Applied Animal Behaviour Science 190 (2017) 18–27

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

The application of learning theory in horse training

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ARTICLE INFO

Article history:
Available online 27 February 2017

Keywords:
Behaviour
Conflict theory
Desensitisation
Habituation
Reinforcement
Stress

ABSTRACT

The millennia-old practices of horse training markedly predate and thus were isolated from the mid-twentieth century revelation of animal learning processes. From this standpoint, the progress made in the application and understanding of learning theory in horse training is reviewed including a discussion of how learning processes are employed or otherwise under-utilised in training. This review describes the process of habituation and the most commonly applied desensitisation techniques (systematic desensitisation, counter-conditioning, overshadowing, response prevention) and propose two additional techniques (approach conditioning and stimulus blending). The salience of different types of cues, the interaction of operant and classical conditioning and the impact of stress are also discussed. This paper also exposes the inflexibility and occasional inadequacy of the terminology of learning theory when translated from the research laboratory situation to the practical setting in horse training. While learning theory provides a rich toolbox for riders and trainers, the training process is subject to the simultaneous use of multiple learning processes. In addition, learning/behavioural outcomes and trained responses are not just the result of simple stimulus-response based interactions but are further shaped by arousal, affective and attachment states. More research is needed in these areas. For the field of equitation science to progress and to improve clarity and use of learning processes, changes in nomenclature are required. In particular, the use of the terms 'positive' and 'negative' as descriptive labels in both reinforcement and punishment modalities are unacceptably misleading for everyday use. These labels inhibit the understanding and recognition of the learning processes that these terms supposedly represent, yet the learning processes they describe are vital for horse riders, handlers and trainers to understand. We therefore propose that these labels should be re-labelled more appropriately as 'addition' or 'subtraction' reinforcement/punishment. This would enlighten trainers on the correct application of learning theory, and safety and welfare benefits for people and horses would follow. Finally it is also proposed that the term 'conflict theory' be taken up in equitation science to facilitate diagnosis of training-related behaviour disorders and thus enable the emergence of improved training practices. The optimal use of learning theory should be established as a fundamental principle in equestrian education.

1. Introduction to learning theory

Horses have been trained for over 4 millennia (Levine, 2005) and riding began in the steppe regions where carts were difficult to maneuver (Kelekna, 2009). Horse riding was mostly for the purposes of transport, war and agriculture, however in the Middle Ages it became a noble pursuit, practiced in the Royal courts as entertainment (Grisone, 1550). Although there is a putative connection between the use of the horse for war and its use for displays of various movements in the Royal courts of Europe, this appears tenuous as horses that were trained in what is now known as classical dressage were thought to be unreliable when overwhelmed by the challenges of battle (Anthony, 2007). The most effective integration of classical dressage into cavalry training came in the eighteenth century in the Prussian cavalry instituted by Seidlitz whose work in making the warhorse more obedient contributed to Prussian victories up to 1800 (Anthony, 2007).

The science of animal learning processes however is relatively recent, emerging in the mid-20th Century. It is therefore not surprising that horse training practices, steeped in tradition, were not informed by these developments. Since then there has been a wide interest in animal learning and cognition in many species. The studies have been driven largely by the fascination of animal intelligence, enhanced by occasional reports of apparently sophis-

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http://dx.doi.org/10.1016/j.applanim.2017.02.020
0168-1591/

ticated intellectual skills displayed by animals. For instance, more than 100 years ago, the horse 'Clever Hans' was assumed to be able to count (Harris, 2010), which of course was later disproved, but – more relevant to equine species – Hans turned out to be extremely adept at classical conditioning: learning subtle and unintentional human body postures that preceded food rewards.

Learning can be defined as a process of adaptive changes in individual behaviour as a result of experience (Thorpe, 1963) and thorough studies of learning abilities and mechanisms of the mammalian and avian brain have led to the development of learning theory. Learning theory describes an approach that explains changes in behaviour produced by mental and/or physical practice, as opposed to other factors, e.g., physiological development. Learning theory includes non-associative learning (habituation and sensitization) and associative learning (classical and operant conditioning). These learning processes account for the entire gamut of behaviour change based on experience in all animal species including horses. The use of learning theory has begun to revolutionize the methods used to train certain classes of animals (e.g. sea mammals used in oceanaria and dogs), and in the early twenty-first century, horse training literature began to be informed about the application of learning theory (e.g. McGreevy, 2007; McGreevy and McLean, 2007, 2010; McLean, 2005a, 2008). Like other mammals, horses learn in straightforward and predictable ways, which is why humans can train and interact so effectively with them. Understanding and applying learning theory can help horse trainers work with their horses in a way that enables and expedites learning yet maintains the horse's welfare as paramount.

A regular feature of this review concerns the observation that learning theory has mostly been developed from experiments on laboratory animals, notably rats and pigeons. Observation of the ridden horse provides a window into the processes of negative reinforcement, and escape and avoidance learning within a practical context. Negative reinforcement in best practice horse training requires the training of responses and ultimately variations in response that are congruent with variations in pressure signals of reins, legs, seat and rider posture in order to facilitate speed, stride length, direction, gait control and posture. It is likely that when signal strengths of certain signals (e.g. the bit and the spur) exceed a particular pressure threshold that there are welfare implications for horses.

There is still much more research to be conducted on equine cognition, particularly in the areas of prospective memory. While the majority of brain structures in horses are human analogues, the same cannot be said for the prefrontal cortex which is considerably more extensive and complex in humans. The ability to prolong memory traces in humans is enabled by our specialised prefrontal cortex and enables humans to visualize events forward and backward, known as prospective memory (Korziol et al., 2011). The extent of this faculty is therefore a significant cognitive difference between the two species. Attributing human-like recall abilities to horses encourages the unproven and detrimental belief that horses are aware of past behaviours and therefore that they are culpable. This assumption directly facilitates the use of punishment based training systems as well as the use of delayed rewards. These have a significant impact on the safety of horse/human interactions and horse welfare.

