sandy and Don Bonem.)

Figure 1.2 Horses can learn to respond to and differentiate between light tactile cues from their riders, regardless of the type of gear used. (Photo courtesy of Dr. Portland Jones and Sophie Warren.)

Figure 1.3 Modern training manuals for many species are based on learning theory.

should step in to measure, analyse and interpret what we do with and to horses.

Understanding the rules of learning can help horse-trainers work with their horses in a way that maintains the horse's welfare as paramount. Learning theory is not necessarily an ethical theory but it helps us train horses in a way that makes it as easy as possible for the horse to respond and succeed during training. Furthermore, it allows us to avoid behavioural side effects such as fear or aggression, caused by inappropriate training.

Veterinary epidemiologists, whose job it is to describe the spread and impact of disorders, often talk about wastage within a population. This is the percentage of animals or, in the case of working animals, the percentage of potential

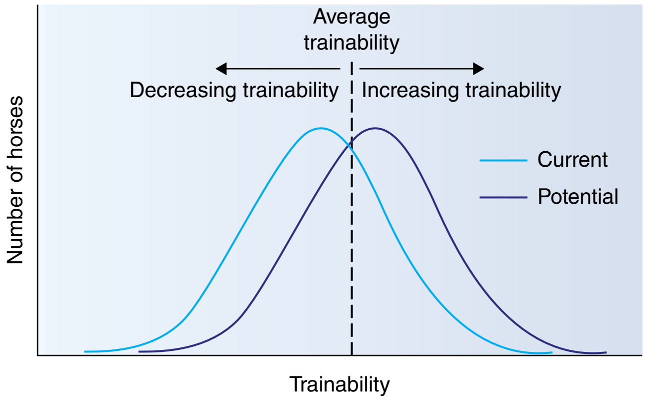

Figure 1.4 Theoretical normal distributions to show how the numbers of horses that cope with training can be increased by using more enlightened approaches. (Reproduced from *Equine Behavior*, copyright Elsevier 2004.)

working days lost through illness or disease. Problem behaviours are the cause of much of this wastage, and in the world of the riding horse it is more significant than many of us would like to imagine (Hothersall and Casey, 2012). A global improvement in application of learning theory, particularly the timing and consistency of pressure and release, could lead to a significant increase in the number of horses considered to be trainable (Figure 1.4).

Horses are being confused on a very regular basis by less-than-ideal handling and become unusable or, worse, dangerous as a result (Hawson *et al.*, 2010a). For example, Buckley (2007) reporting on 50 out of 84 Pony Club horses, noted that this focal sub-set of owners reported a total of 251 misbehaviour days during a 12-month period. Importantly, on more than half of these days, this misbehaviour was classified as dangerous enough to cause potential injury to horse and/or rider. Horse-riding is generally considered to be more dangerous than motorcycle riding, skiing, football and rugby (Ball *et al.*, 2007). In Australia, horse-related injuries and death exceed those caused by any other non-human species (domestic or otherwise) (AIHW National Injury Surveillance Unit, 2005).

Among non-racehorses, previous studies indicate that up to 66% of euthanasia in horses between 2 and 7 years of age was not because of health disorders (Ödberg and Bouissou, 1999). The implication is that they were culled for behavioural reasons. Clearly, this level of behavioural wastage is unacceptably high. The likelihood is that many such horses are mistrusted or labelled troublesome. With their reputation for being dangerous preceding them, they are met with an escalation of tension in the reins or pressure from the rider's legs, the very forces they have learned to fear and avoid. Difficult horses go from one home to the next and are often forced to trial new ways of escaping pressure and satisfying competing motivations.

The Scientific Approach

Science is sometimes accused of objectifying animals, but the emergence of animal welfare science has already created changes in legislation that have improved animal wellbeing. It has shown us how modern diets may prompt obsessive–compulsive disorders; how weaning can affect social relations among animals; and how the behaviour of a breed can be a product of its shape.

