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Published in:
Journal of Veterinary Behavior: Clinical Applications and Research

Publication date:
2017

Citation for published version (APA):
Williams, J., & Randle, H. (2017). Is the Expression of Stereotypic Behavior a Performance Limiting Factor in Animals. *Journal of Veterinary Behavior: Clinical Applications and Research*, *20*, 1-10. https://doi.org/10.1016/j.jveb.2017.02.006

Is the Expression of Stereotypic Behavior a Performance Limiting Factor in Animals?

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Abstract

Stereotypical behavior (STB) has been observed in a wide range of species regardless of its classification. Despite extensive research into factors which contribute to the aetiology of STB and/or influence the expression of STB, few studies have explicitly evaluated if relationships exist between stereotypical behavior and performance variables in livestock or equine athletes. This review explores the impact of STBs on animal performance, using the horse and production animals as examples, to establish whether their expression should be viewed as a positive or negative attribute by the animal industry. Emergent themes within livestock and equine research suggest that individuals that exhibit STBs also demonstrate impaired performance attributes which supports the proposal that STB is a negative characteristic. Much of the empirical evidence available suggests negative environmental stressors represent a greater risk to the economic value of animals compared to STB. Within equestrianism, stereotypic performing horses appear to react and learn in a different way to non-stereotypic horses, which, in professional hands, could enhance their performance potential and value, but with amateur riders could reinforce the negative associations that exist. However performance is a complex phenomenon with any species and multiple endogenous and exogenous factors will contribute to success at any one time. Further research is required that explicitly explores how different STBs influence performance variables alongside consideration of the effect of management systems and environmental stressors, and their role in STB expression in both livestock and horses.

Keywords: livestock, equine athlete, performance, production, abnormal behavior.

Highlights

1. Few studies have explored the relationships between stereotypies and performance.

2. Stereotypical behavior reduces the economic value of livestock and equine athletes.

3. Stereotypical behavior appears to negatively impact production factors in livestock.

4. Stereotypies in the professionally managed horse, translate to enhanced performance.

5. More research evaluating the impact of stereotypies on animal performance is needed.

Introduction

Stereotypical behaviour (STB) has been observed in a wide range of species, regardless of their classification, including livestock (eg. Adenkola and Ayo, 2010) and companion animals (dogs (Protopopova et al., 2014), parrots (Cussen and Mench, 2015), rodents (Novak et al., 2015) and horses (Albright et al. 2015)). STBs are also reported in zoo animals including animals housed in managed environments (Padalino et al., 2014; Shepherdson et al., 2013) and those kept in more natural environments such as in extensive game parks (Kiley-Worthington and Randle, 2005). Both groups of these non-domesticated animals require periodic management for health and veterinary treatment or to facilitate human-animal (paying visitor) interaction (Randle and Kiley-Worthington, 2005). STB can occur in a wide range of ages. They have been noted to occur from birth (Latham and Mason, 2008) as has been reported in horses (e.g. Wickens and Houpt 2015) through to old age (Qi et al., 2008), although for some species key risk times have been identified. Mason and Rushen (2008) highlight that horses/foals are at the greatest risk of developing a new form of stereotypic behavior between 15 and 35 weeks, and that emergence of new stereotypies peaks at 40 weeks.

The expression of STBs in non-human animals is often considered a visual indicator of response to environmental (Averos et al., 2014; Hemmings and Hale, 2013; Shepherdson et al. 2013) or psychological stressors (Gottleib et al., 2013; Pomerantz et al., 2012; McBride and Mills, 2012), and can also be influenced by an individual's temperament (Shepherdson et al., 2013) and personality (Ijichi et al., 2013). STBs are thought to indirectly reflect the welfare status of animals by some (e.g., Mason and Rushen, 2008). Gottlieb et al. (2013) warn that individual behavior expression cannot necessarily be used to assess welfare between subjects because some individuals may express high rates of stereotypic behavior due to frustration (in the sense of not being able to gain access to a resource that may be present in the animal's environment), whilst others may do so in order to cope with a suboptimal environment (i.e. an environment that does not provide all the animal's basic requirements).

Many of the associations proposed between STB and negative performance variables, such as increased injury risk in horses that weave or reduced milk yields in cattle, are often not supported by evidence of causal relationships and are largely based on assumption. This review aims to establish the impact of STB on animal performance, using production animals and performance horses as examples, to establish whether the evidence supports if their expression should be viewed as a positive or negative attribute by the animal industry.