The relative salience of aural, tactile and visual cues to horses remains unknown. In other species there is some literature on the impact of different types of stimuli as conditioned stimuli (CS). The best known work, pioneered by Garcia and Koelling (1966), showed that rats can learn the association between a taste and illness (nausea) very quickly, but learn much less readily about exteroceptive cues (visual and auditory) that predict nausea. Conversely, rats can learn quickly about the relationship between the same exteroceptive cues and pain (a brief shock), but learn very little about a taste-shock association. Therefore, at least some animals have innate predispositions to learn certain CS-unconditioned stimulus (US) associations more readily than other associations. For rats, evolution is likely to have favoured learning a taste-illness association because of the dangers of a diverse foraging lifestyle where taste would be more relevant in that context than visual or auditory stimuli. Conversely, tastes are less likely to predict pain, and again evolution may have selected for the reverse bias in associability. This is an important area for future research in equitation science. It is vital to consider the horse's adaptations as an open grassland forager and social prey animal, in understanding its evolved stimulus preferences.

The interaction of classical and operant conditioning is particularly relevant in equitation. Riders may introduce a seat cue that precedes rein tension to classically condition a deceleration response or they may apply the two cues concurrently. However, the phenomenon known as *blocking* may occur if one CS (e.g. light rein cue) has already been associated with an event. If another stimulus (e.g. seat cue) is introduced, the animal may fail to learn the new association because learning has been blocked by the presence of the first CS. Concurrent application of cues may also result in the situation where cues only work in tandem with each other: When stimulated on their own they do not produce a response. However anecdotal evidence suggests that this rarely occurs in equitation with the simultaneous use of rein and seat aids, although some attenuation of cues may occur. How is this possible? In research, studies have generally been simplistic in that the CS's are typically both of similar associative strength or at least they are formerly benign signals (such as a light and a tone). On the other hand in horse training, the cues have very different origins. The seat can be considered mildly negatively reinforcing (because the pressure it can apply is limited) whereas bit pressure via the reins can be strongly aversive. It would be of interest to explore the relative strengths of association of these cues, their development, competition and their blocking characteristics or otherwise. This is particularly salient because riders often report that rein and seat signals are applied simultaneously.

The characteristics of the learning environment also require further research. Calmness has long been emphasised as an important element in horse training not only for the welfare of the horse (Grisone, 1550; de la Guérinière 1733; German National Equestrian Federation, 1997), but also for the safety of riders and handlers, because a frightened horse poses a significant danger to humans. Indeed, one of the most common cause of human accidents associated with horses is due to their fear reactions, (Keeling et al., 1999; Thomas et al., 2006). Indeed, horse riding and handling accidents are relatively common: the serious injury rate is one for every 350 h of contact, which is 20 times greater than motor cycling (Ceroni, 2007). Learning, however requires slightly elevated arousal levels beyond which learning is reduced. This has been described as the inverted-U relationship between learning and arousal as reflected in the Yerkes-Dodson Law (Yerkes and Dodson, 1908; Mendl, 1999). The optimal arousal level for a specific task is related to how challenging the task is for the individual; simpler tasks can be performed successfully even at high arousal levels whereas challenging tasks are typically performed more successfully at lower arousal levels (Mair et al., 2011; Starling et al., 2013). Thus there is a fine line between raised stress levels sufficient for learning and responding compared to higher stress levels that inhibit learning, and the skill of training using a paradigm of negative reinforcement involves applying this pressure gradient only to the level of optimal learning. Awareness and identification of this threshold is a critical area of study in equitation science and central to this are two major components of psychological stressors (Weiss, 1972; Bassett and Buchanan-Smith, 2007):

- predictability (in horse training classical conditioning provides cues that predict certain events)
- controllability (where the animal is able to manage its behavioural outcome to achieve allostasis, i.e. give a suitable response to lower a drive such as hunger or reduction of somatic pressure)

Over the last few decades there has been a significant ground swell of interest, emotion and enthusiasm for ethical and putative horse-centered approaches to horse training with the rise of animal rights and animal welfare groups as well as popular contemporary training dogmas. Importantly, as a result of the availability and accessibility of imagery through modern media, horse sports and training in general are being brought sharply into public view. As a result, there has been a rise in what are commonly termed positive training methods such as the growing interest in not only incorporating positive reinforcement (including secondary positive reinforcement) into training regimes, but attempting to eliminate the use of aversive stimuli altogether. Similarly, there has been considerable discussion on the use of aversive stimuli such as bits, spurs and whips in horse training resulting in the growing use of bitless bridles (Cook, 2003; Cook and Strasser, 2003), and relabeling of some aversive stimuli to, for example 'carrot sticks' (Parelli, 2003).

This paper reviews the progress made in the last few decades and the various obstacles that have arisen owing to the popularity of understanding and applying learning theory to horse training and the various directions and pitfalls that have arisen through the course of this rapid emergence.

2. Learning theory in practice

2.1. Non-associative learning

Habituation describes the progressive decrease of the amplitude or frequency of a response to repeated sensory stimulation that is not caused by sensory receptor adaptation or motor fatigue (Rankin et al., 2009; Schmid et al., 2015). Animals are frequently bombarded with stimuli from the environment and habituation has evolved to discern which stimuli are important and which can be ignored; it can therefore be argued that habituation is one of the most fundamental learning processes that allows animals to adapt to dynamic environments. Habituation is regarded as a prerequisite for all other types of learning, because it allows animals to filter out innocuous stimuli and focus selectively on important stimuli (Rankin et al., 2009; Schmid et al., 2015). Habituation tends to be relatively long-lasting and 'stimulus-specific', i.e. the animal remains responsive to other stimuli. In the training domain, horses habituate to diverse and dynamic aspects of the physical and social environment, and to the paraphernalia used in training such as saddlery and also to having humans astride. Perhaps the most difficult aspect of foundation training is habituating to the continuous pressure of the girth, which is aversive to some horses (McGreevy and McLean, 2010).