It is the rigour of the scientific approach that ensures that we arrive as closely as possible to the truth about horses. The scientific method sometimes seems tedious because of its insistence in dismantling the elements of the questions piece by piece and its tactic in not setting out to prove a hypothesis but to disprove the null hypothesis (the non-existence of it). It is rather like the legal notion of innocent until proven guilty. Similarly, in science it is empty until proven full. An important tenet in behaviour science is Lloyd Morgan's canon, which dictates that in no case should an animal activity be interpreted in terms of higher psychological processes if it can be reasonably interpreted in terms of processes that stand lower in the scale of psychological evolution and development. Occam's razor (The Law of Parsimony) is a more general maxim that decrees that in making explanations, you should not make more assumptions than the minimum needed, so if a phenomenon can be explained in terms of simple rather than more complex ways, it is more likely to be correct. The more assumptions you have to make, the more unlikely an explanation is. This principle underpins all scientific theory building. It is easy to make rash assumptions about horse behaviour, intent and purpose.

Those with concerns about applying a scientific approach to equitation seem to fear the *construction* of equitation as a science, which is certainly not our intent. Equitation science represents the scientific *study* of equitation; it does not seek to turn equitation into a science. Scientific measuring of variables is important because it allows riding and training techniques to be compared so as to demonstrate what works and what does not. Equitation science will also allow us to measure the welfare consequences of doing the wrong thing. The *physical* interactions between humans and their horses are readily available for study. For welfare reasons, understanding these interactions correctly is crucial because, on the one hand, excessive pressure is often being used to signal to horses and, on the other, we cannot expect horses to know what we require of them without at least some cues.

In all other sports, technologies such as kinematic analysis and pressure-detecting devices have been able to refine human technique. If we accept that horses work best when riders have good technique, we can see that, as sentient beings, they are more deserving of these advances than any piece of sporting apparatus. Like all animals, horses learn most effectively when the training methods are appropriate. Inappropriate training practices can also have a negative impact on a horse's welfare and can lead to conflict behaviours that jeopardise the safety of riders and trainers. Equitation science gives us a way of measuring and interpreting interactions between horses and their riders.

Equitation science has the potential to address a series of important problems. First, it elucidates the role of negative reinforcement and habituation in the learning processes of horses on which we ride and compete. Second, it addresses the need to measure rider interventions that may compromise horse welfare, which will assist the administrating body of equestrian sport, the Fédération Equestre Internationale (FEI), in determining what practices and interventions are acceptable on welfare grounds. For example, devices such as whips and spurs are still used routinely by some trainers. Indeed, at elite levels, spurs and double bridles (which are more severe in their action than regular single bits) are mandatory. Third, and perhaps most important, equitation science will educate current and aspiring riders in how best to apply the core principles of learning theory.

By improving riders' and coaches' basic appreciation of the science that underpins their work, we have been able to engage them in improvements that occupy the cutting edge of equitation. For a scientific horse-training manual, readers are directed to *Academic Horse Training: Equitation Science in Practice* (McLean and McLean, 2008) (www.esi-education.com).

In some sectors of horse-training, such as the sport of dressage, the cues and signals used to elicit alterations in the mobility and posture of horses are known as 'aids'. This word is antique in origin, derived from the French verb 'aider', meaning 'to help'. The notion that cues in any way offer assistance to horses is anthropocentric and has been abandoned in our text because it nourishes the notion of the 'benevolent' horse, the horse that is a willing partner. Horse-trainers should respectfully recognise that training is an act of equine exploitation rather than equine enlightenment, and modern equitation must take full account of the cognitive processes of the horse.

Figure 1.5 Equitation science is for everyone who spends time with horses and ponies. The training techniques presented in this book apply to all types of horses and all disciplines. Regardless of whether you are an international competition rider, a horse-trainer or a leisure rider, knowing how to use learning theory is the key to all good training and good horse welfare. (Photo courtesy of Dagmar Heller.)

Any system of riding that aligns with learning theory will result in subtle signalling and therefore, by implication and necessity, an independent seat. Our contention is that *stop* responses to the bit and *go* responses to the rider's legs are the foundations that underpin all advanced riding techniques. It would be good to see a return to traditional coaching protocols that required novice riders to learn to balance before picking up the reins. This would avoid them delivering conflicting signals.

This book is essentially an introductory text because there is much still to discover about the way mechanisms of horse-training align with more than a century of studies of learning in laboratory animals. There is also room for considerable caution because there is no laboratory equivalent for the ridden horse – you cannot ride a rat. Without restraining a rat, you cannot easily apply and then release pressure, and the horse probably provides the best model for studies of negative reinforcement. This possibility represents one of the most exciting aspects of equitation science.

The aim of this book is twofold: we partly aim to describe learning theory and give examples of how learning theory can be applied to practical horse-training. We also aim to provide an overview of the current state-of-the-art of scientific studies relating to equitation.