Stress

Stereotypical behaviour is often associated with stress in animals. Stress is defined as a *biological response elicited when an individual perceives a threat to its homeostasis and the threat that causes stress is referred to as a stressor* (Moberg, 2000), *the inability of animals to cope with their environment* (Broom and Johnson, 1993) and *unfitness to adapt to the environment and reproduce effectively* (Ewing et al., 1999). Stressors may be positive or eustressors (e.g. hormones which trigger arousal/mating behavior) or negative, known as distressors (e.g. restricted environment which does not facilitate expression of normal behaviors). Stressors are detected by animals' sensory systems to seemingly produce an instantaneous biological response which may or may not be externally observable (von Borell et al., 2007). Biological reactions depend upon the recognition of the features of a stressor and elicit a neurophysiological response which typically comprises cognitive and non-cognitive elements, and include behavioral, autonomic, neuroendocrinological and/or immunological responses (Ichiji et al., 2013). The precise nature and duration of responses to stress depend on the nature of the stressor. A stimulus/situation that is perceived (cognitive element) as a short term threat is characterised by Sympathetic Adrenal Medullary system (SAM) and Central Nervous System (CNS) activity resulting in release of the epinephrine neurotransmitter which prepares the body for action. Conversely, a stimulus/situation that is perceived (cognitive element) as a longer term threat is characterised by responses indicative of long term challenge and the initiation of a coping mechanism. In this situation the hypothalamic–pituitary–adrenocortical (HPA) stress-response system is activated and results in a sustained production of glucocorticoids and mineralocorticoids which are known to enable proactive coping. Once an individual is sufficiently '*stressed'* the HPA-axis becomes more sensitive and more easily triggered by stressors. This is accompanied by high sympathetic reactivity resulting in increased concentrations of catecholamines and elevated parasympathetic reactivity and as a consequence impacts on individual animal performance (von Borell et al., 2007).

Stress is broadly understood by both scientists and lay persons to be characterised by the outcomes or responses given by animals to a series of stressors. Stressors include various aspects of the animal's internal and/or external environment that are compromising homeostasis either physically and/or psychologically, and causing a disruption to what is considered to be 'normal' for that species/breed/individual (Levine, 1985). Furthermore Levine (1985) amongst others emphasized that various measures of an individual suffering from stress are often conflicting, for example behavioral indicators and heart rate variability. Smith et al. (2016) proposed that heart rate correlates with behavioral indices of stress in horses. Although behaviors assumed to be related to stress were seen more frequently when subjects encountered negative stimuli than with positive ones, heart rate responses did not follow the same pattern. It is reasonable to suggest that Moberg's view that 'stress' was better described as a syndrome (a group of symptoms or signs that commonly appear together) in which the visible response/s may represent varying combinations of causes remains wholly applicable. Rightly or wrongly 'stress' is often implicated in the aetiology of STB regardless of the species under examination and is commonly attributed, at least in part, to deficiencies in general husbandry and management (mainly lack of space and direct contact with conspecifics, e.g., Varadharajan et al., 2015) and/or to specific stressors within the environments in which they/individuals are housed (e.g., Shepherdson et al., 2013; Romero et al., 2015). The critical role of stress in the development of resilience in individuals enabling them to cope with the various challenges encountered in the course of daily life, particularly those related to their physical-, and of increased concern, their social-environment is emphasized by Romero et al. (2015). The expression of STB may be one way of coping with such challenges.

Behavior

Stereotypies are often described as abnormal behaviors. Behavior can be broadly described as '*actions or reactions of an individual in response to a particular situation or stimulus*' (for example Grier 1984 cited by King et al., 2012) or more simply 'anything an individual does', although it has also been acknowledged that the term behavior also applies when there is no visible change in behavior, that is, no observable response (Randle, 1995). Although methods of observing, recording and analysing behavior vary substantially, frequently the first sign of illness is detected through observation of changes in the 'normal' behavior of an individual (Grandin, 2015).

There are many arguments about the status and indeed importance of the exhibition of natural behavior for species that are now under the direct management of humans. Whilst studies of individuals within the natural environments in which they evolved are useful for determining and assessing if the behavioral needs of the species are met, account must also be taken of the restrictions associated with the modern-day environments in which animals/individuals are kept and expected to perform. Compliance with the Five Freedoms/Five Needs ensures that individual domesticated animals behavioral needs are considered at the very least (Brambell Report, 1965; Animal Welfare Act 2006). The main measures of environmental adequacy focus on the occurrence of so called natural behaviors (without having an adverse effect on conspecifics and herd-mates; Randle, 1995; Kiley-Worthington, 1990) and the absence of behaviors commonly believed to be indicative of stress including STBs.

In this paper the horse is used as a frequent example as a prey species, known to roam extended distances daily, to spend the majority of the day grazing and to be social, that has been subjected to what can only be considered to be extensive - severe restriction being housed individually and often for extended periods of time. The gravity of this restriction has been recently recognised in Switzerland where daily turn out for horses is now mandatory and group housing strongly recommended (Swiss Animal Protection Organisation, 2016).

