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

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9

10 *Abstract*

11 Stereotypical behavior (STB) has been observed in a wide range of species regardless of its
12 classification. Despite extensive research into factors which contribute to the aetiology of
13 STB and/or influence the expression of STB, few studies have explicitly evaluated if
14 relationships exist between stereotypical behavior and performance variables in livestock or
15 equine athletes. This review explores the impact of STBs on animal performance, using the
16 horse and production animals as examples, to establish whether their expression should be
17 viewed as a positive or negative attribute by the animal industry. Emergent themes within
18 livestock and equine research suggest that individuals that exhibit STBs also demonstrate
19 impaired performance attributes which supports the proposal that STB is a negative
20 characteristic. Much of the empirical evidence available suggests negative environmental
21 stressors represent a greater risk to the economic value of animals compared to STB. Within
22 equestrianism, stereotypic performing horses appear to react and learn in a different way to
23 non-stereotypic horses, which, in professional hands, could enhance their performance

24 potential and value, but with amateur riders could reinforce the negative associations that
25 exist. However performance is a complex phenomenon with any species and multiple
26 endogenous and exogenous factors will contribute to success at any one time. Further
27 research is required that explicitly explores how different STBs influence performance
28 variables alongside consideration of the effect of management systems and environmental
29 stressors, and their role in STB expression in both livestock and horses.

30

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

32

33 Highlights

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

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

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

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

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

40 **Introduction**

41 Stereotypical behaviour (STB) has been observed in a wide range of species, regardless of
42 their classification, including livestock (eg. Adenkola and Ayo, 2010) and companion
43 animals (dogs (Protopopova et al., 2014), parrots (Cussen and Mench, 2015), rodents (Novak
44 et al., 2015) and horses (Albright et al. 2015)). STBs are also reported in zoo animals
45 including animals housed in managed environments (Padalino et al., 2014; Shepherdson et
46 al., 2013) and those kept in more natural environments such as in extensive game parks
47 (Kiley-Worthington and Randle, 2005). Both groups of these non-domesticated animals
48 require periodic management for health and veterinary treatment or to facilitate human-
49 animal (paying visitor) interaction (Randle and Kiley-Worthington, 2005). STB can occur in
50 a wide range of ages. They have been noted to occur from birth (Latham and Mason, 2008)
51 as has been reported in horses (e.g. Wickens and Houpt 2015) through to old age (Qi et al.,
52 2008), although for some species key risk times have been identified. Mason and Rushen
53 (2008) highlight that horses/foals are at the greatest risk of developing a new form of
54 stereotypic behavior between 15 and 35 weeks, and that emergence of new stereotypies peaks
55 at 40 weeks.

56 The expression of STBs in non-human animals is often considered a visual indicator of
57 response to environmental (Averos et al., 2014; Hemmings and Hale, 2013; Shepherdson et
58 al. 2013) or psychological stressors (Gottlieb et al., 2013; Pomerantz et al., 2012; McBride
59 and Mills, 2012), and can also be influenced by an individual's temperament (Shepherdson et
60 al., 2013) and personality (Ijichi et al., 2013). STBs are thought to indirectly reflect the
61 welfare status of animals by some (e.g., Mason and Rushen, 2008). Gottlieb et al. (2013)
62 warn that individual behavior expression cannot necessarily be used to assess welfare

63 between subjects because some individuals may express high rates of stereotypic behavior
64 due to frustration (in the sense of not being able to gain access to a resource that may be present
65 in the animal's environment), whilst others may do so in order to cope with a suboptimal
66 environment (i.e. an environment that does not provide all the animal's basic requirements).