The purpose of this book is not to sell or publicise a particular training method, but to communicate the principles of learning theory and the science of equitation (Figure 1.5). It should be noted that just because a training method can be explained through learning theory does not necessarily mean that it is ethical or safe. Training is essentially an exploitative event and it is always the responsibility of the trainer to prioritise the horse's welfare and safety above any training goal.

2

Ethology and Cognition

Introduction

Ethology is primarily the scientific study of adaptive behaviour in animals, as it evolved in a natural environment; applied ethology is the study of animal behaviour in the human domain. Equine ethology is, strictly speaking, limited to the study of horse behaviour in free-ranging contexts (Figure 2.1). Cognition, on the other hand, is mechanisms by which animals acquire, process, store, and act on information from the environment. The study of cognition covers many topics, such as perception, learning, memory and communication. We will explore equine cognition later in this chapter, but let us first look at the horse's natural or innate behaviours (i.e. its ethology).

It is useful to think of a horse in terms of the way it fits into its social group, the domestic setting and its interactions with humans, including the work we require of it. These can be encapsulated by the term *umwelt* (from the German word for 'environment' or 'surrounding world' (von Uexküll, 1957)). Every organism reshapes its own umwelt when it interacts with the world. *Umwelt* is a useful concept as it explains how invasions into a horse's world can have effects in other domains. Physiologically, we can think of a single stressful facet of the horse's world as lowering the threshold at which other events become frustrating (Figure 2.2). Therefore, a horse that is in an inappropriate social group may be less responsive during training and, equally, a horse that has encountered inconsistent training may be more likely to be stressed by marginally frustrating aspects of its world when not being ridden.

The biological constraints on what a horse can physically do clearly set limits to what it can be trained to do. Its cardiovascular characteristics affect its stamina and ability to take in oxygen and expel carbon dioxide (Evans *et al.*, 2006). Its musculoskeletal attributes affect its ability to contract and extend its scope over obstacles. In addition, its perception and visual acuity affect its ability to judge the position of hazards (Hall, 2007).

Beyond these physical constraints, there are also cognitive restraints that apply to the horse's ability to process and remember information. These are limitations to learning and, therefore, limitations on training that we will consider in this chapter. It is interesting to reflect upon strategies that have facilitated survival. They include a horse's ability in making associations between stimuli and weakness in generalising among stimuli. Clearly, on an individual level, such cognitive characteristics can have a critical impact on the success of our work with horses. Even with the most outstanding training programmes, with perfect timing and consistency, these constraints may have considerable impact on performance in competition.

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Figure 2.1 Feral horses and herds that receive minimal management, such as these Konik horses in Oostvaarders Plassen, the Netherlands, provide critical information on normal horse behaviour.

Figure 2.2 Success in horse-training is influenced by many variables.

The Horse in a Domesticated Niche

While humans have been interacting with horses for many millennia through hunting, it is only relatively recently that horses have become beasts of burden and been used for transport, war, agriculture and, more recently, sport and leisure. Direct evidence suggests that horses were domesticated at around the end of the second millennium BC (Levine, 2005), although some sources suggest a much earlier onset of domestication. However, genetic analyses suggest that domestication in the horse was not a single event, but rather took place at several separate locations (Jansen *et al.*, 2002). Since the beginnings of domestication, various techniques for horse-training have been developed and passed on to subsequent generations orally or through literature. The oldest preserved written treatise on horse-training stems from Xenophon [translated by Morgan, 1962]. All these techniques are underpinned and constrained by the biology of the horse. Many, but not all, of these training systems align with contemporary learning theory (Boot and McGreevy, 2013). When it comes to getting the most out of horses in sport and work, we need to be well acquainted with their behaviour. Effective and humane training *always* takes account of the animal's ethology, but training systems, however successful, can only ever partially align with the animal's ethogram (behavioural repertoire).