Sensitisation is the opposite process of habituation, whereby response intensity is increased. If an individual experiences a series of arousing attractive or aversive stimuli, sensitisation describes the likelihood that it will respond more quickly or with more intensity to this or another stimulus that is presented soon after. Sensitisation is often characterised by response enhancement to a whole class of stimuli in addition to the one that is repeated. For example, pigeons that are exposed to painful stimuli (small electric shocks) become more responsive to loud noise (Siqueira et al., 2005). Similar situations may arise in horse training, where horses exposed to painful or fearful stimuli show increased responsiveness to both the original and other arousing stimuli. For example a horse that has shied (swerved sideways) from a dog that suddenly jumped out from the bushes may learn to shy repeatedly at the smallest threshold stimulus in similar circumstances thereafter.

Dishabituation, on the other hand, is the recovery of a habituated response. It describes the situation where the presentation of a stimulus, which is different to the one the animal has habituated to, results in an increase in the decremented response to the original stimulus (Rankin et al., 2009). Although a strong stimulus has traditionally been used to produce dishabituation, there is some discussion in the literature that any different stimulus can serve to dishabituate a response. For example, Marcus et al. (1988) studied the defensive gill and siphon withdrawal response in the marine snail *Aplysia*, and found that a touch or a weak electric shock produced better dishabituation than did a strong shock. There is some discussion in the literature as to whether dishabituation is caused by sensitisation, or by a disruption of the habituation process (Steiner and Barry, 2014; Schmid et al., 2015). Similarly in horse training, dishabituation can explain the return of a previously decremented response. In the practical situation, however, it can be difficult or impossible to ascribe the return of a behavioural response to a specific process, and this reflects the disjunction between theory and practice.

2.1.1. Desensitisation techniques

Habituation refers to the process of response decrement whereas desensitisation techniques refer to the methods applied to achieve habituation. Horses are innately neophobic (fearful of the unfamiliar) and often find the characteristics of various stimuli aversive: magnitude; novelty; proximity; sudden appearance or occurrence; movement, especially erratic (therefore hard to identify even if familiar); or advancing towards the horse (e.g. Christensen et al., 2005, 2008, 2011; Lansade et al., 2007, 2008; Christensen, 2013). The behavioural response is characterised by avoidance; ranging from a slight increase in distance to the fear object to a rapid and powerful flight response. Avoidance is usually followed by alertness towards the stimulus and finally by investigative behaviour. The duration of the different phases varies from seconds to minutes and depends partly on the stimulus characteristics and partly on individual differences in fearfulness and curiosity (e.g. Lansade et al., 2008; Christensen et al., 2011; Marsbøll and Christensen, 2015). This natural investigative behaviour can be exploited during desensitisation training, where it may be beneficial to allow the horse to keep its distance to the object of its fear until it shows a natural motivation to approach. Another important point to remember during training is that avoidance/escape behaviour is reinforced by increased distance to the aversive stimulus, which can lead to the intensification of the undesired behaviour.

Four main desensitisation techniques can be derived from the applied animal behaviour literature: systematic desensitisation, counter-conditioning, overshadowing and response prevention (McLean, 2008; Mills et al., 2010). Given the neophobic nature of horses and the importance and implications of horses' fear reactions for human safety, surprisingly few studies have explored habituation to novel stimuli and the subsequent imperative of developing desensitisation techniques for horses (Christensen, 2006, 2013; Górecka et al., 2007; Hartmann et al., 2011; Leiner and Fendt, 2011). Based on a practical application of these methodologies, we propose some additional techniques (approach conditioning and stimulus blending) following an analysis of the more commonly used desensitisation techniques:

(1) Systematic desensitisation

The term refers to a gradual habituation to an arousing stimulus. Systematic desensitisation is a commonly used behaviour modification technique for the alleviation of behaviour problems caused by inappropriate arousal. The process in animals is an adaptation of a psychotherapy technique for humans (Wolpe and Lazarus, 1969). In a controlled situation, the animal is exposed to low levels of the arousing stimulus according to an increasing gradient, and rewarded when it remains relaxed or shows an appropriate response. An increase in the level of the stimulus is not made until the animal reliably fails to react to the previous level. In this way the technique aims to raise the threshold for a response. For example, police horses are often systematically desensitised to noise, smoke, flags, rapidly advancing people and objects.

(2) Counter-conditioning (response substitution)

The term refers to conditioning of an incompatible response to the undesired one, so that only the desired reaction occurs. The term literally means training an animal to show a behaviour which is counter to the one the trainer wishes to eliminate. The technique is widely used in combination with systematic desensitisation. By ensuring that the preferred behaviour is more rewarding, the animal learns to perform the new behaviour when exposed to the problematic stimulus. In practice, the animal is presented with the problem stimulus simultaneously with a stimulus (e.g. food) that inherently arouses an alternative response, which is counter to the underlying problem behaviour. Eventually the animal should learn that the problem stimulus is now a predictor of a positively reinforced (rather than aversive) event (Taylor, 2010).

(3) Overshadowing

The term describes the phenomenon whereby habituation to the least salient stimulus takes place when two or more stimuli that are competing for the same response are presented concurrently (McLean, 2008; Mills et al., 2010). In the practical setting of horse training, overshadowing provides an effective method of desensitising horses to aversive stimuli such as clippers, needles or other invasive procedures. These aversive and invasive procedures frequently elicit a withdrawal response in the horse. Similarly, when a horse learns to respond to e.g. lead rein signals of forward or reverse, they are initially acquired because they too produce a withdrawal response, which through the refinement of further training, diminish to light lead rein cues. Therefore outcompeting the withdrawal response elicited by the clippers through the use of the lead rein cues of forward and reverse can be a useful overshadowing protocol. The horse must therefore be reliably trained to step forward and back from lead rein cues via operant conditioning. Overshadowing differs from systematic desensitisation and counter-conditioning principally because of the use of mobility responses.

(4) Response prevention (Flooding)

The method consists of restraining the animal to remain in the situation which it fears while avoidance responses are prevented, until the animal's apparent resistance ceases. In contrast to systematic desensitisation, counter-conditioning and overshadowing, in response prevention there is no gradual habituation to the aversive stimulus: instead the horse is forced to endure the aversive stimulus at full intensity, usually for a protracted period of time. The method was originally developed to treat human phobias and was claimed to be less time-consuming and more effective than systematic desensitisation (Baum, 1970; Hussain, 1971). The aim of the procedure is to enable the individual to either habituate or learn an alternative appropriate response to the stimulus through the removal of reinforcement for the fearful behaviour (Hussain, 1971). For elimination of the response to occur it is important that the stimulus is not withdrawn before cessation of the response occurs; if the animal remains in a state of heightened arousal and the stimulus is withdrawn, the response may be negatively reinforced and consequently strengthened. Such incorrect implementation of flooding is one of the significant risks of the procedure. Another cause of concern is that, if an animal is being restrained and exposed to uncontrollable aversion, learned helplessness may result. In this case, the animal will be apathetic and may superficially appear to tolerate the aversive stimulus, but its welfare is seriously compromised.