Performance

Performance has multiple definitions, including *how well an individual does a piece of work or an activity* (Cambridge online dictionary and thesaurus, 2010), *the action or process of performing a task or function… capability of an entity… task or operation seen in terms of how successfully it is performed* (Oxford English Dictionary, 2016) or the i*dentification of specific behaviors (actions) and specific performance outcomes (goals)* (Williams, 2013; McGarry, 2009), and relates to humans expectations of horses (Randle, 2015). Most species are expected to demonstrate performance in one way or another, for example livestock species are required/forced to breed regularly, usually on an annual or often more frequent basis, produce milk, meat and/or fibre depending on the commodity and consumer demand. Zoo species are required to be able to cope with living in a fundamentally unnatural environment, tolerate close proximity with humans albeit usually ‘protected’ and to breed as part of worldwide *ex situ* conservation programmes (Caspermeyer, 2014).

For some species such as horses and dogs, performance may also be measured on an individual’s apparent ability to tolerate interaction with humans. For example breeds such as the Siamese cat, toy dogs and, to an extent, the Arabian horse, have been selectively bred to tolerate and even seemingly seek human contact. There are numerous anecdotal but learned sources that refer to Arabian horses as having “a good ability to form a cooperative relationship with humans” and being “willing to please”. Some breeds have been selectively developed to be able to perform other physical work related tasks such as draught work for example heavy horses (Drum et al., 2007). Traditionally South Devon cattle were triple purpose animals, being used for draught work in addition to producing meat and milk (Randle, 1995). Huskies are also used for sled work (Wayne and von Holdt, 2012). Other breeds have become fundamental to human sporting pursuits such as working and sporting dogs (Cobb et al., 2015) and horses within equestrian sport (Randle, 2015; Williams, 2015).

STB is often associated with reduced economic value in livestock (Bench et al., 2013) and animals used for sport (McBride and Hemmings, 2009) due to the perception that they are related to impaired performance. Historically, within the animal industry, the expression of stereotypical behavior has been considered a detrimental characteristic in livestock. For example Fraser et al. (2013) refer to the 10 ‘General Principles for the Welfare of Animals in Livestock Production Systems’ adopted by the World Organisation for Animal Health in 2012 guide the development of animal welfare standards which include reference to STBs in this context.

Anecdotal suggestions also exist within the livestock industry relating expression of STB to the reduced economic value of production animals. Yet despite this, limited research has explicitly evaluated if this perception is accurate. In production animals STBs have been associated with reduced output such as milk yields in cows (Sutherland et al., 2012; Redbo et al., 1992), impaired growth performance measures such as decreased lean muscle mass and poor meat quality in pigs (Bench et al., 2013) and fleece quality (due to wool biting) in sheep (Cooper and Jackson, 1996). Similarly STBs have been associated with reproductive fecundity in pigs where an increase in occurrence of STBs is linked with a decrease in the number of live young produced over an individual sow's reproductive life time (von Borell et al., 2007). Therefore it is perhaps not surprising that the farmers assume that there is a lower economic value for production animals that exhibit STBs compared to their non-stereotypic counterparts.

The effect of STB on performance within animals used by humans for sporting pursuits is poorly understood. No studies have examined if STB explicitly affects the performance of sporting dogs; however, research has suggested that a link exists between behavioral measures of welfare and ability in guide dogs (Vincent and Leahy, 1997) and explosive-finding (search) dogs (Rooney et al., 2004). For example Cao et al. (2014) demonstrated in Belgian Malinois dogs that extreme circling behaviour, considered to be compulsive behavior, was an external indicator of superior performance. Identification of canine stereotypical behavior is uncommon amongst dog owners and within the canine industry generally, with owners more likely to consider their dog to be suffering from separation anxiety or some stress–related condition (Rooney et al., 2009). Interestingly Overall and Dunham (2002) reported canine incidence of stereotypical behaviour of 2% not dissimilar to in humans. More recent data are not available. In contrast in equestrianism there is a long established culture when selling horses which recognises equine STBs and classifies them as an ‘unsoundness’, that is a negative performance characteristic with an associated reduction in economic value of between 31 and 59% for affected individuals (Krisová et al. 2015; McBride and Long, 2001). Because of the industry recognition and visible nature of equine STB research exploring why horses perform STBs, particularly those that are often linked to performance outputs, the horse represents a suitable model to examine the impact of STB on performance.