The word 'wild' is deliberately avoided here, as there are no longer any examples of truly wild horses. Most free-ranging horses are feral horses (i.e. descendants of domesticated horses that escaped from intensive human management). An exception is the Przewalski horse (*Equus przewalski*). These horses were, until recently, considered a separate species from domestic horses (*Equus caballus*) due to anatomical and genetic differences. However, genetic differences are due to chromosome fusion (i.e. the same genetic material is present, only arranged in a different number of chromosomes). Przewalski horses became extinct in their natural habitat in the 1950s (Mohr, 1971), but from a small nucleus of 13 foundation animals (one of which was a hybrid with the domestic horse), they survive today in captivity and in successfully re-introduced free-ranging populations (e.g. in Mongolia) (Boyd and Bandi, 2002; King, 2002). The survival story of Przewalski horses is an extraordinary one, and we are indeed fortunate to be able to study them in a variety of contexts. It is likely that since domestication, selective breeding has altered their fear threshold, but the hyper-reactive tendencies of the horse have not been completely eradicated.

Nevertheless, it has been proposed that the major cognitive change that occurred during selective breeding over the millennia was the capacity for habituation, including the tolerance of the nearby presence of potential predators (such as humans or dogs). Indeed, the driving force of domestication is thought to be selection for tameness (Trut *et al*., 2009). While tameness involves innate changes of reactions to humans, it is likely in part also comprised of increased habituation abilities. The domestic horse habituates readily to a wide array of environmental and social stimuli (Miller, 1995). Such an ability to habituate to threatening stimuli may have been maladaptive for the wild horse but has been selected for in the domestic horse.

Perception

The laboratory challenges we design for horses to test learning are constrained by the subject's ability to perceive. For example, when we give horses visual learning tasks, their performance depends upon the features of their visual system. A horse's ability to look at the ground when grazing and simultaneously scan the horizon for potential predators (Harman *et al*., 1999) may limit its ability to focus attention on a single object (Lea and Kiley-Worthington, 1996). A horse must lower its head to observe stimuli on the ground because doing so projects the image onto the most sensitive area of the retina (Harman *et al*., 1999). The need for visual surveillance and the necessity to respond in ways that afford the horse a better view of potential threats are attributes that often provide troublesome intrusions in ridden work (Hall, 2007). In terms of vision, horses are classed as dichromats because they have two types of cone photopigment. Consequently, the colours they most easily discriminate are yellow, orange and then blue (Grzimek, 1952; Hall *et al*., 2005).

Horses have evolved to spend approximately 60% of their time grazing so their eyes are at a set height above the ground, but it is a mistake to assume that all horses perceive the world in the same way. Studies of ganglion cell distribution suggest that skull shape may affect visual acuity (Evans and McGreevy, 2006) (Figure 2.3). Equally, the height of stimuli above the ground (Hall *et al*., 2003)

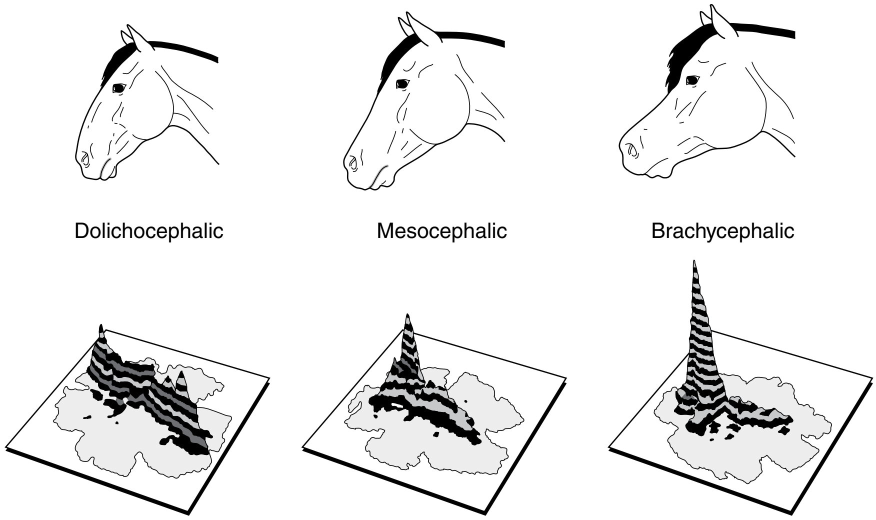

Figure 2.3 Retinal ganglion cell-density maps from horses of three breeds with the dorsal part of the retina in the background, ventral in the foreground, nasal to the left and temporal to the right. Each shaded band represents 400 cells/mm^2. Studies of the retinae of horses with different skull shapes have shown that (at least some of) the neural tissue of morphologically diverse breeds differs. Brachycephalic horses, such as Arabians, are thought to have lower acuity in their peripheral vision field and a central field with higher acuity.

and relative to the height of the observing animal's head will affect the way in which stimuli are perceived. So, ponies and horses cannot be expected to perceive the same stimuli in the same way, and experimental tests with visual stimuli should take account of the head and neck position of subjects. In addition, individual horses, like humans, may possess different levels of visual acuity, which can be expected to impact their reactivity to visual stimuli.

