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Review

The advent of equitation science

Paul D. McGreevy *

Faculty of Veterinary Science, Gunn Building (B19), University of Sydney, NSW 2006, Australia

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Abstract

The lengthy association of humans with horses has established traditional equestrian techniques that have served military and transport needs well. Although effective, these techniques have by-passed the research findings of modern psychologists, who developed the fundamentals of learning theory. That said, the pools of equestrian debate are far from stagnant. The latest wave of horse whisperers has offered some refinements and some novel interpretations of the motivation of horses undergoing training. Additionally, the Fédération Equestre Internationale (FEI) has introduced the concept of the 'happy equine athlete' and, in the light of the hyperflexion (Rollkür) debate, recently examined the possible effects of some novel dressage modalities on equine 'happiness'. However, many still question the welfare of the ridden horse since it is largely trained using negative reinforcement, has to respond to pressure-based signals and is seldom asked to work for positive rewards. Science holds tremendous promise for removing emotiveness from the horse-riding welfare debate by establishing how much rein tension is too much; how much contact is neutral; how contact can be measured; how discomfort can be measured; how pain can be measured; and how learned helplessness manifests in horses. These are some of the topics addressed by equitation science, an emerging discipline that combines learning theory, physics and ethology to examine the salience and efficacy of horse-training techniques.
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Keywords: Horse; Training; Learning theory; Welfare; Equitation science

1. Introduction

At its most humane, horse riding relies on subtle interactions between horses and humans (McGreevy, 2002). We have a profound influence on the behaviour of our horses, in-hand and under saddle, through riding with stimuli from our hands on the reins and our legs on the sides of the horse and more subtly with the use of weight position and movement through the seat (McGreevy, 2004).

Behavioural responses have evolved to reduce the basic drives, including hunger, thirst, pain and discomfort, sexual desire, and freedom from predators. Animal trainers tap into these needs when they use rewards during training (McGreevy and Boakes, 2006). Rewards can reduce basic drive and thus reinforce the responses that gain them. For example, when training draught animals to turn left or right, trainers can make use of the fact that cattle, donkeys, camels, elephants and horses comply with human demands to escape pressure. Depending on the species and the gear being used, they turn when a rein is pulled because doing so helps to reduce the pressure in the mouth, nose or ear.

Throughout their lives, horses in work learn to offer responses that result in the reduction of pressure. This is underpinned by the principle of negative reinforcement, i.e., that a response is more likely in the future if it brings about the removal of an aversive stimulus. During their early training, domesticated horses learn: that the pressure of the bit via the reins disappears when they stop or slow; that the pressure of the rider's legs or spurs disappears when they go forward. To be effective and humane, horse training must involve subtle application of pressure and its immediate removal once an animal complies. However, when horses cannot consistently obtain freedom from such

* Tel.: +1 530 752 0290; fax: +1 530 752 6042.
E-mail address: paulm@vetsci.usyd.edu.au

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Fig. 1. An example of unwelcome behaviour that might be shown by horses undergoing competing behavioural needs. (Photograph with permission of Sandy Hannan.)

pressures, chronic detrimental conflict may arise (McGreevy and McLean, 2005). Conflict can render horses sour, unresponsive and dangerous (see Fig. 1). Given that the correct application of learning theory makes horse-use more sustainable, there is an evident and pressing need for more empirical study of learning theory in Equidae.

2. Background

2.1. Basics of learning theory

Learning allows animals to use information about the world to tailor their responses to environmental changes. Training institutes novel responses by drawing out desirable innate behaviours and suppressing undesirable ones (McGreevy and Boakes, 2006). There are two major categories of learning: non-associative (involving a single stimulus) that can be either habituation and sensitisation; and associative (involving a relationship between at least two stimuli becoming established). These are referred to as either classical (Pavlovian) conditioning or operant (instrumental) conditioning (see Table 1).