Production Animals

Within farming, environmental conditions such as stocking density and individual space (Aguayo-Ulloa et al., 2014; Averos et al., 2014), access to food and water (Bench et al., 2013; Redbo and Nordblad, 1997), and bedding type and quantity (Texiera et al., 2014; Tuttyens et al., 2005) have been demonstrated to cause stress and have been linked with variation in the expression of stereotypies across species. Each of these examples represent stressors which can induce an adaptive response (positive or negative) within individual animals to enable them to cope with their environment (Moberg, 2000; Broom and Johnson, 1993). Adaption is thought to be influenced by an animal’s temperament or personality which will dictate if a reactive (passive response apparently not addressing the stressor or its impact) or proactive (active response attempting to remove the stressor or themselves from it) adaptation strategy is implemented (Figure 1) (Ichiji et al., 2013). Exposure to stressors stimulates a physiological stress response /responses which will depend on whether the stressor is positive (improves performance: motivates an animal to overcome the challenge presented, usually short-term) or negative (reduces performance: aversive, negative state where presenting challenges are not overcome, in neither the short or long-term) and the strategy the individual adopts towards it (Ichiji et al., 2013; von Borrell et al., 2007). In response to a stressor or stressor animals may demonstrate behavioral, immunological or neuroendocrine changes (Figure 1) including increased expression of STB. It appears that the physiological responses shown by animals to stress can affect the common outputs by which production performance is measured, so the expression of STB has the potential to be used as viable welfare indicator in animals, with increased levels of STB synonymous with reduced welfare. For example increased stereotypy expression in sows has been shown to suppress estrus behavior and reduce sexual behavior, and has also been associated with lower piglet birth weight and the number of live births within litters when compared to non-stereotypic peers (von Borell and Hurnik, 1990).

Interestingly, the reduced reproductive status and fecundity measures observed by von Borell and Hurnik (1990) were attributed to higher levels of cortisol present in the reactive stereotypic pigs. High levels of cortisol have been shown to occur as a result of increased and sustained HPA activity (von Borell et al., 2007). Therefore the expression of stereotypies could also be considered to represent a visual measure of the neuroendocrine response to stress within production animals, with the resultant increase in cortisol production underpinning the reduced reproductive status observed. It could be argued that there is some truth in the assumption that (due to the physiological responses observed and their effects) reduced economic value may be associated with stereotypic livestock. Yet evidence also suggests that if the adverse effect of environmental stressors can be resolved, and a positive environment which meets animals' needs provided, stereotypic animals' fecundity would be improved and their economic value increased (von Borell et al., 2007).

In intensive production systems utilized in modern farming, there is the propensity to enhance the emergence and effect of negative environmental stressors within housing and management systems. These factors can then lead to an increase in the expression of STB and associated corticosteroid production in livestock. For example, sheep housed in intensive systems for finishing (i.e., rearing to slaughter weight) are often kept in indoor pens with a higher stocking density compared to free ranging animals which are finished by grazing in paddocks (Llonch et al., 2006). Intensive systems have been associated with an increased incidence of STB (Aguayo-Ulloa et al., 2014) and redirected behaviors (Dwyer and Bornett, 2004; Gougoulis et al., 2010) including wool biting and pulling, bar mouthing and biting, and pen chewing) suggesting the sheep are reacting to the chronic stress of the restricted and barren environment they inhabit (Fraser et al., 2013). This is not an ovine specific trait - similar increases in STB have been recorded in intensively housed pigs (for example: Averos et al., 2010) and poultry (for example: Lay et al., 2011). A similar behavior can be seen where horses run their teeth up and down metal bars comprise their stables (McGreevy et al., 1995).

While intensive systems can promote desirable production characteristics such as carcass homogeneity (Miranda de la Lama et al., 2010), they can also stimulate increased cortisol levels in animals due to chronic stress associated with their environment (Ichiji et al., 2013). Stereotypic animals will experience higher cortisol levels than their non-stereotypic counterparts (Freymond et al., 2015) and those with STB may be predisposed to react more during handling or when being transported to slaughter (Novak et al., 2015). Chronic stress has been shown to negatively affect meat quality and to reduce the economic value of a carcass (Bench et al., 2013; Fonseca et al., 2104). In pigs, chronic stress is associated with pale, soft and exudate meat rather than the preferred and higher quality dark, firm and dry meat (Adzitey and Nurul, 2011; Warriss et al., 1993). Similar properties have also been reported in equine carcasses after long and stressful transport journeys prior to slaughter (Lanza et al., 2009). Research suggests that negative environmental stressors pose a risk to all animals, e.g., increasing susceptibility to illness, and as such environments where such stressors are present should be considered likely to result in reduced economic value of livestock, regardless of the expression of STB. Sufficient evidence exists within livestock research to suggest that links exist between the environment animals inhabit, how these environments are managed, the expression of STB and production performance measures (Bench et al., 2013; von Borell et al., 2007). However it appears that managing the environments which the animals inhabit in order to reduce stress is the key factor in reducing variables that adversely affect performance and production, rather than simply focusing on STB, per se (Waran and Randle, 2017). In this interpretation the presence of STB indicates a problematic environment for the livestock. Stereotypic animals will react more to stressors, in general, within their environment and this pattern may underlie the negative association between STB and economic value of livestock. When farmers observe STB in their livestock which are subsequently sold for less money than those without STB, the potential to perpetuate the idea that stereotypic animals represent an inferior economic investment compared to non-stereotypic animals exist and releases the farmer from an obligation to further examine the putative environmental contributors over which he has control. This anecdotal view of STB animals could represent a lack of understanding within the livestock industry of how management systems can positively or negatively affect welfare parameters, including expression of STB. Future studies are required that explicitly explore the relationships between STBs and different management systems, and how these influence the expression of stereotypies and production measures such as milk yield, reproduction and meat quality to inform farming practices.