As also noted above, these techniques can be highly overlapping and can be used concurrently, e.g. systematic desensitisation can be advantageously used in combination with the other techniques. For example, systematic desensitisation, overshadowing and counter-conditioning may be used to enable a horse to habituate to various invasive procedures. Owing to the varying temperaments of horses, different techniques may suit individual horses. In addition, variations of elements from the above techniques can form the basis for additional desensitisation techniques based on learning theory and equine ethology, which appear highly relevant in horse training:

a) **Approach conditioning**. This method exploits the natural tendency of horses to explore and approach unknown objects, in combination with systematic desensitisation. The horse is stimulated by the rider or handler to approach the object of its fear, which is retreating as the horse approaches, i.e. the approach behaviour is negatively reinforced. The horse may then be signaled to stop before it reaches its fear threshold, so that the object retreats even further. The horse is then signaled to catch up. As soon as the horse slows its approach it is deliberately stopped and this is repeated until the horse comes as close as possible to the object. The method has been successfully applied to horses that are afraid of tractors and diggers, motorbikes and trams.
b) **Stimulus blending**. The method uses a closely resembling stimulus to which the horse has already habituated to systematically desensitise the horse to the original fear-inducing stimulus. The fear-inducing stimulus is applied gradually and concurrently at the lowest threshold of fear with the known, non-fear-inducing stimulus, and then systematically increased in intensity. For example a horse may be afraid of aerosol sprays but unafraid of being hosed. The aural and tactile characteristics of the aversive stimulus (e.g. aerosol) are gradually mixed with the habituated one (e.g. the hose) making identification of the formerly aversive one difficult and perceptually different. The old benign stimulus can then be diminished and finally terminated after which the horse will show habituation also to the new stimulus.

Practical examples of the different desensitisation techniques are given in Table 1.

2.1.2. Habituation to aversive stimuli

A specific situation in horse training is the habituation to bit and leg pressure, which is obviously undesired, and the terms 'heavy mouth' and 'lazy sides' have been used to describe horses which show a diminished response to rein and leg signals. Unfortunately, this habituation frequently occurs because the horse has been exposed to relentlessly higher levels of pressure than intended and has not been negatively reinforced (i.e. pressure removed) for the appropriate behaviour. This inability to control the aversive stimulus may lead to certain levels of learned helplessness (Seligman, 1972), which negatively affects horse welfare (Hall et al., 2008; McGreevy and McLean, 2010). A 'heavy mouth' may result from the horse finding the leg/spur/whip more aversive, i.e. the horse habituates to the least aversive stimulus. While habituation to mildly aversive stimuli may not affect the animal's wellbeing (e.g. 'contact'), there is likely to be a point on the pain continuum where

Table 1
Examples of desensitisation techniques.

Technique	Practical example
Systematic desensitisation	Example: the horse is fearful of aerosols. As a first step a handler brings an aerosol close to the horse and strokes it on the body with the bottle (no spraying). This is to habituate the horse to the visual characteristics of the aversive stimulus. When the horse shows no avoidance responses, a next step is to stand some meters from the horse and spray in the opposite direction, preferably with water, i.e. a fluid with no smell. This is to gradually habituate the horse to the aural characteristics of the aversive stimulus. The handler gradually steps closer to the horse, and when the horse shows no responses to the handler standing next to it and spraying in the other direction, the handler can gradually spray closer to the horse. Before spraying directly on the horse's coat, the handler should stroke the horse with a hand and spray gently on the hand. At all stages, it is important to ensure that the horse is only rewarded for appropriate responses, i.e. the aerosol should be removed or spraying terminated when the horse stands still. Positive reinforcement (e.g. food, wither scratching) can be used as an additional reinforcer for appropriate behaviour.
Counter-conditioning	Example: the horse is fearful of objects on the ground. When the horse discovers e.g. a piece of plastic on the ground it shows a strong avoidance response. A practical solution in terms of counter-conditioning could be to place a highly appreciated food on the plastic, i.e. a stimulus that elicits desired responses (approach and eating) which is counter to the unwanted avoidance response (Christensen et al., 2005). If the horse is frequently presented with objects on the ground that all contain food, the horse is likely to learn that the original problem stimuli are now a predictor of a positive event.
Overshadowing	Example: the horse is needle-shy. When the horse sees the person approaching with the syringe it becomes hyper-reactive and pulls against the handler's lead rein tension in its attempts to escape. The needle pricking the horse's skin also induces a severe flight response. The solution in terms of overshadowing involves the horse being trained to step back and forward from lead rein tension so that the horse's reaction is elicited from the lightest of lead rein cues. Next the person with the syringe approaches the horse with the syringe and as soon as the horse displays even the smallest of fear responses, the person with the syringe stops and remains immobile so that the distance between the horse and the syringe stays constant. The horse is then signalled to step back one step and perhaps then forward a step. Initially the response is delayed and the light cue is ignored because the horse's attentional mechanisms are overshadowed by the syringe so the handler then increases the motivational pressure of the lead rein so that in a few repetitions the horse is now responding to light signals of the lead rein. The horse's reaction to the syringe has, at this distance, decreased. The syringe is now brought closer to the horse and as soon as the horse shows the slightest fear reaction, the process is repeated. This process continues until the horse's response to the syringe has diminished. Positive reinforcement at each increment enhances the acquisition of the lowered arousal. The lead rein signals and their associated mobility responses soon achieve stimulus control of the horse's locomotion and thus overtake the syringe for salience. The less salient stimulus either no longer elicits or greatly diminishes withdrawal from the original, more salient stimulus. The procedure however is most successful if the process is begun at the lowest levels of arousal (McLean, 2008).
Response prevention	Example: the horse is afraid of objects that are brought close to its body. Using the response prevention/flooding technique, the horse may be tethered and exposed to the full blown version of the aversive stimulus, e.g. relentless flailing of a sack or other material until it discovers that escape is impossible and it eventually calms down. This maximal exposure therapy is supposed to make the horse more accepting of various paraphernalia that it will encounter in training.
Approach conditioning	Example: the horse is fearful of tractors, motor bikes or trams and attempts to escape, in order to lower its fear. However if the process is reversed whereby the horse approaches the retreating machine, this can have the opposite effect: its fear is lowered because the machine itself escapes. This technique has been used in training police horses. In best practice, when the horse closes in on the machine it is stopped, thus allowing the machine to increase its distance from the horse. The horse is then stimulated to approach again and each time it draws closer to the machine before it is stopped. Stopping the horse apparently increases its motivation to approach. This is continued until the horse actually makes contact with and investigates the machine.
Stimulus blending	Example: the horse is fearful of aerosols. In this technique, a stimulus to which the horse has already habituated is used to blend with the problem stimulus. If the horse is used to hosing on its body, the aerosol is introduced during hosing and on the hosed patches of skin. The sound and feeling of the usual water on the horse's body will blend with the novel sound and tactile feeling of the aerosol, making it less distinct. The hosing can then be terminated while the spraying continues.

