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Neural modulators of temperament

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1 Neural Modulators of Temperament: a multivariate approach to personality trait
2 identification in the horse

3

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15 Agricultural University

16

17 ABSTRACT

18 A relationship between dopamine and temperament has previously been described in
19 human cases of dopaminergic dysfunction. Adjustment in temperament prior to
20 disease manifestation can enable the early identification of individuals at risk of such
21 conditions, and scope exists to extend this application of temperament alterations to

22 cases of dopaminergic dysfunction in horses. A multivariate and mixed-methods
23 approach utilising a questionnaire along with two inferred measurements of dopamine
24 activity (Spontaneous Blink Rate [SBR] and Behavioral Initiation Rate [BIR]) were
25 recorded from direct observation of animals (n=99) to identify the potential relationship
26 between dopamine and temperament in horses. Principal components analysis (PCA)
27 of 36 temperament variables revealed nine Principal Components, including 'Anxiety'
28 and 'Docility', which accounted for 72.4% of the total variance. Component scores were
29 calculated and correlated with SBR and BIR utilising Spearman Rank Correlation
30 Coefficient analysis. The component 'Anxiety' was found to have a significant positive
31 relationship with SBR, whereas 'Docility' was observed to have a significant negative
32 relationship with SBR. These results indicate a relationship between dopamine and
33 temperament within the horse that is certainly worthy of further study. Potential
34 mechanisms involving neural dopaminergic and GABAergic systems are presented, in
35 addition to how such alterations could be utilised to probe for equine dopamine
36 dysfunction pending future research.

37 Highlights

- 38 • A significant positive correlation was observed between 'Anxiety' and dopamine levels
- 39 • A significant negative correlation was found between 'Docility' and dopamine levels
- 40 • Chronic dopamine adaptations may initially manifest as temperament alterations
- 41 • Potential exists to identify horses at risk of dopamine dysfunction development through
42 analysis of temperament

43 Key words: Temperament; Dopamine; Equine; Behavior; Anxiety; Docility

44

45

46 **1.0 Introduction**

47 Equine temperament is defined as any characteristic of an individual which emerges at a
48 young age and appears to be stable, over both time and situation (Lansade & Simon, 2010).
49 However, this could neglect the distinct behavioral manifestation of temperament. Indeed,
50 Stur (1987) suggested temperament is the sum of inherited and learned behavior patterns,
51 whilst Kilgour (1975) highlights the distinct physical, hormonal and nervous characteristics of
52 an animals' temperament. It is the combination of temperament and environmental conditions
53 which are proposed to amalgamate as equine personality (see Randle, 2015). Temperament
54 is of importance for the performance and leisure horse, for competition success as well as
55 improving equine welfare and understanding (Visser *et al.*, 2001; Randle, 2015). It is perhaps
56 for this reason that a plethora of temperament research does exist for the horse, utilising both
57 questionnaire and behavior methodologies (Seaman *et al.*, 2002; Momozawa *et al.*, 2003;
58 Visser *et al.*, 2008). Whilst a number of studies have investigated learning and memory
59 functioning in horses in relation to temperament traits (Lansade & Simon, 2010; Lansade *et*
60 *al.*, 2013; Valenchon *et al.*, 2013), the way in which this relates to neural functioning has not
61 been investigated. This is perhaps surprising given Kilgour's (1975) early reference to
62 'nervous organisation' in his temperament definition, as well as the influence of prefrontal,
63 striatal and hippocampal circuitry on such tasks (Izquierdo & Medina, 1997; Seger & Cincotta,
64 2005; Cartoni *et al.*, 2013).

65
66 Of particular interest to date is the relationship between the neurotransmitter dopamine (DA)
67 and its role in temperament manifestation, with specific reference to human conditions of DA
68 dysfunction, such as Parkinson's disease (PD), a hypodopaminergic condition (Burch &
69 Sheerin, 2005). An interesting aspect of PD onset is the emergence of a pre-morbid

70 personality which can predate the emergence of motor symptoms, in some instances by
71 decades (Todes & Lees, 1985). Indeed, PD patients often present with stoic, rigid and slow
72 temperaments as a part of this characteristic parkinsonian personality (Dagher & Robbins,
73 2009), whilst also demonstrating low novelty seeking scores (Kaasinen *et al.*, 2001). This
74 alteration in temperament has previously been linked to the hypodopaminergic characteristic
75 of PD, though some conflicting evidence does remain (Kaasinen *et al.*, 2001).