Although horses have limited ability to focus on objects that are close to them, they have good distance vision and a very extensive visual field (Harman *et al.*, 1999). This is important as it allows them to scan the horizon for potential threats. However, they rarely need to see close up with high acuity and because the eye's proximity to objects is generally limited by the length of the nose (Wouters and De Moor, 1979), very close objects are felt via the skin and vibrissae of the muzzle. Within the retina of the horse there is an area of maximal sensitivity (similar to the fovea of the human eye) termed the visual streak and it is only in this area that the horse has any real visual acuity (Ehrenhofer *et al.*, 2002). In the more peripheral areas of the retina, the structure suggests that the horse is particularly sensitive to subtle changes in light and stimulus motion (Ehrenhofer *et al.*, 2002).

Heffner and Heffner (1983; 1984; 1986; 1992) have explored the horse's ability to discriminate between sounds of variable frequency and intensity. They report that sounds need to be louder for horses than for humans and indicate that equine hearing is more ultrasonic than the human counterpart (50 Hz–33.5 kHz for horses compared with 20 Hz–20 kHz for humans).

There is also intriguing evidence of horses' ability to recognise individuals cross-modally, from both their appearance and the sounds of their voices. Horses were shown a familiar conspecific and then heard the played-back call of a different affiliated conspecific. They indicated that the incongruent combination violated their learned associations by responding faster and looking for longer in the direction of the call than when the call matched the herd member they had just been shown (Proops *et al.*, 2009). The impact of the special features of equine hearing on training may be limited in some equestrian codes where the use of the voice by trainers and riders is either not encouraged or actively forbidden. Some interesting exceptions are the use of the voice in driving, to cue transitions on the lunge and in other codes of horsemanship.

Trainers usually report that horses are quick to acquire these cues, so it is worth bearing in mind that, if they can be used with consistency, auditory signals are humane. It is fascinating to note that in 360 BC Xenophon [translated by Morgan, 1962] regarded it as orthodox to calm down a horse with a chirrup, a smooching noise made with the lips alone, and to rouse it by clucking the tongue against the roof of the mouth. Without using terms that have their origins in modern learning theory, he also noted that these behavioural outcomes were the product of classical associations with operant techniques, so swapping the learned cues would also swap the effects: 'Still, if from the first, you should cluck when caressing and chirrup when punishing, the horse would learn to start up at the chirrup and calm down at a cluck.'

Generally, ears that are constantly pricked forward are associated with fearful behaviour, and the horse flickers its ears loosely forward and back when it is ridden and relaxed (McLean and McLean, 2008). It is important to note that many riding guidelines (e.g. German National Equestrian Federation, 2012) describe ear movements (especially alternate pinnae flicking caudally) as evidence that the horse is attending to the rider's signals (Figure 2.4), an aspect that is commonly evaluated in dressage tests. However, in a study in which riders were asked to tense their bodies, pretending to be nervous, horses reacted with predominantly backwards pointing, rather than flicking pinnae, compared to control situations (von Borstel, 2008), perhaps providing some evidence that horses' ears indeed provide information on their direction of attentional focus. A more in-depth assessment of the significance of ear movements in the ridden horse may assist dressage judges of the future

Figure 2.4 Ears moving independently are typically regarded as a sign of attentiveness.

if they are to score a given performance for behavioural legacies of inhumane training.