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

73

74 *Stress*

75 Stereotypical behaviour is often associated with stress in animals. Stress is defined as a
76 *biological response elicited when an individual perceives a threat to its homeostasis and the*
77 *threat that causes stress is referred to as a stressor (Moberg, 2000), the inability of animals*
78 *to cope with their environment (Broom and Johnson, 1993) and unfitness to adapt to the*
79 *environment and reproduce effectively (Ewing et al., 1999). Stressors may be positive or*
80 *eustressors (e.g. hormones which trigger arousal/mating behavior) or negative, known as*
81 *distressors (e.g. restricted environment which does not facilitate expression of normal*
82 *behaviors). Stressors are detected by animals' sensory systems to seemingly produce an*
83 *instantaneous biological response which may or may not be externally observable (von Borell*
84 *et al., 2007). Biological reactions depend upon the recognition of the features of a stressor*
85 *and elicit a neurophysiological response which typically comprises cognitive and non-*
86 *cognitive elements, and include behavioral, autonomic, neuroendocrinological and/or*

87 immunological responses (Ichiji et al., 2013). The precise nature and duration of responses to
88 stress depend on the nature of the stressor. A stimulus/situation that is perceived (cognitive
89 element) as a short term threat is characterised by Sympathetic Adrenal Medullary system
90 (SAM) and Central Nervous System (CNS) activity resulting in release of the epinephrine
91 neurotransmitter which prepares the body for action. Conversely, a stimulus/situation that is
92 perceived (cognitive element) as a longer term threat is characterised by responses indicative
93 of long term challenge and the initiation of a coping mechanism. In this situation the
94 hypothalamic–pituitary–adrenocortical (HPA) stress-response system is activated and results
95 in a sustained production of glucocorticoids and mineralocorticoids which are known to
96 enable proactive coping. Once an individual is sufficiently ‘*stressed*’ the HPA-axis becomes
97 more sensitive and more easily triggered by stressors. This is accompanied by high
98 sympathetic reactivity resulting in increased concentrations of catecholamines and elevated
99 parasympathetic reactivity and as a consequence impacts on individual animal performance
100 (von Borell et al., 2007).

101 Stress is broadly understood by both scientists and lay persons to be characterised by the
102 outcomes or responses given by animals to a series of stressors. Stressors include various
103 aspects of the animal’s internal and/or external environment that are compromising
104 homeostasis either physically and/or psychologically, and causing a disruption to what is
105 considered to be ‘normal’ for that species/breed/individual (Levine, 1985). Furthermore
106 Levine (1985) amongst others emphasized that various measures of an individual suffering
107 from stress are often conflicting, for example behavioral indicators and heart rate variability.
108 Smith et al. (2016) proposed that heart rate correlates with behavioral indices of stress in
109 horses. Although behaviors assumed to be related to stress were seen more frequently when
110 subjects encountered negative stimuli than with positive ones, heart rate responses did not
111 follow the same pattern. It is reasonable to suggest that Moberg’s view that ‘stress’ was

112 better described as a syndrome (a group of symptoms or signs that commonly appear
113 together) in which the visible response/s may represent varying combinations of causes
114 remains wholly applicable. Rightly or wrongly ‘stress’ is often implicated in the aetiology of
115 STB regardless of the species under examination and is commonly attributed, at least in part,
116 to deficiencies in general husbandry and management (mainly lack of space and direct
117 contact with conspecifics, e.g., Varadharajan et al., 2015) and/or to specific stressors within
118 the environments in which they/individuals are housed (e.g., Shepherdson et al., 2013;
119 Romero et al., 2015). The critical role of stress in the development of resilience in
120 individuals enabling them to cope with the various challenges encountered in the course of
121 daily life, particularly those related to their physical-, and of increased concern, their social-
122 environment is emphasized by Romero et al. (2015). The expression of STB may be one way
123 of coping with such challenges.

124 *Behavior*

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

133 There are many arguments about the status and indeed importance of the exhibition of natural
134 behavior for species that are now under the direct management of humans. Whilst studies of
135 individuals within the natural environments in which they evolved are useful for determining

136 and assessing if the behavioral needs of the species are met, account must also be taken of the
137 restrictions associated with the modern-day environments in which animals/individuals are
138 kept and expected to perform. Compliance with the Five Freedoms/Five Needs ensures that
139 individual domesticated animals behavioral needs are considered at the very least (Brambell
140 Report, 1965; Animal Welfare Act 2006). The main measures of environmental adequacy
141 focus on the occurrence of so called natural behaviors (without having an adverse effect on
142 conspecifics and herd-mates; Randle, 1995; Kiley-Worthington, 1990) and the absence of
143 behaviors commonly believed to be indicative of stress including STBs.