Sporting animals: the horse

At the present time there are 944,000 horses in Great Britain (BETA, 2015). Substantial expectations are placed on horses by humans regardless of their intended use (Table 1). To meet these expectations horses will need to adapt or suppress their natural behavior to demonstrate the required performance related outcomes, in addition to learning behaviors that may be outside of their natural behavioral repertoires. For example, to facilitate ridden work regardless of equestrian disciplines, the horse must *learn* to suppress its natural behavior which would be to remove the human from its back. Horses used for competition-related performance are also subjected to specific management regimes which usually integrate some form of physical restriction. For example, competition horses are usually stabled for long periods with restricted turnout and forage intake compared to their free-ranging or semi-feral counterparts (Kiley-Worthington, 1990; Sarrafachi and Blokhuis, 2013; Williams, 2013). Many of these horses, e.g., race horses, are also maintained on an unnaturally high plane of nutrition. These horses may experience physical and/or social and/or psychological restriction (Kiley-Worthington, 1990, 2005). These restrictions may *also* be due to unavoidable constraints of those responsible for the horses such as restricted access to pasture, especially in poor weather.

In many circumstances horses may be managed and especially housed in a particular way that is traditional/expected for that type of horse, as defined by the individual's type and/or function/purpose. Table 1 describes the physical and mental expectations associated with a range of equitation disciplines and how performance based on discipline expectations may be measured. For example, dressage horses traditionally experience limited turn out for fear of injury. Ideally horses would be housed and managed in a way that ensured that individuals can express the range of natural behaviors outlined within the Animal Welfare Act 2006. In reality, if a detailed assessment were to be conducted against a framework of basic criteria with the aim of ensuring the animal's basic needs will be met, the goal of the Welfare Act is unlikely to be achieved. It is likely that the modern competition horse will experience stressors within their *normal* environment which could place them at risk of developing stereotypies. The Horse Welfare Wageningen Project (2012) (and associated analysis guide) outline a comprehensive set of horse behaviors and physical signs that can be investigated and recorded in order to determine the impact of management systems on individual horses behavior. This multifactorial approach also includes data generated on the occurrence of abnormal behaviors.

In horses, the occurrence of abnormal behavior, i.e., behaviors that are traditionally referred to as stable vices (defined by the Oxford Dictionary *as bad or neurotic habits of stabled horses, typically arising as a result of boredom*, OED, 2016), but in more contemporary literature are referred to as stereotypies. Stereotypical behavior is defined broadly *as the persistent repetition of an act, especially for no obvious purpose and which can be exhibited at a number of levels* (in its early development in response to identifiable cause/s, mid-development where it has become a reliable response in the presence of its cause/s, or late development where the STB becomes emancipated from the cause, i.e., it occurs in the absence of its cause (see also Mills and Nankervis, 1999).

Any horse that is sold should be deemed fit and any unsoundness declared either by the vendor or by an independent veterinary professional (usually employed by the potential purchaser). An unsoundness is defined as a performance limiting factor - for example lameness or respiratory dysfunction - which adversely affects an individual horse's ability to function effectively in the role assigned to it (e.g., as a leisure horse or racehorse). The exhibition of an aberrant behavior may be considered an example of unsoundness. Declaring any unsoundness inevitably results in a reduction in the value of a horse at least to a certain extent (e.g., Krisová et al. 2015). STBs in horses are anecdotally linked to poor performance (McBride and Hemmings, 2009; Fraser and Broom, 1990; Ralston, 1982; Wickens and Heleski, 2010), impaired ability to learn (Hemmings et al. 2007) and an increased risk of injury (McBride and Hemmings, 2009) or a predisposition to certain forms of injury due to physical consequences of repetitive physical movements associated with the STB (e.g., weaving).

As with production animals, the expression of STBs has been reported to reduce the economic value of sports horses (Krisová et al. 2015; McBride and Hemmings, 2009). This loss is due to perceived performance limiting factors associated with STBs. Many horse owners believe STBs are contagious, and so do not wish to have a stereotypic horse on the yard (Sarafichi and Blokhuis, 2013; McBride and Long, 2001). Interestingly, owners who have had direct experience of horses that exhibit STB maintain that STBs do not negatively affect performance, and that performance based measures and values are equitable to those of non STB horses (Nagy et al., 2010). To date there are no published data available to substantiate these anecdotal propositions.