Classical conditioning focuses on associations that build up between stimuli. An example of classical conditioning is when stallions produce courtship behaviours in association with the breeding barn alone. Operant conditioning focuses on the effect of certain responses. It is to do with the ways in which the animal *operates* in its environment. Most training systems use operant conditioning, which relies on reinforcement and punishment (reinforcement making future responses more likely and punishment making them less likely). For example, the animal receives a cue (command, trigger, signal or 'aid'), performs a response and gets a reward (primary reinforcer). Primary reinforcers are any resources that animals have evolved to seek (e.g., food, water, comfort, sex, play, liberty, sanctuary and companionship).

Operant conditioning enables an animal to associate events over which it has control. This increases the *controllability* of the environment and represents the crucial difference between operant conditioning and classical conditioning (which increases predictability). Operant conditioning consists of presenting or omitting some reward or punishment when the animal makes a specific response (Kratzer et al., 1977). The likelihood of an association arising depends on the relationship between the first event and the second via stimulus–response–reinforcement chains. What works for horses is immediate comfort or immediate relief from discomfort. Operant conditioning can have potential benefits for horse welfare by improving choice. In classical conditioning, rewards become associated with stimuli, while in operant conditioning they become associated with responses. Riders use classical conditioning when they replace pressure cues with previously neutral signals, such as changes in their position (seat) (McGreevy, 2004). Importantly, this use of the adjective 'classical' should not be confused with its use in reference to classical equitation, as described by the so-called *anciens maîtres* (de Bragance, 1976).

Positive reinforcement involves the addition of a primary reinforcer (see Fig. 2). Positive reinforcement alone does not lend itself to safe equitation, effective ridden train-

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Table 1
Terms used in learning theory

Term	Definition
Associative learning[a]	The process that establishes a relationship between at least two stimuli. There are two subdivisions under the umbrella of associative learning. These are classical conditioning and operant conditioning
Non-associative learning[a]	The process by which an animal is exposed to a single stimulus and becomes habituated or sensitised to it
Classical conditioning[b]	The process whereby the unconditioned or conditioned response becomes elicited from a conditioned stimulus (Pavlov, 1927). In equitation it is the process where learned responses are elicited from more subtle versions of the same signal or to entirely new signals
Operant conditioning[b]	Training the horse to respond consistently to signals through positive reinforcement and negative reinforcement (Skinner, 1938; McLean, 2003)
Habituation[b]	The waning of a response to a repeated stimulus as a result of frequent exposure (not fatigue)
Negative reinforcement[b]	The subtraction of something aversive (such as pressure) to reward the desired response and thus lower the motivational drive (Skinner, 1953)
Positive reinforcement[b]	The addition of something pleasant (a reinforcer) to reward the desired response and thus lower the motivational drive for that reinforcer (Skinner, 1953; McLean, 2003)

[a] McGreevy (2004).
[b] McGreevy et al. (2005).