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

150

151 *Performance*

152 Performance has multiple definitions, including *how well an individual does a piece of work*
153 *or an activity* (Cambridge online dictionary and thesaurus, 2010), *the action or process of*
154 *performing a task or function... capability of an entity... task or operation seen in terms of*
155 *how successfully it is performed* (Oxford English Dictionary, 2016) or the *identification of*
156 *specific behaviors (actions) and specific performance outcomes (goals)* (Williams, 2013;
157 McGarry, 2009), and relates to humans expectations of horses (Randle, 2015). Most species
158 are expected to demonstrate performance in one way or another, for example livestock
159 species are required/forced to breed regularly, usually on an annual or often more frequent

160 basis, produce milk, meat and/or fibre depending on the commodity and consumer demand.
161 Zoo species are required to be able to cope with living in a fundamentally unnatural
162 environment, tolerate close proximity with humans albeit usually ‘protected’ and to breed as
163 part of worldwide *ex situ* conservation programmes (Caspermeyer, 2014).

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

176 STB is often associated with reduced economic value in livestock (Bench et al., 2013) and
177 animals used for sport (McBride and Hemmings, 2009) due to the perception that they are
178 related to impaired performance. Historically, within the animal industry, the expression of
179 stereotypical behavior has been considered a detrimental characteristic in livestock. For
180 example Fraser et al. (2013) refer to the 10 ‘General Principles for the Welfare of Animals in
181 Livestock Production Systems’ adopted by the World Organisation for Animal Health in
182 2012 guide the development of animal welfare standards which include reference to STBs in
183 this context.

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

196 The effect of STB on performance within animals used by humans for sporting pursuits is
197 poorly understood. No studies have examined if STB explicitly affects the performance of
198 sporting dogs; however, research has suggested that a link exists between behavioral
199 measures of welfare and ability in guide dogs (Vincent and Leahy, 1997) and explosive-
200 finding (search) dogs (Rooney et al., 2004). For example Cao et al. (2014) demonstrated in
201 Belgian Malinois dogs that extreme circling behaviour, considered to be compulsive
202 behavior, was an external indicator of superior performance. Identification of canine
203 stereotypical behavior is uncommon amongst dog owners and within the canine industry
204 generally, with owners more likely to consider their dog to be suffering from separation
205 anxiety or some stress-related condition (Rooney et al., 2009). Interestingly Overall and
206 Dunham (2002) reported canine incidence of stereotypical behaviour of 2% not dissimilar to
207 in humans. More recent data are not available. In contrast in equestrianism there is a long
208 established culture when selling horses which recognises equine STBs and classifies them as

209 an ‘unsoundness’, that is a negative performance characteristic with an associated reduction
210 in economic value of between 31 and 59% for affected individuals (Krisová et al. 2015;
211 McBride and Long, 2001). Because of the industry recognition and visible nature of equine
212 STB research exploring why horses perform STBs, particularly those that are often linked to
213 performance outputs, the horse represents a suitable model to examine the impact of STB on
214 performance.

215

216 *Production Animals*

217 Within farming, environmental conditions such as stocking density and individual space
218 (Aguayo-Ulloa et al., 2014; Averos et al., 2014), access to food and water (Bench et al.,
219 2013; Redbo and Nordblad, 1997), and bedding type and quantity (Texiera et al., 2014;
220 Tuttyens et al., 2005) have been demonstrated to cause stress and have been linked with
221 variation in the expression of stereotypies across species. Each of these examples represent
222 stressors which can induce an adaptive response (positive or negative) within individual
223 animals to enable them to cope with their environment (Moberg, 2000; Broom and Johnson,
224 1993). Adaption is thought to be influenced by an animal’s temperament or personality
225 which will dictate if a reactive (passive response apparently not addressing the stressor or its
226 impact) or proactive (active response attempting to remove the stressor or themselves from it)
227 adaptation strategy is implemented (Figure 1) (Ichiji et al., 2013). Exposure to stressors
228 stimulates a physiological stress response /responses which will depend on whether the
229 stressor is positive (improves performance: motivates an animal to overcome the challenge
230 presented, usually short-term) or negative (reduces performance: aversive, negative state
231 where presenting challenges are not overcome, in neither the short or long-term) and the
232 strategy the individual adopts towards it (Ichiji et al., 2013; von Borrell et al., 2007). In