Equine personality

Within equestrianism, horses which exhibit STBs are not viewed positively. Despite poor understanding of the etiology of equine STB (Normando et al., 2011), many riders and owners believe stereotypies can be copied and do not want a stereotypic horse on their yard (McBride and Long, 2001). Stereotypic horses generally possess a reduced economic value than non-stereotypic horses (McBride and Hemmings, 2009) which is highlighted in sales adverts where "*no vices*" (i.e., no STBs) is included as it is viewed as a desirable characteristic. STBs have been associated with reactivity in individual horses (Bachmann et al., 2003), breed of horse (Albright et al., 2009), breeding / genetic predisposition (Albright et al., 2009) and suboptimal management (Cooper and Albentosa, 2005; Cooper and Mason, 1998). Suboptimal management includes stabling with no or limited turnout (the opportunity to move freely and usually graze typically in a grass paddock) (Visser et al., 2008) and suboptimal management conditions (Cooper and Albentosa, 2005). Nagy et al. (2010) reported that professional riders believe stereotypic horses can demonstrate learning characteristics which they consider advantageous to competitive performance (Roberts et al., 2015). Professional riders are focused on competition success (Wolframm et al., 2015) and should also be skilled in riding and handling more challenging horses which stereotypic individuals could represent. One could argue that the competitive potential of an individual horse could outweigh negative aspects leisure and amateur riders associate with STBs.

Elite human athletes, including riders, have been shown to possess different personality traits, including increased extroversion, compared to people who participate in sport for fun (Allen et al., 2011; Wolframm et al., 2015; Woodman et al., 2010). Extroversion is characterized by an increased tendency for excitability in humans (Wolframm et al., 2015). If the hypothesis is that STB horses possess more reactive personalities, they may also be considered as having extroverted personalities and possessing a suitable temperament for competition (Ichiji et al., 2013). Competitive riders may value extrovert characteristics that they recognize from self-reflection and feel have a positive effect on performance, when selecting their equine partner, so the presence of STB is not a key consideration.

Practitioners within the Equine Industry also suggest that STBs are performance limiting. For example, locomotor STBs in horses have been associated with an increased risk of orthopaedic injury, soft tissue strain and poor performance (McBride and Hemmings, 2009). Oral STBs are linked to a higher incidence of gastric ulcers (Nicol et al., 2002), colic (Archer et al., 2004) and dental pathologies (Marsden, 2002; Wickens et al., 2013). There is limited evidence that STBs contribute to the aetiology of these conditions.

Differences in the frequency of STB expression have been reported across equestrian disciplines (Hausberger et al., 2009) and associated with more intensive management systems (for example, dressage and eventing, integrating restricted turnout and low forage diets) compared to management systems involving more turnout and higher forage diets (slow release energy) (such as endurance horses) (McGreevy et al., 1995). Normando et al. (2002) make the point that English horse management systems (referring explicitly to restrictive stabling practices) and riding precludes increased expression of STB, and apparent lack of progress is confirmed by their reiteration of the same point almost a decade later (Normando et al., 2011). Stress has been associated with riding practices, and is thought to be key factor within the aetiology of equine STB (Mills et al., 2002; Normando et al., 2011). In reality, it is likely that multiple environmental stressors trigger the occurrence and display of STB in horses, so all factors which could cause negative/harmful stress, including not allowing horses to demonstrate their STBs, should be considered when managing horses for optimal performance.

STB in horses has been linked to differences in learning behavior which could affect performance and management, and consequently influence how owners value their horse. Hemmings et al. (2007) and Parker et al. (2008) have proposed that stereotypic horses exhibit altered brain chemistry compared to non-stereotypic individuals, presenting with basal ganglion dysfunction and alterations in dopamine physiology which influence their ability to learn (Parker et al., 2009; Roberts et al., 2015). Chronic stress, particularly when young (in horses this could represent weaning, handling or when they are being backed for riding) can activate dopamine transmission, increase sensitivity to dopamine and lead to a higher percentage of D1 and D2 receptors in the basal ganglion fundamentally altering its functionality (Parker et al., 2008; 2009). These changes appear exacerbated in stereotypic animals (Hemmings et al., 2007). Since dopamine is a key neurotransmitter that is involved in learning and reward-motivated behavior, changes in dopamine pathways could influence equine behavior and performance (McBride and Parker, 2015).

Comparisons of stereotypic and non-stereotypic horses' ability to learn new tasks have demonstrated that stereotypic horses demonstrate a poor extinction capacity and accelerated and more reinforced (stronger) learning than their non-stereotypic counterparts (Ninomyia, 2007). Stereotypic horses then require more to unlearn what was taught (either intentionally or indeed accidently) (Hemmings et al., 2007; Parker et al., 2008; Roberts et al., 2015). Roberts et al. (2015) demonstrated that although both oral- and locomotor- stereotyping horses exhibit increased dopamine sensitivity, differences exist between their learning performances. Horses that performed oral STB learned tasks more quickly and took longer to achieve extinction than horses which performed locomotor STB. This work supports professional riders' views that stereotypical horses, in particular those that crib-bite (refer to Roberts et al, 2017 in this issue), possess a heightened learning ability or as some perceived increased intelligence (Roberts et al., 2015; Williams, 2013).