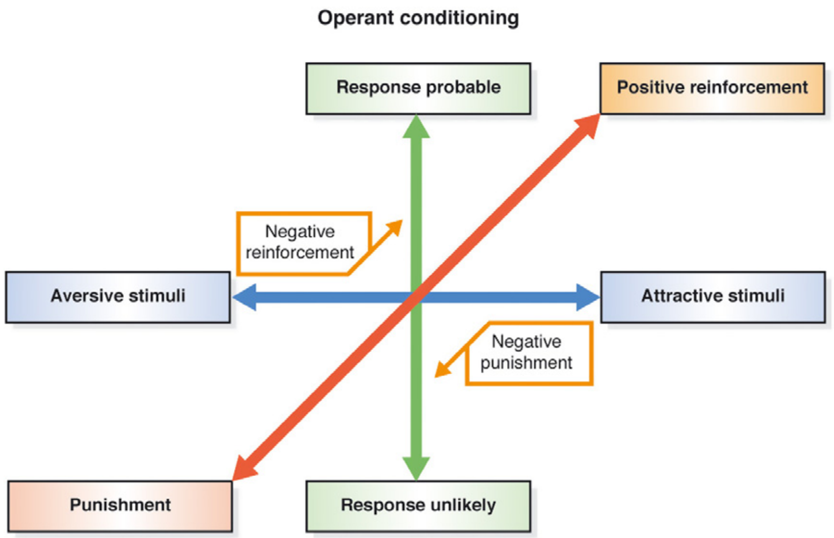

Fig. 2. Reinforcement and punishment can be regarded as part of a continuum. N.B. Negative in this training scheme refers only to the removal of an outcome for the animal (i.e., removal of an aversive stimulus or removal of a reward).

ing or prolonged maintenance of extreme postures. Along with negative punishment, which operates to reduce the likelihood of a behaviour by removal of a reward, it is rarely used in the ridden horse.

The word negative in 'negative reinforcement' indicates only the removal of an influence and is not a 'bad' modality per se. The removal of pressure is the reward (reinforcer). Educated horses show an association between negatively reinforced responses and light tactile signals (e.g., minimal rein tension). So, after foundation training (breaking-in), horse-training involves combinations of operant conditioning and classical conditioning. The subtleties of negative reinforcement in horses are very poorly understood, not least because data derived from the traditional species (primarily rats) used for learning studies in psychology contexts are of such limited use in equitation.

Negative reinforcement underpins all equitation but, in the best cases, it is very subtle and relies on the immediate release of pressure as an instantaneous reward. Failure to release pressure can cause conflict and have behavioural and physiological manifestations that can shorten the horse's working life.

3. Traditional horse training

Coming from a military background, traditional horse training aimed to develop horses that were so compliant they would lose all sense of self-preservation. Horses were expected to be submissive to the commands of a rider, and blame for failure to conform fell on the horse. Such an approach forces a horse into a state of conflict and prompts him to trial strategies to remove at least one of the competing stimuli, sometimes by attempting to dislodge the rider. Pain in the musculoskeletal system notwithstanding, it is easy to see how a horse that has learned to buck and rear is trying to solve problems created during training. The two

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least welcome outcomes of inappropriate training techniques are the inadvertent cultivation of such dangerous responses and the emergence of apathy and learned helplessness (Webster, 1994). Thus, inappropriate training practices can lead to conflict behaviours that jeopardise the safety of riders and handlers and can have a negative impact on the horse's welfare.

Equine education has been clouded by the use of anthropomorphic terminology in describing horse behaviour and the implication that the horse has some moral culpability in its training, as well as by the use of unhelpful terms such as 'natural' and 'unnatural' 'aids'. Additionally, contemporary horse-training dogma provides many obstacles to effective equine learning, such as training too many responses simultaneously with consequent overshadowing of one signal by another (Lieberman, 1990). Complicating the training process is a traditionalist theory that horse riding is an art that should not be subjected to scientific mechanisms, leading to confusion surrounding the terminology used in training horses and riders.

Ideally, equestrian technique combines art and science, but students of equitation encounter only a few measurable variables, such as tempo, rhythm and outline, alongside many more conceptual ones, such as harmony, looseness, respect and leadership (McGreevy and McLean, 2005). This unbalanced mixture and the lack of empirical means to measure and terms to express equestrian technique account for some of the confusion and conflict that arises in many human–horse dyads. Effective riding involves the correct application of negative reinforcement and the subsequent transfer of stimulus control to various classically conditioned cues (such as those coming from the seat). However, the performance of the horse under saddle and the consequent development of riding instruction tend to focus on outcomes rather than mechanisms.

4. Outcomes vary with context

The context of horse-riding can vary radically within one discipline. For example, in dressage, there can be a great divide between the competitive riding by modern elite riders and the training undertaken by classical riders. For example, competitive dressage has developed aspects that seem to value 'impressions of power' in the horse rather than 'lightness' in the rider's signalling, outcomes that riding masters of the 18th century might find unacceptable (Ödberg and Bouissou, 1999). Meanwhile, suggested mechanisms have been discussed at length (e.g., Roberts, 1992) but almost without any data to inform the discussion.