In general, there is a great deal still to be discovered about equine perception. While vision has received the most attention in studies of equine perception, it has been pointed out that 'senses probably of more crucial importance to the horse's environment have been neglected' (Saslow, 2002; Nielsen *et al*., 2015). For example, olfaction is critical in interactions between horses, but has been the focus of remarkably few studies (Christensen and Rundgren, 2008). The same is true for tactile perception, despite its importance in equitation (Ahrendt *et al*., 2015). Tactile sensitivity is determined by different types of mechanoreceptors in the skin, ranging from receptors that can detect finest pressures of less than 1 g to nociceptors that are activated at very high pressures sending signals of pain to the brain (Woolf and Ma, 2007; Maricich *et al*., 2009). Distribution of these receptors determines tactile sensitivity, and there are considerable, individual differences in horses' responses to standardised tactile stimuli (König von Borstel and Krauskopf, 2016). Sensitivity of the skin of the ventral thorax (the sides, where the rider's legs make contact) and the mouth has a profound impact on a horse's response to training cues from the legs and reins. Likely, from a training perspective, there is an optimal level of tactile sensitivity, such that neither overly sensitive horses perform best with conventional training techniques (as they easily suffer from pain or discomfort due to tack or rider interactions), nor highly insensitive horses perform best as they may be more likely to react to pressure by ignoring it rather than by attempting to evade it through a learned response. Surprisingly, no relationships between tactile sensitivity and various aspects of trainability, such as the horses' reactions to rider cues, could be detected (König von Borstel and Krauskopf, 2016). However, this may well be due to the weaknesses of the traditional evaluation system for trainability and other personality traits (König von Borstel *et al*., 2013). rather than to a true lack of relationships between tactile sensitivity and trainability.

Breed and individual differences may be in part due to cushioning effects of thicker layers of skin tissue and subcutaneous fat but it is also possible that different patterns of mechanoreceptors are responsible for differences in sensitivity.

The Equid Ethogram

We do well to study the horse's social behaviour repertoire (its social ethogram) when considering how to be effective and remain safe while handling these animals. The agonistic ethogram of the bachelor band (all-male groups found in free-ranging herds) has been described in detail and includes a total of 49 basic behaviours, 3 complex behavioural sequences and 5 distinct vocalisations (McDonnell and Haviland, 1995).

Like humans, horses are highly social animals. This explains why horses kept in isolation are more likely to show separation-related behaviours and stereotypies than those kept in group-housing conditions (Cooper and McGreevy, 2002; Hartmann *et al*., 2012). Companionship is important to horses. The instinct for togetherness is so strong that grooming each other at the base of the neck can have relaxing effects. Feh and de Mazières (1993) showed that grooming and stroking horses just in front of the withers (Figure 2.5) causes a significant lowering of heart rate compared with other regions. Apparently, this serves to strengthen familial bonds. It would be interesting to explore how much of the heart-rate response to wither scratching is learned and how much is innate.

Given that all aspects of behaviour are subject to natural selection, ethology is not merely the study of innate behaviours but also the study of how selection, both natural and artificial, has influenced learning processes and capabilities. Natural selection will, for example, have influenced whether an animal learns well individually, or learns by observing conspecifics, or both. It will have influenced such variables as relative attention

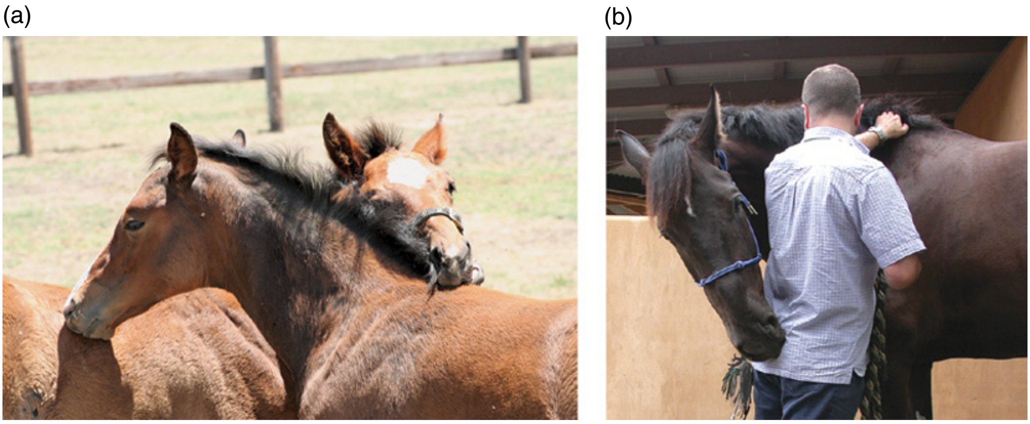

Figure 2.5 (a) Horses allogrooming and (b) human grooming a horse's withers.

devoted to learning new food-finding techniques versus scanning for predators.