In humans, individuals with heightened dopamine activity have been shown to learn faster when learning acquisition is combined with praise (Frank et al., 2004), supporting the professional riders' perspective. In practice, these qualities should counteract the negative economic impact of STBs in horses, however it may not be this simple. The shift displayed by stereotypic horses to stimulus-response learning, which is firmly embedded when first learned, could make these horses a challenging prospect to manage and ride for the average horse owner / rider. It may not be that stereotypies themselves are performance limiting but the qualities STB horses possess. These horses are motivated to learn quickly and retain what they learn, whether the responses are wanted. Its stands to reason that stereotypic horses with inexperienced trainers/riders may learn inappropriately, react and respond to incorrect cues if they are rewarded for undesirable behaviors due to poor / limited handling and riding skills.

The trainer/rider may not realise they have facilitated these traits, resulting in the horse being labelled as *difficult* or *stubborn.* It is this characterization which could contribute to the negative perception of STB amongst general equestrians, and equally, as undesirable characteristics, perpetuate the reduced economic value of affected horses. A professional rider/trainer with heightened experience and skill levels may correctly apply learning theory and utilize the stereotypic horses' stimulus-response learning in a positive manner, to promote positive performance traits. Further research evaluating the longitudinal effect of STB on performance measures including success within disciplines and economic value as well as assessing career longevity is required to substantiate these effects.

Conclusion

Despite extensive research into factors which contribute to the aetiology of STB and/or influence the expression of STB, few studies have explicitly evaluated if relationships exist between stereotypical behavior and performance variables in livestock or equine athletes. However, emergent themes within livestock and equine research suggest that individuals that exhibit STBs also demonstrate impaired performance attributes which supports the proposal that STB is a negative characteristic. Similarly within equestrianism, stereotypic horses appear to react and learn in a different way to non-stereotypic horses. Professional riders and trainers could utilise these traits combined with their advanced skills to enhance the performance potential and value of stereotypic horses. Stereotypic horses trained by amateur riders, who currently represent 96% of the horse owning population, may suffer from an approach that could reinforce the negative associations that exist.

Performance is a complex phenomenon with any species and multiple endogenous and exogenous factors will contribute to success at any one time. Research is required that explicitly explores how different STBs influence performance variables, and how these interact with management systems and environmental stressors for both livestock and horses. Individual horses, as companion animals, are not as protected by rigorous legislation in the same way as individual animals classified as livestock. Horse keepers, regardless of the equestrian discipline with which they associate, will argue that they are keeping and managing their horses in an appropriate manner, albeit it often subject to financial, resource- and weather- related constraints. Yet the fact remains that a proportion of horses will suffer from inadequate living conditions or husbandry, and for some, their expression of STB is taken as the norm, and as a given. Given the existence of physiological evidence for enhanced motivation and learning ability, it may be argued that - at least for some equine individuals - expression of STB is not necessarily a performance limiting factor. The situation is different in livestock individuals simply due to the fact that many cows, sheep and pigs for example do not benefit from such a long term (around 20 years for some individuals) and frequent (often twice daily with direct physical contact) relationship as horses do with an individual human.

Conflict of interest statement

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

Funding

No external parties funded this paper.

Authorship

The idea for the paper was conceived by Jane Williams and refined in conjunction with Hayley Randle. This study is a review and does not involve any experiments or data analysis. The paper was written by Jane Williams and Hayley Randle.

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795 **Table captions**

796 Table 1 Discipline specific expectations of horses kept for human use.

797

Discipline	**Expectation (to cope)**	**Measurable outcomes for performance**
Leisure Horse	To remain calm, be traffic proof, to be adaptable, to cope with varying demands, often multidisciplinary. To potentially become accustomed to multiple handlers, riders and management regimes.	Does not exhibit flight response in potentially stressful situations. Leisure rider happiness. Reliability as a riding horse. Rider/owners enjoyment. Perform alone and in company.
Companion horse	Injury free. Calm. Cope with a less/non active life often in one single environment.	Lack of injury. Lack of stress behaviours.
Showing	To remain calm in the show ring. Behaves appropriately under varying conditions. To become accustomed to travel and the show environment, and different horses in close vicinity and with multiple riders	Trainability, placings and prize money.
Showjumping	Fitness. Ability to jump multiple types of obstacles. Ability to travel at speed, shorten and lengthen strides and remain manoeuvrable. Cope with different competitive environments, competition schedule (variable management regimes including restricted stabling and turnout). Varying trainers/riders/ training methods.	Trainability, placings and prize money.
Dressage	Ability to perform complex movements without damage. Ability to adapt to multiple equipment/tack. Travelling. Cope with training methods and gadgetry. Protective husbandry practices which may include restricted turnout. Varying trainers/riders / repetitive training methods.	Placings. Trainability: submission, quality of gait, collection and submission.