5. Gadgets

Welfare is compromised by excessive tension as well as by the physical attributes of the interface between the human and the horse. With any piece of tack, the broader the area that touches the horse the less discomfort it will cause and the less readily it can be used in the negative reinforcement paradigm. This is why horses can be easily trained to pull against harnesses, breast-plates and collars used on well-muscled areas, such as the shoulders and pectoral regions, but are reluctant to fight pressure from bits in the mouth (especially if they touch only in small areas, as in the case of bladed and twisted bits). When used only occasionally, chains in the curb groove or in the mouth are likely to have a strong effect, especially in the short term.

Most naïve horses respond to humans as they would to any predator. They behave in ways that help them avoid pressure, physical or psychological, by moving away bodily or posturally. These basic evasive responses can be modified successfully to produce a highly responsive equine performer or unsuccessfully to produce a problem horse. When trainers encounter horses that rapidly enter conflict and as a result do not comply, they often experiment with increased pressure to overcome resistance. Mechanical restraints and stimulants may be used to magnify the pressure that riders can apply. Because of the perceived need to force horses into an 'outline' and make them work 'on the bit' (another hotly debated term), the tendency is to use stronger bits as the first approach to solving the problem. (This accounts for the multiplicity of bits on the market.) As with any device, when many versions are available, chances are that none provides all the answers. Furthermore, enlightened trainers rarely reach for such gadgets. They recognise that where aversive stimuli fail to elicit the desired response and begin to cause behavioural conflict, the application of more force should be avoided.

Frustrated trainers often try bits that apply pressure to different parts of the mouth or to the same area of the mouth but with greater severity. Even though they can and sometimes do sever the tongue (Rollin, 2000), saw-chain bits (the so-called mule bits and correction bits) are readily available to riders who are having problems getting horses to respond to milder bits (see Fig. 3). If changing or increasing mouth pressure is unsuccessful, an alternative or additional means of making the horse adopt the desired shape is to apply pressure to other parts of the head, so 'training' devices such as curb chains, gags, hackamores, bosals, draw reins, balancing reins and chambons may be employed. Unfortunately, the tendency is to develop a reliance on these extra pulleys, rather than to use them solely for retraining.

Similarly, martingales and tie-downs that apply pressure to prevent evasive raising of the head are rarely dispensed with. If the horse fails to show sufficient forward movement or impulsion, trainers direct their attention to the flanks where they can increase the pressure and more effectively drive the horse forward or simply away from the rider's leg using whips and spurs. Although, for some, these stimulants are distasteful, they are not necessarily contraindicated. They can be used with subtlety and employed transiently to empower the rider's leg signals.

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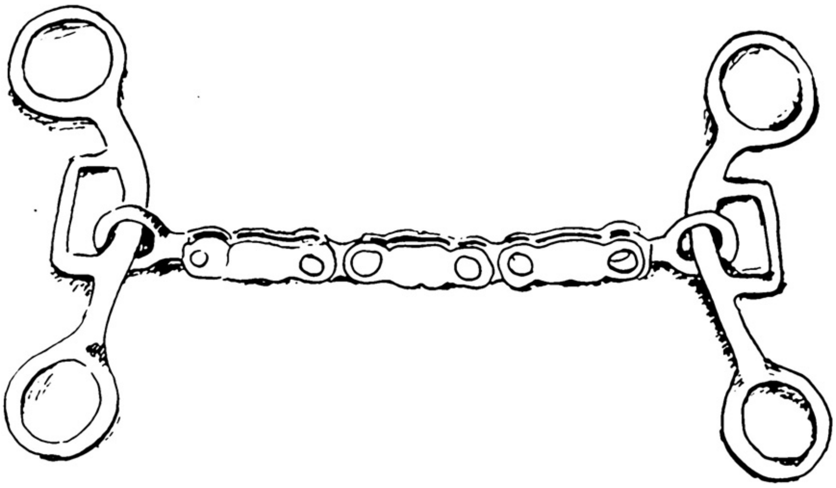

Fig. 3. A mule gag bit. Available online, this extremely severe bit is capable of causing significant trauma to the soft tissues of the mouth. Vendors warn that the device should be used with caution and that horses wearing this bit should not be tied up [by the reins].