233 response to a stressor or stressor animals may demonstrate behavioral, immunological or
234 neuroendocrine changes (Figure 1) including increased expression of STB. It appears that the
235 physiological responses shown by animals to stress can affect the common outputs by which
236 production performance is measured, so the expression of STB has the potential to be used as
237 viable welfare indicator in animals, with increased levels of STB synonymous with reduced
238 welfare. For example increased stereotypy expression in sows has been shown to suppress
239 estrus behavior and reduce sexual behavior, and has also been associated with lower piglet
240 birth weight and the number of live births within litters when compared to non-stereotypic
241 peers (von Borell and Hurnik, 1990).

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

254 In intensive production systems utilized in modern farming, there is the propensity to enhance
255 the emergence and effect of negative environmental stressors within housing and
256 management systems. These factors can then lead to an increase in the expression of STB and
257 associated corticosteroid production in livestock. For example, sheep housed in intensive

258 systems for finishing (i.e., rearing to slaughter weight) are often kept in indoor pens with a
259 higher stocking density compared to free ranging animals which are finished by grazing in
260 paddocks (Llonch et al., 2006). Intensive systems have been associated with an increased
261 incidence of STB (Aguayo-Ulloa et al., 2014) and redirected behaviors (Dwyer and Bornett,
262 2004; Gougoulis et al., 2010) including wool biting and pulling, bar mouthing and biting, and
263 pen chewing) suggesting the sheep are reacting to the chronic stress of the restricted and
264 barren environment they inhabit (Fraser et al., 2013). This is not an ovine specific trait -
265 similar increases in STB have been recorded in intensively housed pigs (for example: Averos
266 et al., 2010) and poultry (for example: Lay et al., 2011). A similar behavior can be seen
267 where horses run their teeth up and down metal bars comprise their stables (McGreevy et al.,
268 1995).

269 While intensive systems can promote desirable production characteristics such as carcass
270 homogeneity (Miranda de la Lama et al., 2010), they can also stimulate increased cortisol
271 levels in animals due to chronic stress associated with their environment (Ichiji et al., 2013).
272 Stereotypic animals will experience higher cortisol levels than their non-stereotypic
273 counterparts (Freymond et al., 2015) and those with STB may be predisposed to react more
274 during handling or when being transported to slaughter (Novak et al., 2015). Chronic stress
275 has been shown to negatively affect meat quality and to reduce the economic value of a
276 carcass (Bench et al., 2013; Fonseca et al., 2104). In pigs, chronic stress is associated with
277 pale, soft and exudate meat rather than the preferred and higher quality dark, firm and dry
278 meat (Adzitey and Nurul, 2011; Warriss et al., 1993). Similar properties have also been
279 reported in equine carcasses after long and stressful transport journeys prior to slaughter
280 (Lanza et al., 2009). Research suggests that negative environmental stressors pose a risk to
281 all animals, e.g., increasing susceptibility to illness, and as such environments where such
282 stressors are present should be considered likely to result in reduced economic value of