habituation may escalate into learned helplessness (McGreevy and McLean, 2010). For example, the girth around the horse's thorax presents an aversive experience for the ridden horse that may manifest as habituation, however the actual perceived experience by the horse remains unknown.

In European horse sports, the concept of contact provides a conundrum for riders, trainers and horses alike. Both rein and leg contact are typically regarded as neutral stimuli (McGreevy and McLean, 2010). Rein and leg pressures above a certain threshold are intended to be motivators for acceleration, deceleration and alterations in direction. Clearly a most perplexing aspect of equitation for both horse and rider is the pressure gradient – what pressures are to be habituated to ('contact') and what pressures are intended to be responded to? The chronic fluctuation of this threshold boundary is likely the source of some confusion as it is unprecedented in nature.

2.2. Associative learning

2.2.1. Classical conditioning

Classical conditioning was one of the first concepts of learning to be described (Pavlov, 1927) and can be observed in the majority of phyla. Classical conditioning is simply the formation of an association between two stimuli. For example, the animal is presented with a neutral stimulus (e.g. a visual signal) and this is followed by a biologically important stimulus (e.g. an aversive stimulus such as pain or a pleasant stimulus such as food or freedom). The initial neutral stimulus comes to evoke a response as a consequence of being associated with the intrinsically important unconditioned stimulus, US. The most efficient uptake of classical conditioning occurs when the novel stimulus is presented prior to the biologically important stimulus. Classical conditioning has evolved to maximise an animal's efficiency in exploiting its ecological niche where neutral stimuli that regularly occur before significant aversive or appetitive stimuli come to reliably predict them. In horse training, classical conditioning plays an important role; both intentionally through the pairing of subtle tactile, visual or auditory cues and learned responses and unintentionally through associations between the myriad external stimuli of which the human may be completely unaware. The 'Clever Hans' phenomenon illustrates the horse's remarkable abilities in classical conditioning and serves to remind us that horses may learn things other than what is intended.

2.2.2. Operant conditioning

Operant Conditioning, also known as Instrumental learning, is the major learning process involved in horse training and involves the variable effects of adding or subtracting wanted or unwanted stimuli to increase or decrease the likelihood of a response. Behavioural scientists typically refer to four quadrants that arise

Table 2
The quadrants of reinforcement and punishment.

	Reinforcement *Increasing the likelihood of a behaviour*	Punishment *Decreasing the likelihood of a behaviour*
Negative (Subtraction)	The removal of an aversive stimulus to reward a desired response Example: Rein tension is applied until the horse stops and the removal of the tension rewards the correct response.	The removal of a desired stimulus to punish an undesired response Example: The horse tries to take food from the handler but food is withheld until the behaviour ceases.
Positive (Addition)	The addition of a pleasant stimulus to reward a desired response Example: The horse approaches when called for and receives a carrot to reward the response.	The addition of an aversive stimulus to punish an undesired response Example: The horse bites and receives a slap on the muzzle.

from the interaction of these variables when identifying the nature of learned responses (Table 2).

The characteristics of stimuli typically used in horse training are principally tactile. Horse handlers and riders use pressure of the head collar or bridle respectively to elicit and reinforce, via negative reinforcement, decelerating and turning responses. Acceleration responses are also negatively reinforced in-hand with head collar pressure or the rider's leg pressure under-saddle. In optimal training, the light aid precedes any period of stronger pressure so that, through classical conditioning, the horse learns to respond from light versions of pressure for acceleration, deceleration and alterations of direction. Voice cues, body postural cues and occasionally visual cues are also installed via classical conditioning when horses have learned to respond (McGreevy and McLean, 2010).

Positive reinforcement has typically been poorly administered in horse training owing to anthropomorphic belief systems and overestimation of equine cognitive abilities. For example, horse people have commonly praised their horses (e.g. saying 'Good Boy') as if this action is reinforcing, whereas in fact it is not, unless paired with a primary positive reinforcer. In addition horse people commonly believe that patting horses via neck slapping is rewarding for the horse. The recent work of Thorbergson et al. (2015) has shown that wither scratching is more rewarding than patting. Similarly, Hancock et al. (2014) found that wither scratching resulted in affiliative behaviour (e.g. grooming), whereas patting resulted in acceleration in ridden horses (possibly because of its similarity to positive punishment or because acceleration is inadvertently negatively reinforced). Unsurprisingly, the use of positive reinforcement has seen a dramatic rise in popularity in horse training in the last few decades, particularly in the format of secondary reinforcement with the introduction of 'clicker training' in the late 1990's (Kurland, 1999). Clicker training describes the use of secondary positive reinforcement using a specific click sound that emanates from a hand held device. Once the association between the sound of the clicker and a primary positive reinforcer (typically a small food item) has been achieved via classical conditioning, the method can be used to train horses to perform a range of exercises from basic responses in-hand and under-saddle to trailer loading (Kurland, 1999; Hendriksen et al., 2011).