The predisposition of an individual horse to learning and training reflects interactions between the ethology of the horse and the selection of breeds, maternal behaviour, weaning protocols, nutrition, housing, early handling, subsequent training and numerous individual differences. The complexity of the unique background that emerges for each horse from these influences explains why an identically rigid structure and timeframe of training can never be imposed on all horses effectively, although the need for fundamental responses (including *stop*, *go* and *turn*) is universal and learning theory can be optimally applied to all horses. Fundamental differences between horses lie in the time needed to train a specific quality. Good trainers recognise this and customise their interventions with each horse accordingly (Podhajsky, 1966). That said, to be effective, the mechanisms used in each custom-built approach should be applied with absolute adherence to the principles of learning theory.

Therefore, equine ethology informs us not only about communication but also about equine behavioural needs and preferences, learning processes and motivation. It helps us to predict some of the ways horses *out* of their natural environment (i.e. in the domestic context) might react and cope with various challenges, and how behaviourally flexible, compliant and adaptive they may be. As such, equine ethology underpins enlightened and effective training but, despite the efforts of some marketing teams, it cannot be used to label a training system or philosophy *per se* without misrepresenting ethology itself.

Cognition: Memory and Learning

While horses show considerable performance in how quickly they can learn certain things, their performance is nowhere near the levels achieved by some primates and dolphins. These species rapidly learn to apply certain rules to novel problems and can often solve novel problems at first attempt (Leslie, 1996). Rule-learning is likely to be more adaptive for a cooperative predator than a grazing animal for which food procurement relies more on memory than higher mental abilities such as planning. In addition, the extra neural circuitry for higher mental abilities requires extra brain tissue which, as Deacon (1990) showed, is significantly more expensive energy-wise than any other tissue in the body. Evolutionary theory decrees that, like its physical abilities, an animal's mental abilities would be the result of the adaptive forces that it faced, particularly in procuring food, over the eons of its evolution (McLean, 2001).

Free-ranging horses occupy a home-range that they learn to exploit for resources and safety. By using different parts of the range, they can capitalise on the available food and water resources, even by using different terrains at different times of year (Olsen, 1996; Linklater *et al*., 2000). The capacity of horses to return to bountiful grazing spots is a critical contributor to their success in foraging. Horses choose the richest patches when they have recent experience of them, but when they do not have such experience, they adopt a strategy of dynamic averaging that allows them to choose their feeding sites according to the long-term average richness of the available sites (Devenport *et al*., 2005) (Figure 2.6).

Horses' knowledge of the range facilitates their escape from predators and even biting insects (Linklater *et al*., 2000). Their daily treks allow them to become familiar with tiny landscape changes, especially visual ones (Hall, 2007) that are avoided or otherwise investigated if they appear innocuous from afar. Horses require considerable spatial representation abilities to migrate when seasonal ecological conditions demand, to be able to navigate between patches of preferred grazing in their home range (Howery *et al*., 1999) and travel up to 25 km to drink (Stoffel-Willame and Stoffel-Willame, 1999). How free-ranging horses use this to structure their home ranges and form cognitive maps (Tolman, 1948) warrants further investigation (Leblanc and Duncan, 2007), and this is best studied in the niche for which they have evolved (Hothersall and Nicol, 2007). This should allow us to see how cognition in the domestic horse is truly illustrated, exploited and at times frustrated by conditions provided by the domestic environment.

Clearly, memory and learning mechanisms are intimately entwined. Nerve fibres grow by following genetically determined positional cues towards the general target with which they synapse. Then, fine-tuning of the pattern and density of projections is accomplished by the horse's experience. Relationships between synapses are constantly being remodelled through increases or decreases in the size and strength of associations that also lead to the formation of new pathways. Working memory, declarative memory and procedural memory are well understood as is the process of long-term potentiation, which increases synaptic strength and strengthens pathways (Kandel *et al*., 2000). What is less clear is the extent of the working memory in horses and if it relates to long-term potentiation in the same way as it does in humans.