283 livestock, regardless of the expression of STB. Sufficient evidence exists within livestock
284 research to suggest that links exist between the environment animals inhabit, how these
285 environments are managed, the expression of STB and production performance measures
286 (Bench et al., 2013; von Borell et al., 2007). However it appears that managing the
287 environments which the animals inhabit in order to reduce stress is the key factor in reducing
288 variables that adversely affect performance and production, rather than simply focusing on
289 STB, per se (Waran and Randle, 2017). In this interpretation the presence of STB indicates a
290 problematic environment for the livestock. Stereotypic animals will react more to stressors,
291 in general, within their environment and this pattern may underlie the negative association
292 between STB and economic value of livestock. When farmers observe STB in their livestock
293 which are subsequently sold for less money than those without STB, the potential to
294 perpetuate the idea that stereotypic animals represent an inferior economic investment
295 compared to non-stereotypic animals exist and releases the farmer from an obligation to
296 further examine the putative environmental contributors over which he has control. This
297 anecdotal view of STB animals could represent a lack of understanding within the livestock
298 industry of how management systems can positively or negatively affect welfare parameters,
299 including expression of STB. Future studies are required that explicitly explore the
300 relationships between STBs and different management systems, and how these influence the
301 expression of stereotypies and production measures such as milk yield, reproduction and
302 meat quality to inform farming practices.

303

304 *Sporting animals: the horse*

305 At the present time there are 944,000 horses in Great Britain (BETA, 2015). Substantial
306 expectations are placed on horses by humans regardless of their intended use (Table 1). To

307 meet these expectations horses will need to adapt or suppress their natural behavior to
308 demonstrate the required performance related outcomes, in addition to learning behaviors that
309 may be outside of their natural behavioral repertoires. For example, to facilitate ridden work
310 regardless of equestrian disciplines, the horse must *learn* to suppress its natural behavior
311 which would be to remove the human from its back. Horses used for competition-related
312 performance are also subjected to specific management regimes which usually integrate some
313 form of physical restriction. For example, competition horses are usually stabled for long
314 periods with restricted turnout and forage intake compared to their free-ranging or semi-feral
315 counterparts (Kiley-Worthington, 1990; Sarrafachi and Blokhuis, 2013; Williams, 2013).
316 Many of these horses, e.g., race horses, are also maintained on an unnaturally high plane of
317 nutrition. These horses may experience physical and/or social and/or psychological
318 restriction (Kiley-Worthington, 1990, 2005). These restrictions may *also* be due to
319 unavoidable constraints of those responsible for the horses such as restricted access to
320 pasture, especially in poor weather.

321 In many circumstances horses may be managed and especially housed in a particular way that
322 is traditional/expected for that type of horse, as defined by the individual's type and/or
323 function/purpose. Table 1 describes the physical and mental expectations associated with a
324 range of equitation disciplines and how performance based on discipline expectations may be
325 measured. For example, dressage horses traditionally experience limited turn out for fear of
326 injury. Ideally horses would be housed and managed in a way that ensured that individuals
327 can express the range of natural behaviors outlined within the Animal Welfare Act 2006. In
328 reality, if a detailed assessment were to be conducted against a framework of basic criteria
329 with the aim of ensuring the animal's basic needs will be met, the goal of the Welfare Act is
330 unlikely to be achieved. It is likely that the modern competition horse will experience
331 stressors within their *normal* environment which could place them at risk of developing

332 stereotypies. The Horse Welfare Wageningen Project (2012) (and associated analysis guide)
333 outline a comprehensive set of horse behaviors and physical signs that can be investigated
334 and recorded in order to determine the impact of management systems on individual horses
335 behavior. This multifactorial approach also includes data generated on the occurrence of
336 abnormal behaviors.

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

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

357 physical consequences of repetitive physical movements associated with the STB (e.g.,
358 weaving).

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

368

369 *Equine personality*

370 Within equestrianism, horses which exhibit STBs are not viewed positively. Despite poor
371 understanding of the etiology of equine STB (Normando et al., 2011), many riders and
372 owners believe stereotypies can be copied and do not want a stereotypic horse on their yard
373 (McBride and Long, 2001). Stereotypic horses generally possess a reduced economic value
374 than non-stereotypic horses (McBride and Hemmings, 2009) which is highlighted in sales
375 adverts where “*no vices*” (i.e., no STBs) is included as it is viewed as a desirable
376 characteristic. STBs have been associated with reactivity in individual horses (Bachmann et
377 al., 2003), breed of horse (Albright et al., 2009), breeding / genetic predisposition (Albright et
378 al., 2009) and suboptimal management (Cooper and Albentosa, 2005; Cooper and Mason,
379 1998). Suboptimal management includes stabling with no or limited turnout (the opportunity
380 to move freely and usually graze typically in a grass paddock) (Visser et al., 2008) and