76
77 In contrast, patients who exhibit schizophrenia, a hyperdopaminergic condition (Breier *et al.*,
78 1997) demonstrate an increased prevalence for anxiety disorders (Pallanti *et al.*, 2004; Achim
79 *et al.*, 2009). Moreover, anxiety is thought to contribute as part of the prodromal stage of
80 schizophrenia (Park *et al.*, 2016). When considered in the context of the proposed
81 mechanism of anxiogenic drugs which ultimately elevates neural DA levels (Cancela *et al.*,
82 2001), this suggests that chronic DA reduction or elevation can manifest as a significantly
83 altered temperament.

84
85 Horses can also present with hyper- and hypo-dopaminergic conditions, including stereotypic
86 behaviours (SB; McBride & Hemmings, 2005; Roberts *et al.*, 2015) and pituitary pars
87 intermedia dysfunction (PPID; McFarlane *et al.*, 2005), respectively. Interestingly, there is
88 also an observation that horses with PPID present with significant alterations in temperament,
89 including an increase in depression, lethargy and apathetic manifestations with disease
90 progression (Bradaric *et al.*, 2013). However, this temperament alteration has not yet been
91 linked with the reduction of DA which occurs within these animals. Furthermore, in the light
92 of the pre-morbid personality associated with PD and anxiety within the prodromal phase of
93 schizophrenia, it is plausible that dopaminergic alterations could manifest prior to

94 conventional diagnosis through analysis of temperament traits. This approach would however
95 need to proceed mindful of the balance between genotypic determination of temperament
96 and subsequent environmental modification of behavioural output. Whilst temperament and
97 personality type research has been conducted in horses (for example see Momozawa *et al.*,
98 2003; Momozawa *et al.*, 2005a; Lloyd *et al.*, 2007, Nagy *et al.*, 2010; Ijichi *et al.*, 2013), the
99 way in which the result of this relates to dopaminergic function has yet to be determined
100 empirically. Interestingly however, Momozawa *et al.* (2005b) observed a significant
101 relationship between *DRD4* (dopamine D4 receptor subtype) single nucleotide
102 polymorphism, an A-G substitution causing an amino acid change from asparagine to aspartic
103 acid (Hori *et al.*, 2013). Absence of the 'A' allele resulted in significantly increased 'Curiosity'
104 and lower 'Vigilance' scores than those with the 'A' allele (Momozawa *et al.*, 2005b). Whilst
105 persuasive of an influence of dopamine over temperament in the horse, the precise
106 mechanisms as to how the *DRD4* gene directly influences temperament in any species is
107 currently unknown and requires further research.

108

109 Previous research has demonstrated the successful utilisation of the proven DA correlates
110 spontaneous blink rate (SBR) and behavioral initiation rate (BIR) to investigate dopaminergic
111 function in oral and locomotor stereotypy in the horse (Roberts *et al.*, 2015), but as of yet no
112 links have been made to any temperament data. It is for this reason that SBR and BIR were
113 utilised here to examine the role of dopamine in the generation of temperament. A
114 questionnaire was used to gather temperament data due to previous validation of this
115 approach within the literature (Momozawa *et al.*, 2003; Momozawa *et al.*, 2005a; Lloyd *et al.*,
116 2007). Results of this study could provide a valuable basis for the early identification of horses
117 undergoing initial DA dysfunction thereby improving welfare through timely intervention.

118

119 **2.0 Methods**

120 *2.1 Sample Population Characteristics and Management*

121 A sample of 100 horses of varying backgrounds were sought, comprising 52 geldings, 44
122 mares and four stallions, aged 2-25 years (mean±SD 12.17±6.24 years) and included some
123 stereotypy performing horses (n=3 crib-biters, n=15 weavers, n=9 box walkers) due to
124 previously described linkage between SB, dopamine (Cabib & Bonaventura, 1997) and
125 temperament traits (Dagher & Robbins, 2009; Park *et al.*, 2016). All animals were recruited
126 through direct contact from private owners (n=40), and were kept at various locations in
127 Gloucestershire and Wiltshire, in the South West of England during the study period (June
128 2014-January 2015). In addition, these animals differed in terms of management regime,
129 breed (ranging from native breeds to sport horses) and use (from leisure to polo and
130 competition disciplines such as polo and dressage) in order to source a representative cross-
131 section of the UK horse population with the level of variance favoured for Principal
132 Component Analysis (Ijichi *et al.*, 2013). As such, selection criteria required that the horse
133 was free from acute clinical disease (excluding dopamine pathology) and able to be led from
134 a head collar and lead rope (Ijichi *et al.*, 2013).