Driving	To remain calm, be traffic proof, to be adaptable to varying environments. Dexterity and speed. Ability to respond to rider over and above conspecifics that may be working alongside (pairs, fours).	Trainability, placings.
Hunting	Fitness. Ability to travel at speed, transport, working in changing groups of horses. Ability to cope with extended periods of standing. Ability to cope with a wide range of physical environments. Varying riders. Ability to cope with dogs and unexpected physical environmental features. Ability to jump. Ability to cope with rider falls. Being able to cope with extended (summer) holiday period.	Lack of injury, days off work.
Team Chasing	Fitness, ability to jump at speed, working with conspecifics, expectation to leave other horses.	Placings, speed.

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Endurance	Fitness, stamina, speed, working alone, passing- and being passed by- other horses. Varying terrains. Travel. Unfamiliar stabling. Rider related equipment – e.g. flappy map cases!	Veterinary parameters- fitness and behaviour. Speed. Self-preservation.
Polo	Fitness, stamina, speed, tight turns and bursts of acceleration Controlled aggression towards other horses to facilitate bump and ride-off manoeuvres. Working in close proximity to others. Good temperament to stand calmly in polo lines between chukkas. Multiple riders Use of multiple items of equipment, with potentially conflicting actions. Varying levels of rider expertise and weight	Speed, avoidance of injuries. Chukkas scored. High or low goal status (linked to player ratings)
Polocrosse	Fitness, stamina, speed, tight turns and bursts of acceleration Controlled aggression towards other horses to facilitate bump and ride-off manoeuvres. Working in close proximity to others. Good temperament, cope with polocrosse sticks. Multiple riders. Use of multiple items of equipment, with potentially conflicting actions. Varying levels of rider expertise and weight	Speed, avoidance of injuries.
Horse ball	Fitness, stamina, speed, tight turns and bursts of acceleration Working in close proximity to others. Good temperament, cope with ball and manoeuvres.. Multiple riders. Use of multiple items of equipment, with potentially conflicting actions. Varying levels of rider expertise and weight.	Speed, points scored, avoidance of injuries
Vaulting	Change of environments, being lunged for extended periods, human doing crazing things, impact on back, competitive environment. Travel	Calmness and consistency in gaits. Obedience. Lack of reaction to environmental stressors.

Eventing	Fitness, stamina, speed, able to jump and perform complex movements, adaptability, transport, unfamiliar stabling and management regimes. Different trainers / riders. Different equipment and expectations. Temperament to perform effectively at three different disciplines	Placings, points scored. remain injury free?
Hunter trials / cross-country	Fitness, stamina, speed, ability to jump, adaptability, transport, unfamiliar stabling etc. Different trainers / riders. Equipment and expectations.	Placings, points scored.
Racing	Speed ±stamina, high plane of nutrition and restrictive management regimes, working in strings, jumping (NH), transport, varying riders, Starting gates, different competitive environments. Long transport periods, early start of competitive career including sales preparation (flat racing)	Placings, winnings, breeding value / status: black type (placing in premium races which enhances breeding value), remain injury free
Trec	Fitness, adaptability. Different sections. Multiple equipment esp. rider related.	Placings, winnings.
Horse agility	Obstacles, obedience in-hand, willing termperament.	Trainability, placings, winnings.
Rodeo	Audience noise. Equipment (bucking straps)	Time to dislodge rider and quality of bucking / leaping.

Bull fighting	Bovines, audience noise, equipment	Self-preservation, speed and manoeuvrability.
Reining	Ability to lope and gallop with fast acceleration, circle, spin, turn and stop at speed, good temperament	Placings, winnings.
BARREL RACING	Competition environments, transport etc. Audiences. Speed	Placings, winnings.
Jousting	Ability to run at another horse, coping with environment, frightening stimuli including the jousting lance being carried by own rider and the opposing rider. Quick speed. Short term run.	Ability to maintain speed and straight line.
Pony Club/Riding Club	Adaptability, changing groups of horses, different disciplines, transport, travel etc. Variable environment, speed, cope with aversive stimuli, noise. Varying trainers. Inexeprienced / novice/ young / part-time / amateur riders.	Adaptable horse, trainability, ability to perform range of disciplines (may not excel in any but would be classified as a *good* allrounder).
Gymkhanas	Environment, speed, cope with aversive stimuli, noise, brats	Adaptable horse. Rosettes
Riding School/Trekking centre	Varying riders. Rider inexperience and weight. Confusing signals. Habitual routes. Varying conspecifics. Expected not to show fear related behaviours, or get stressed. Expectation - work hours. Stabling during day. Tack fit. Insensitive rider signals and loading during riding.	Safety. Rider falls (lack of). Absence of negative behaviours.

Education Centre / College	Lack of varied working environment. Managed fitness levels to prevent injury to less experienced riders. Multiple riders. Confusing signals. Being stabled a lot during day, or more (if have weather related turn out issues)	Safety statistics, soundness.
Service horses	Stabling, restricted access to grazing. Expectations dealing with aversive situations. Heavy equipment. Lack of individualised equipment choice/use/fit.	Calmness during work.

Figure captions

Figure 1: Different animal responses to stressors (von Borell et al., 2007).