381 suboptimal management conditions (Cooper and Albentosa, 2005). Nagy et al. (2010)
382 reported that professional riders believe stereotypic horses can demonstrate learning
383 characteristics which they consider advantageous to competitive performance (Roberts et al.,
384 2015). Professional riders are focused on competition success (Wolframm et al., 2015) and
385 should also be skilled in riding and handling more challenging horses which stereotypic
386 individuals could represent. One could argue that the competitive potential of an individual
387 horse could outweigh negative aspects leisure and amateur riders associate with STBs.

388 Elite human athletes, including riders, have been shown to possess different personality traits,
389 including increased extroversion, compared to people who participate in sport for fun (Allen
390 et al., 2011; Wolframm et al., 2015; Woodman et al., 2010). Extroversion is characterized by
391 an increased tendency for excitability in humans (Wolframm et al., 2015). If the hypothesis is
392 that STB horses possess more reactive personalities, they may also be considered as having
393 extroverted personalities and possessing a suitable temperament for competition (Ichiji et al.,
394 2013). Competitive riders may value extrovert characteristics that they recognize from self-
395 reflection and feel have a positive effect on performance, when selecting their equine partner,
396 so the presence of STB is not a key consideration.

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

403 Differences in the frequency of STB expression have been reported across equestrian
404 disciplines (Hausberger et al., 2009) and associated with more intensive management

405 systems (for example, dressage and eventing, integrating restricted turnout and low forage
406 diets) compared to management systems involving more turnout and higher forage diets
407 (slow release energy) (such as endurance horses) (McGreevy et al., 1995). Normando et al.
408 (2002) make the point that English horse management systems (referring explicitly to
409 restrictive stabling practices) and riding precludes increased expression of STB, and apparent
410 lack of progress is confirmed by their reiteration of the same point almost a decade later
411 (Normando et al., 2011). Stress has been associated with riding practices, and is thought to be
412 key factor within the aetiology of equine STB (Mills et al., 2002; Normando et al., 2011). In
413 reality, it is likely that multiple environmental stressors trigger the occurrence and display of
414 STB in horses, so all factors which could cause negative/harmful stress, including not
415 allowing horses to demonstrate their STBs, should be considered when managing horses for
416 optimal performance.

417

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

429 in learning and reward-motivated behavior, changes in dopamine pathways could influence
430 equine behavior and performance (McBride and Parker, 2015).

431 Comparisons of stereotypic and non-stereotypic horses' ability to learn new tasks have
432 demonstrated that stereotypic horses demonstrate a poor extinction capacity and accelerated
433 and more reinforced (stronger) learning than their non-stereotypic counterparts (Ninomyia,
434 2007). Stereotypic horses then require more to unlearn what was taught (either intentionally
435 or indeed accidentally) (Hemmings et al., 2007; Parker et al., 2008; Roberts et al., 2015).
436 Roberts et al. (2015) demonstrated that although both oral- and locomotor- stereotyping
437 horses exhibit increased dopamine sensitivity, differences exist between their learning
438 performances. Horses that performed oral STB learned tasks more quickly and took longer to
439 achieve extinction than horses which performed locomotor STB. This work supports
440 professional riders' views that stereotypical horses, in particular those that crib-bite (refer to
441 Roberts et al, 2017 in this issue), possess a heightened learning ability or as some perceived
442 increased intelligence (Roberts et al., 2015; Williams, 2013).

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

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

463

464 *Conclusion*

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

476 Performance is a complex phenomenon with any species and multiple endogenous and
477 exogenous factors will contribute to success at any one time. Research is required that

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

493

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505

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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 temperament. | Trainability, placings, winnings. |
| Rodeo | Audience noise. Equipment (bucking straps) | Time to dislodge rider and quality of bucking / leaping. |

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|-------------------------------|---|--|
| 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. Inexperienced / 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 <i>good</i> 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. |

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|----------------------------|--|-------------------------------|
| 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. |

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800 **Figure captions**

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