More recently it has been observed that because heart rates can be lowered by stroking horses on the neck (Normando et al., 2003), this region can also be used as a site of primary reinforcement and may be preceded by a secondary reinforcer such as voice or clicker. It has been proposed that as with the dog-human relationship, which is underpinned by attachment features, similar attachment characteristics most likely hold true for horse-human relationships (McLean et al., 2013). Early research has shown great promise in terms of convenience and outcome for these secondary reinforcement pairings with tactile stimuli to be researched and utilised in horse training (McGreevy and McLean, 2010; Hancock et al., 2014; Thorbergson et al., 2015). Nonetheless, it is important to recognise that, owing to the danger of horse-human interactions, caution must be exercised in advocating a predominantly positive reinforcement based approach to training under-saddle because reliability of solely positively reinforced deceleration responses, especially in challenging environments, are yet to be confirmed. For example, a frightened horse may be less motivated to respond to a positively reinforced deceleration cue (e.g. a voice command) than to a negatively reinforced stimulus which increases in intensity until the horse responds.

Negative reinforcement characteristically involves the use of aversive stimuli. It is virtually impossible to avoid aversive stimuli in horse training since novel stimuli can be initially aversive (Misslin and Ropartz, 1981). It is important to remember that while the word 'aversive' denotes something that an animal wants to avoid, it is not necessarily overly frightening or painful (Innes and McBride, 2008), but rather may cause the horse discomfort. Nonetheless some authors have cautioned against exposing animals to aversive stimuli (Reinhardt, 1992; Laule et al., 2003). Because of the ubiquitousness of negative reinforcement use in horse training, riding and handling, it is critical that horse people recognise that negative reinforcement is implicit whenever tactile controlling devices are used, such as reins, legs, whips, spurs and that they learn to use it optimally. Horses are extremely adept in responding to negative reinforcement, because it reflects how they learn under natural conditions, e.g. when a conspecific displaces another individual. Usually the displacement will start as a mild cue which is increased in intensity until a response is achieved. In the horse – human situation, they can learn, via negative reinforcement, to remove a human hand from their head (known as head-shyness), to remove people from their space by displacing them, to remove the farrier by kicking out, to avoid being mounted by stepping away and to remove people through threat displays (McGreevy and McLean, 2010). For this reason, many trainers recognise the importance of avoiding being displaced by a horse's behaviour when in contact with them (Parelli, 2003).

Positive punishment is defined as the addition of an aversive stimulus to lower the frequency of a behaviour. Positive punishment is common in equestrian culture for behaviours such as biting and kicking or refusing to jump obstacles. To be effective in learning, the punishing stimulus must be contingent with the behaviour it is intended to suppress. Positive punishment is however cautioned because of its well-documented side-effects such as:

a) Lowered motivation to trial new behaviours (Haag et al., 1980)
b) Habituating the animal to punishing stimuli leading to learned helplessness (McGreevy and McLean, 2009)
c) Fear reactions may be learned on one trial and are inerasable (Le Doux, 1994)
d) Deleterious emotional changes
e) Negative associations with the punisher (Mills, 1998)
f) Learning deficits (Parker et al., 2008)
g) The possibility of PTSD (post-traumatic stress disorder) emerging, resulting in latent aggression (Bradshaw, 2009)

Negative punishment is less common in equestrian culture. If a horse paws when tethered, then walking away from the horse may serve to negatively punish the behaviour. On the other hand, anecdotal reports of riders removing food, water or attention after a poor competition performance occur from time to time, however there are no performance benefits associated with this action and of course there are concerns regarding negative welfare implications.

One of the main issues that arises in relation to the use of learning theory terminology in equitation is that it is common, even in research, to confuse the terms positive and negative with the value judgments of 'bad' for negative and 'good' for positive. For example, training that is deemed good is often referred to as positive training while training that is considered bad and unethical is frequently termed negative training and aversive stimuli are often termed negative stimuli. For example, McBride and Mills (2012) attest that "emotional responses with positive reinforcement differ from negative reinforcement and punishment in that the former are almost entirely positive rather than largely or wholly negative." Given the body of research (as described later in this review) describing some deleterious effects of appetitive reinforcement, it is unreasonable to conclude that positive reinforcement effects are almost wholly positive. In any objective view of learning theory it is important for trainers to remember that animals have maintained abilities in all learning processes for effective exploitation of their biological niches.

Because of the confusion surrounding the terms positive and negative (initially coined in the mathematical connotations of addition and subtraction), it is proposed in this review that the terms positive reinforcement, positive punishment, negative reinforcement and negative punishment are replaced with the following new terms: 'addition reinforcement', 'addition punishment', 'subtraction reinforcement' and 'subtraction punishment'. Adopting this proposal should add significant clarity to learning theory and enable horse trainers (and researchers) to comprehend and utilise it, thus enhancing the welfare of trained animals.

2.2.2.1. Combined reinforcement. Horse riding and training is largely a process of negative reinforcement, however positive reinforcement can be used in conjunction with negative reinforcement, putatively to enhance the reinforcing effects. This combination effect is known as 'combined reinforcement' and this terminology is gaining common parlance amongst researchers. Research has shown that when combined reinforcement is used (both positive and negative reinforcement), the aversive effects of negative reinforcement may be reduced (McKinley, 2004; Warren-Smith and McGreevy, 2007).

As positive reinforcement has become more popular in the training of the ridden horse, it is important to accurately recognise the negative reinforcement components of these under-saddle interactions and therefore to be cautious in attributing results solely to positive reinforcement. Since horses did not evolve to be ridden or led, and since they are motivated to remove even the light touch of an insect, then any discomfort exerted by humans is likely to be significantly inconvenient. Whether negative reinforcement training of horses is augmented by primary or secondary positive reinforcement, the actual mechanism of learning should be termed combined reinforcement. Combined reinforcement has been shown to be useful in many training situations such as with rhesus monkey husbandry and even dolphin management (Stacey et al., 1999). For example, captive dolphins are positively reinforced for accepting veterinary interactions but at the same time they are restrained by a net which negatively reinforces immobility.