6. Welfare concerns

Horse-riding in a wide variety of domains, from western horsemanship (including the use of tie-downs and sliding stops) to elite dressage, is currently under scrutiny from a welfare viewpoint and new entrants to the sport should realise that they are engaging in a fairly high-profile pursuit. The non-racing industry of horse-riding, as a sporting and leisure activity for animal-lovers, can survive only if equitation in general retains a good public image (Endenburg, 1999). Whereas the equestrian welfare debate in the 1970s revolved around the practice of rapping, which was then outlawed from show-jumping by the international Equestrian Federation (Fédération Equestre Internationale; FEI), its current focus is dressage. In a sense this means we are getting to the core of the matter, because

Fig. 4. Hyperflexion (also known as Rollkür or 'deep-and-round training') used in the warming-up an elite equine athlete. (Photograph with permission from www.sustainabledressage.com).

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dressage literally translates as, training, and forms the basis of many individual equestrian disciplines, including jumping and eventing. Of particular current interest in dressage circles internationally is the topic of hyperflexion of the neck (also known as Rollkür). This practice is used as part of warming-up prior to dressage tests and draws criticism on the basis of its tendency to restrict vision, respiration and head movement (see Fig. 4). It highlights some of the current debates surrounding the preparation of horses for modern dressage, such as the notion of 'contact', the connection between the rider and the horse.

The FEI currently defines hyperflexion of the neck as a technique of working/training to provide a degree of longitudinal flexion of the mid-region of the neck that cannot be self-maintained by the horse for a prolonged time without welfare implications. Over-bending as a learned response may be as acceptable as other forms of negatively reinforced postural responses, such as lateral bending. However, cervical flexion as a result of sustained bit pressure has a lot more to do with compliance and pain avoidance than suppleness. Therefore, some forms of hyperflexion may be extreme, dangerous and capable of compromising welfare. It may be dangerous for riders since it can 'deaden the brakes' and that can lead to bolting and other unwelcome behaviours as a manifestation of habituation. It can compromise welfare since horses can learn that there is nothing they can do to remove the pressure. If the horse's head is on its chest it has nowhere else to go and the animal may develop a state of learned helplessness, a cognitive state yet to be explored in horses. Even though we have yet to determine exactly how horse welfare may be compromised by the use of this intervention, it seems unhelpful to assume that it can be likened to the discomfort a human might feel if required to maintain cervical flexion due to external forces (see Fig. 5).

7. The advent of equitation science

The increasing profile of latter-day horse whisperers has made horse folk question their traditional practices and also prompted them to enquire why novel techniques operate (McGreevy, 2004). Equitation science meets the need for more understanding of the behavioural mechanisms that give rise to outcomes in the context of any human-horse interface. In August 2005, the First International Equitation Science Symposium (IESS) was held in Australia (http://www.aebc.com.au/Symposium_home.htm). It attracted speakers from six countries and participants from many more. The Symposium was organised by a group of equine scientists and veterinarians who share the view that problems with the ridden horse are difficult to address because of the current lack of science in equitation.

Sceptics have argued that science objectifies the horse and reveals the prejudice of humans who always need to be able to explain animal behaviour and deny the spirit of human-horse relationships (Skipper, 1999). However, equitation science does not seek to turn equitation into a science. It aims to develop scientific methods to study, measure and interpret interactions between horse and rider during equitation. The scientific measuring of variables is important because it allows techniques to be compared in order to demonstrate what works and what does not. It also allows us to measure the welfare consequences of doing the wrong thing.