Memory

A memory is a set of encoded neural connections. The encoding can take place in several parts of the brain and the neural connections can be widespread. The horse's memory is

Figure 2.6 Grazing horses do not randomly forage but instead select food on the basis of sight, smell, taste and previous experience of that pasture.

excellent and in some respects may be superior to human memory. While our memory can be altered by our recall, contexts and reasoning abilities, the memory of the horse appears more stable, perhaps because it is unclouded by reflection or projection (McLean, 2001), or perhaps we just have yet to design methodologies that reveal that horses are capable of these (Goodwin, 2007). Hanggi and Ingersoll (2009) showed that horses could remember stimulus categorisation tasks without practice for up to 10 years, and horses were also able to apply the previously learned concepts immediately to novel stimuli. However, thinking, analysing and reflecting can corrupt memory. Humans are continuously reflecting (i.e. thinking without 'doing') on some of our memories, retrieving them from storage when we think or tell a story, then later re-storing them. Importantly, after this process of reflection, the memories are stored a little differently. They are altered by the contexts in which we reflect on them (physical, emotional, perceptual aspects of the moments of reflection). Our elaborate prefrontal cortex, the characteristics of which are uniquely human (Bermond, 1997), is responsible for this reflective ability (Kandel *et al.*, 2000). The absence of tissues with the unique cellular characteristics of the human prefrontal cortex (Kandel *et al.*, 2000; Premack, 2007) and the stability of equine working memory currently suggest that such reflection does not occur in horses.

Learning

As with all species, learning in the horse relates directly to survival requirements and it is generally accepted that it is appropriate to discuss issues of cognition, learning and memory without resorting to the term 'intelligence' (Linklater, 2007). Intelligence aside, the complexity of learning can be mapped-out in accordance with a hierarchy of learning abilities from habituation to conceptualisation (Table 2.1).

Every horseperson knows that the horse is acutely aware of changes in its visual environment. To the detriment of training, the horse appears to remember far better than the rider 'what happened where'. For example, riders may occasionally notice that the horse goes better on one part of the circle than elsewhere and, gradually, if training is correct, the length of this sector increases. The horse makes associations between the

Table 2.1 Hierarchy of learning abilities.

Level	Learning
1) Habituation	Learning not to respond to a repeated stimulus that has no consequences
2) Classical conditioning	Making responses to a new stimulus that has been repeatedly paired with an established effective stimulus
3) Operant conditioning	Learning to repeat a voluntary response for reinforcement or not to repeat a voluntary response to avoid punishment
4) Chaining responses	Learning a sequence of responses to obtain a reinforcement at the end of the sequence
5) Concurrent discriminations	Learning to make an operant response to only one set of stimuli from more than one set of stimuli applied concurrently
6) Concept learning	Discrimination learning based on some common characteristic shared by a number of stimuli
7) Conjunctive, disjunctive and conditional concepts	Learning of concepts that emerge from the relationship between stimuli such as 'A and B' (conjunctive), 'A or B' (disjunctive) and 'If A, then B' (conditional)
8) Bi-conditional concepts	Logical reasoning, such as 'Option A is likely if,' and only if, 'Option B is present'

Source: Adapted from Thomas (1986) and Murphy and Arkins (2007).

behaviour it is currently doing and where it is doing it. This context-specific (or place-dependent) learning can be a very useful tool in training (Chapter 8, Training). For example, some behaviours that are hard to train should be trained in the same place until some reliability emerges. On the other hand, context-specific learning can be a hindrance if, through classical conditioning, the horse learns to exacerbate flight-response behaviours in certain places or contexts. The horse learns tense and fearful responses more rapidly and more indelibly than other responses (McLean, 2004). Sometimes it takes just one or two episodes of a flight response to cause repetition in the same contexts. Fear memories can be suppressed with error-free practice, but when circumstances are the same, the response can return with alarming speed and accuracy. This is known as spontaneous recovery. For this reason, it is an essential principle that flight response behaviours (Figure 2.7) should be properly identified and training schemes should generally be tailored to avoid them.

At the same time, it is acknowledged that horses may detect subtle differences in the behaviour of a nervous human and respond with increased preparedness. von Borstel (2008) and Keeling *et al.* (2009) have shown how a nervous human can affect a horse's reactions or responses. They demonstrated how variations in equine heart rate followed very similar heart-rate activity patterns for both trainers and riders. The relationship between these patterns persisted when some individuals were told in advance that an umbrella would be opened suddenly as they rode or led a horse past an experimenter with the umbrella. Although the umbrella was not actually opened, the person's anticipation of fear responses significantly increased the heart rate in both the person riding or leading and the horse when compared with control conditions. Thus, horses appear to be able to detect subtle changes in a rider's emotional state and react to them with changes in their own level of arousal. Since an appropriate level of arousal is important for optimal learning performance (Starling *et al.* 2013), it

Figure 2.7 Horse showing a flight response under-saddle. (Photo courtesy of Minna Tallberg.)