While operant conditioning provides a 'toolbox' for trainers, there are other factors that influence the outcome of learning and therefore the learning modality that the trainer might choose. It is vital to remember that horse training is largely dependent on motivation. In the natural environment there may be a number of conflicting motivations and the most salient one will be responded to. This is an important question as far as safety is concerned. While food as a primary reinforcer can achieve a high degree of salience, and may outcompete the motivation for avoidance of aversive stimuli to some extent, it is unlikely to outcompete the motivation for flight response in strongly frightening situations. In this light, one might see that negative reinforcement and positive punishment might out-compete positive reinforcement and negative punishment for salience; however this does not account for the insecurity of the particular animal which may also have an influence on the outcome. For example a well-trained horse trained through positive reinforcement may be less likely to be fearful than one poorly trained in negative reinforcement in certain challenging circumstances. Given the high death and serious injury rates of humans in horse-human interactions, the relative salience of positive, negative and combined reinforcement protocols in challenging situations needs to be explored.

As details of operant and classical conditioning paradigms that explain horse training have been identified, other more esoteric aspects of training have now come under the research spotlight. Recent work has highlighted the importance of various factors that influence learning outcomes such as arousal, affective states (Starling et al., 2013) and attachment (McLean et al., 2013). Highly aroused horses may be differently motivated for food or the removal of aversive stimuli and furthermore, highly aroused states may inhibit learning. Positive and negative affective states may also influence learning. One study showed that although negatively reinforced horses showed more negative emotions during training compared to positively reinforced horses, the former were more optimistic in a judgement bias test (Freymond et al., 2014). In addition, the bond between horses and humans may be explained via attachment theory and this in turn is likely to affect learning outcomes if the animal's attentional mechanisms are directed more toward one person than another (Fureix et al., 2009; Sankey et al., 2010).

The field of equine biomechanics is also rapidly emerging and gives insight into the kinematics of equine locomotion and its characteristics. Because operant and classical conditioning implicitly involve particular biomechanical responses in horses, this field will continue to supply riders and trainers valuable information. Recent work by Maes and Abourachid (2013) implies that it is only during the swing phase of the horse's limbs that pressures and signals can be responded to because the stance phase of limbs is preoccupied by mechanical constraints. Such information directly informs trainers and riders of the precision and timing required for training success. Further work on laterality and the characteristics of the diagonal couplets should provide deeper insights for trainers in coming years.

2.3. Theoretical anomalies

The practical application of learning theory and ethology to equitation science has emphasised the vagaries of the terminology that is currently applied and translated from the research laboratory situation. Dawkins (2005) famously remarked that discrete box thinking is "the tyranny of the discontinuous mind". He was referring to the manmade compartmentalisation of objects or processes that facilitate our understanding of nature but are actually not totally reflective of the natural world. This is a very important point to bear in mind with regard to learning theory. Many tend to view the four quadrants as discrete boxes when in reality there is considerable overlap. As Perone (2003) has shown, negative reinforcement and positive reinforcement can be seen as analogous in terms of the ethological theory of drives and motivations. He poses the question: does the rat press the lever to obtain food (positive reinforcement) or does he press it to remove hunger (negative reinforcement)? In this sense positive and negative reinforcement can be seen as overlapping. In terms of the neural architecture also, the structures of the basal ganglia involved in the reinforcing agents of both aversive and attractive stimuli are analogous (Schmidt, 1998; Kandel et al., 2000). These terms are scientifically useful but not always truly revelatory of the spectrum of natural processes. Hineline (1977) made similar observations regarding the terms escape and avoidance learning. He described these terms as technical rather than descriptive.

Negative reinforcement and positive punishment can also be difficult to distinguish because the definitions concern the outcome (increasing versus decreasing a response). However in some instances, there is overlap and a precise definition is hampered. For example, if a horse makes an undesired stop when it is required to walk forward, the rider immediately applies leg pressure. This may partly punish the stopping behaviour and – if applied correctly – reinforce moving forward again. In addition, negative punishment can be seen to overlap positive reinforcement. For example in cases of positive reinforcement, the trainer is withholding the food and delivering when deemed appropriate so from the horse's point of view, it is negatively punished through its inability to get the food at will and this may account for some documented behaviour issues that are associated with the periodic presentation of appetitive stimuli, such as aggression and ritualistic behaviour (Staddon, 1977; Looney and Cohen, 1982).

Another example of how horse training does not precisely align with textbook learning theory is the rider's seat. Riders use their seat in various directions so that they follow the horse's back kinematics in all gaits as well as speed and line variations. For centuries it has been known that riders can emphasise certain seat movements so that they not only follow the horse's movement but they can also cue various locomotory responses. This is confirmed with the development of seat-pressure sensor pads which show that these seat variations can vary many newtons (De Cocq et al., 2010; Bogisch et al., 2014). Because the rider's seat can implement some range of pressure, this places it in the realm between classical conditioning and negative reinforcement notwithstanding the uncontrolled weight shifts and movements of riders. Seat pressure sensors show variations in seat pressures in each footfall, gait and limb tempo (Bogisch et al., 2014). Variations in seat pressures are utilised as signals in many forms of equitation (McGreevy and McLean 2010). Nevertheless the precise demarcation of what constitutes a pressure compared to a classically conditioned cue is interesting and identifies the order between classical conditioning and negative reinforcement.