Learning theory describes the ways in which animals learn and thus establishes clear guidelines for correct training practices and methods of behaviour modification. Since riding manuals usually by-pass the central tenets of learning theory (Waran et al., 2002), the 1st IESS focused on the application of learning theory to horse training with the aim of improving the welfare of horses in the human

Fig. 5. An example of anthropomorphic argument used to criticise hyperflexion in equitation. Science can use differences in quadrupedal and bipedal anatomy to explain flaws in this approach but needs to measure any distressing effects of hyperflexion and explore the role of habituation and learned helplessness in animals that are regularly hyper-flexed. (Photograph with permission from Uwe Spenlen).

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domain (McGreevy et al., 2005). It also helped to elucidate breed differences in the way horses perceive their environment (Evans and McGreevy, 2005), causes of wastage that relate to behavioural problems (Hayek et al., 2005) and debunked some old myths (Ödberg, 2005; Warren-Smith and McGreevy, 2005). Best of all, the Symposium heralded the emergence of two novel systems for measuring rein-tension (Warren-Smith et al., 2005; de Cartier d'Yves and Ödberg, 2005) (see Fig. 6).

These first steps towards measuring rider-horse interactions will prove critical. If we advance our understanding of negative reinforcement in general we can make significant improvements in our understanding of learning in the ridden horse. One of the most fundamental questions in equitation is: What is the optimal level of contact between any given horse and its rider?

So, the current agenda in equitation science focuses on the development of instrumentation. Tension-measuring devices permit assessment of the behaviour of humans as they engage with the horse's head. The amount and duration of pressure required to elicit a standard response (such as leading forward) varies from horse to horse. Preuschoft et al. (1999) and Clayton et al. (2003) have measured pressures placed in a horse's mouth during training, but the systems they used are expensive, which may preclude their use in everyday training. This problem must be addressed since making such devices accessible to enlightened coaches and allowing riders to demonstrate the increasing subtlety of their signals should see a reduction in the general reliance on gadgetry.

Furthermore, since true contact reflects not just rein tension but transmission of seat and leg pressures, there is an urgent need to develop a pressure-sensitive saddle cloth and half-chaps (to be worn by the rider) that permit assessment of the rider's movement in the saddle and engagement with the horse's sides. No published work has attempted to quantify these stimuli, despite the insistence in the lay literature that non-reins cues are more important than reins cues at the highest levels of competition (Loch, 1977; Sivewright, 1984; Wallace, 1993; Wynmalen, 1947). Measuring these stimuli will allow us to define the stimuli currently involved in competitive equitation.

a

b

Fig. 6. Reincheck™ the rein gauge tensiometer currently being used in Australian studies. (Photograph with permission from Amanda Warren-Smith.)

8. Possible solutions

This huge field of study requires careful and objective evaluation of training methods and will ultimately result in improved welfare and enjoyment of riding for both horses and riders. It will also address why horse-related injuries and deaths exceed those caused by any other non-human species (domestic or otherwise) (AIHW National Injury Surveillance Unit, 2005). And, since the horse is arguably the best animal model for studies involving negative reinforcement, this sort of science will contribute tremendously valuable data to the learning literature.

The need for equitation-monitoring technologies is acute because equitation science, as a discipline, is still in its infancy. Rather than waiting for competing methods to create schisms, we have a golden opportunity to develop measuring devices and chart the parameters at the heart of this project from the outset. Once measuring devices are validated, we will be able to determine the normal range of stimuli used in equitation and then survey those currently involved in competitive equitation. This is especially exciting since it will allow us to define the elite athlete's behaviour. Converting the pressure detected on the horse's sides and the tension in the reins to a signal that can be read at a distance without the need for any wiring will

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allow riders and their coaches (who, by necessity are on the ground rather than on the horse's back) to view a common display and agree on variations to current practice.