2.4. *Welfare-related issues in training*

2.4.1. *Problems with negative reinforcement*

Horse handlers and riders tend to rely heavily on tactile cues delivered by legs, the bit, whips and spurs, which present an array of difficulties. Because it is the removal of the pressure that is the reinforcing agent, the timing of removal is fundamentally salient. There are at least two problems inherent in the use of negative reinforcement in equitation science:

a) The reinforcing attributes of negative reinforcement (the pressure reduction) are not fully understood by riders, trainers and coaches (Warren-Smith and McGreevy, 2006). Riders of all skill levels are often unaware of the way in which they unintentionally negatively reinforce fear or hyper reactive responses such as rearing and shying where the horse is accidently rewarded for the behaviour. The use of aversive stimuli in horse training can only be sustainable within the context of negative reinforcement where the aversive pressure is preceded by a classically conditioned cue (light pressure, voice) and ceases when the correct response is offered.

b) The removal of rein pressure particularly, requires considerable skill in riding the moving horse in the various gaits. Egenvall et al. (2012) showed that the release of rein pressure should be at the onset of the desired behaviour, which may be difficult to recognise or predict. Otherwise, behaviours indicative of conflict or stress increase if release of pressure is late. This highlights a cognitive difference between horses and dogs; Mills (1998) showed that it is possible to be later in reinforcing a dog for a particular behaviour than it is with a horse. Furthermore, the movement of the horse makes it difficult to deliver precise signals. One of the important features of horse riding pedagogy surrounds the maintenance of a stable connection from the rider's hands to the horse's mouth and the maintenance of a stable leg and seat position (the latter moving with the kinematics of the horse's back in each gait, speed and direction).

Errors in negative reinforcement account for major behaviour problems when subtracted pressures are poorly timed and serve to strengthen incorrect responses leading to conflict behaviours and prolonged stress (McLean, 2005b). It is therefore essential that riders are trained in the optimal use of negative reinforcement and it is clear that the correct use of learning theory should be established as a 'first principle' in equestrian coaching.

2.4.2. *Problems with positive reinforcement*

In various animal species locomotory activity such as pacing behaviour (Staddon and Simmelhag, 1971) and wheel-running (Segal, 1969, 1972; Staddon, 1977), as well as aggression (Looney and Cohen, 1982;) and excessive eating and drinking (Falk, 1971) have been induced by the use of food reward schedules. In horses, stereotypies such as weaving and crib-biting have also been shown to be associated with food delivery. While positive reinforcement provides an important and powerful training protocol, it should be remembered that frustration can occur which can not only be distressing to the horse but sometimes dangerous for humans if the frustration escalates to aggression.

Another problem may occur when a signal reliably precedes an appetitive event and as a result the subject's approach responses are conditioned to the signal or the person delivering it, rather than the desired behaviour. This is known as 'sign tracking' where the subject becomes obsessed with the rewarding agent and attempts to remain near it with excessive frequency (Hearst and Jenkins, 1974). It is commonly seen in horses in positive reinforcement schedules that they harass the trainer for food, known as 'mugging'. For this reason, many astute trainers initially teach the horse that food is only delivered when the horse looks away. The use of positive reinforcement has a very important place in training; however trainers should always be mindful of its downfalls. Training is essentially an exploitative event and there is no ubiquitous training modality; all have advantages and pitfalls.

3. Conflict behaviour

The pressures applied to the animal via the halter, bit, rider's legs, spurs and whips may, in many cases, regularly exceed tolerable levels or may not be removed appropriately, leading to hyper-reactive behaviours in attempts to escape the stressor. Therefore the ridden and led horse's experience of discomfort/pain in the form of incorrectly applied negative reinforcement may constitute the greatest amounts of regularly experienced unpredictable and uncontrollable aversive stimuli, leading to conflict behaviours and other indirect behaviour changes. Conflict behaviours have been reported in various equestrian disciplines (Kienapfel et al., 2014; Górecka-Bruzda et al., 2015). On the other hand, the horse world typically labels hyper-reactive behaviours as resistances and evasions, where the horse is commonly seen as benevolent, malevolent and largely culpable (McGreevy and McLean, 2010). Insofar as rehabilitating horses that have been exposed to continuous stressors arising from dysfunctions in the application of negative reinforcement, equestrian culture offers many inappropriate solutions such as treating the issues as losses of respect and submission. There is much research to be done to investigate and determine the importance of exposing the animal to the original aversive stimulus but retraining through reinforcement and shaping of the correct response as well as the potential role here of combined reinforcement. This suggests for example, identifying that certain unwelcome behaviours might result from dysfunctions in the negative reinforcement of acceleration, deceleration or turn responses and thus retraining these may offer the solution for successful rehabilitation (McGreevy and McLean, 2010).

The term conflict theory was proposed by McLean (2010) to highlight the significance of the correct use of negative reinforcement and the deleterious effects of getting it wrong. Of great importance here is the undeniable fact that negative reinforcement relies on a pressure/pain continuum, so when a horse is reinforced for the wrong response or not reinforced at all, the ongoing exposure to painful stimuli must have a detrimental effect on the horse's mental security. Being unable to predict or control relentlessly strong bit pressure or spur assaults on a regular basis must amount to a significant deterioration of a horse's mental stability well before the apparent signs of learned helplessness set in. Therefore, where McBride and Mills (2012) have suggested that poor husbandry may account for the greatest psychological insult, it is suggested in this review that the effect of enduring conflict through errors in principally negative reinforcement should also be given strong consideration. Accordingly, the term 'conflict theory' should become established in the literature of equine retraining and rehabilitation of behaviour disorders that relate to dysfunctions in training protocols.

4. Conclusion

This paper has presented a detailed overview of the application of learning theory to practical horse training including the progress and obstacles that have arisen. One major point is that the practical application of learning theory and ethology to equitation science has emphasised the vagaries of terminology applied and translated from the research laboratory situation. Learning theory supplies a relevant and useful toolbox for trainers and riders, but current laboratory-based definitions do not always fully align with the practical training situation. It is crucial to always be mindful that training is essentially an exploitative event and there is no ubiquitous training modality; all have advantages and pitfalls and outcomes may be influenced by arousal, affective and attachment states. It is therefore essential that riders are trained in the optimal use of reinforcement and it is clear that the correct use of learning theory should be established as a 'first principle' in equestrian coaching.

It is further suggested that the current nomenclature of 'positive' and 'negative' in both reinforcement and punishment modalities are misleading and are more appropriately termed 'addition' or 'subtraction' reinforcement/punishment. Such a change would enlighten trainers on the correct use of learning theory and would yield welfare benefits for horses and animals in general.

Finally it is suggested that the term 'conflict theory' be added to academic literature which would assist diagnoses of training-related behaviour disorders and greatly facilitate the emergence of improved training practices.

Conflict of interest statement

None.

Acknowledgement

Not applicable.

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