In a further innovation, this technology will allow coaches to create a training template for a given horse between lessons at which he/she is present in person. For example, a coach could ride the horse through a standard set of training exercises on dressage test and generate an electronic file that shows other riders how to get the best from the horse. This file could be used as a training template by junior riders with significant deviations from the template between face-to-face lessons being logged for subsequent discussion between the rider and the coach.

Without vital research of this sort, there is little hope of improvement in the inherent problems of coaching riders subjectively. There is growing evidence that there is a gap in the knowledge of professional equestrian coaches, and that equitation is lagging behind other human–animal interfaces. A recent study indicates that Australian equestrian coaches are inconsistent in the way they define and report the use of training interventions (A.K. Warren-Smith and P.D. McGreevy, unpublished data). Horses are being confused on a very regular basis and as a result become unusable or, worse, downright dangerous.

This line of enquiry may also inform aspects of the ethical debate around negative reinforcement protocols per se. We plan to use analgesics to establish the role of discomfort in equitation and this will allow us, for the first time, to investigate the mechanisms that enable operant conditioned cues in equitation to work in relatively naïve horses. It is generally accepted that signals given to advanced horses are elegant in their subtlety (Loch, 1977; Sivewright, 1984; McGreevy and McLean, 2005). However, this process has never been studied empirically. By plotting the emergence of the subtle signals given to horses as they progress through training, we will be able to detect the transition between operant and classical conditioning.

Once we can distinguish between operant and classically conditioned cues, we will have all the mechanistic data that explain human–horse interactions in the context of the ridden horse. This will allow conceptual investigations of the unique characteristics of elite horses and riders (including talent, flair and intuition) that transcend scientific analysis. Although the elite riders will always be those who learn the fastest and get the best from their horses with a minimum of apparent effort, the use of the mechanistic data from the studies of the horse–rider interface will be invaluable from an educational perspective, since it will allow novice riders to mimic elite riders and catalyse their ascendance from novice to advanced horses.

By measuring the pressures and weight distribution of riders and saddles on the horse's back while in motion, we will also be able to relate lameness and performance problems to asymmetry (McGreevy and Rogers, 2005). An additional welfare benefit is that we will be able to measure the thresholds of tolerance of flexion and hyperflexion in naïve horses and trained horses from a variety of disciplines. This will greatly inform the welfare debate surrounding hyperflexion.

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 that occur in 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 FEI in determining what practices and interventions are acceptable on welfare grounds. Currently, devices such as whips and spurs are used regularly by some trainers. Indeed, at elite levels, spurs and double bridles (which are more severe in their action than regular, single bits) are mandatory. The right instrumentation and titration of the pain involved in the use of various gadgets will help to define the correct and humane use of such devices. Third, and perhaps most important, the current project educates current and aspiring riders in how best to apply the core principles of learning theory.

By reducing confusion among riders and, therefore, conflict in horses, equitation science will make horse-riding safer (McGreevy and McLean, 2005; Waran et al., 2002) and reduce behavioural wastage (Hayek et al., 2005). It will also form a foundation for continuing advances in training practices and the design of equipment. The potential benefits of horse-specific studies include a better understanding of the way in which we train other species that are ridden or used for draught work.

9. Conclusions

One of the abiding obstacles to effective training is poor understanding of learning theory by riders. If novice riders could use the principles of operant conditioning to avoid giving conflicting signals as they learned to balance, many riding-school horses would feel the immediate benefit. What we have learned from the evolution of studies of human behaviour should ensure that, in its infancy, equitation science can take the best possible route to maturity. The central point to remember is that equitation science measures only the measurable. The intense and undoubted rapport we share with our horses will continue to complement our understanding of effective approaches to training and will never be threatened by scientific findings. Far from objectifying the horse in any way, equitation science can identify effective, irrelevant and abusive training techniques.

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