135

136 *2.2 Equine Temperament Questionnaire*

137 Owners were asked to complete a two-part questionnaire. The first section of the
138 questionnaire was designed to collect information regarding the management and feeding
139 regime of each individual, along with factors (i.e. breed) shown by other studies to impact
140 upon temperament (Hausberger & Muller, 2002; Lloyd *et al.*, 2008). Section 2 was based on

141 previous equine temperament questionnaires (Momozawa *et al.*, 2003; Momozawa *et al.*,
142 2005a; Lloyd *et al.*, 2007). A 1-9 Likert scale was used to assess 41 temperament
143 descriptions. Each description was identified by a definition in order to ensure that participants
144 had an agreed understanding of the temperament term being used. For example the
145 temperament description '*Concentration*' was accompanied by the definition '*is trainable and*
146 *undisturbed by the environment*'. All of the chosen temperament descriptions were selected
147 from the aforementioned studies, though some were omitted due to repetition or irrelevance
148 with reference to dopamine. One additional temperament description '*Impulsive*' with
149 accompanying definition '*tends to act without forethought, regardless of the consequences*'
150 was added, as impulsivity is thought to be characteristic of abnormal behaviors such as
151 stereotypy (Garner & Mason, 2002) and has links back to dopamine transmission (Cools,
152 2008).

153

154 *2.3 Spontaneous Blink Rate Observation*

155 The method to assess SBR for all of the horses has previously been described in Roberts *et*
156 *al.* (2015). To reduce stress for the animal during observations, all horses had visual contact
157 with conspecifics. The purpose of this was for both ethical reasons i.e. not to isolate a social
158 species, but also to avoid artificially inducing alterations in the horses SBR due to external
159 factors. Each horse was stabled in their home stable and habituated to the researcher's
160 presence by having the researcher stand calmly outside the stable with the horse in full view
161 for 10 minutes prior to the observation period. Following the 10 minute habituation period,
162 continuous method sampling was utilised where each full blink (defined by Karson (1983) as
163 bilateral paroxysmal brief repetitive eye closures occurring continuously) was recorded with
164 a mechanical counter for 30 minutes. Considering the anatomy of the horse, it was difficult

165 for a solo observer to record true bilateral eye closures, so only the left eye was observed for
166 all horses. As such, the horses head collar remained on throughout to ensure the horse
167 remained in position in such a way that the observer had full view of the horses left eye whilst
168 outside the stable at all times. This procedure was repeated in the same manner over three
169 consecutive days, allowing a mean SBR/30minutes to be calculated for each horse.

170

171 *2.4 Behavioral Initiation Rate Observation*

172 This procedure has previously been described for use in the horse by Roberts *et al.* (2015),
173 based on BIR observations of bank voles (Garner & Mason, 2002). The horse was stabled
174 within their home stable and habituated to the observers' presence for 10 minutes as
175 described in Section 2.3. Following habituation, each behavioral initiation was recorded by
176 continuous sampling utilising a mechanical counter for 30 minutes where the observer was
177 positioned outside of the stable though with full view of the horse. All behaviors performed
178 were defined by a pre-determined ethogram (McDonnell, 2003), and similar to Garner and
179 Mason (2002) only the number, not the type, of behaviors was recorded. Furthermore, each
180 bout of behavior was recorded as one initiation irrespective of the previous behavior,
181 consequently the sequence 'Feeding – Grooming – Feeding – Drinking – Standing Rest' was
182 recorded as four initiations (Garner & Mason, 2002; Roberts *et al.*, 2015). Thus, movement
183 made as part of an identifiable behavior, for example lifting of the head whilst still undergoing
184 mastication as part of feeding was accepted as part of the behavior and therefore not
185 recorded as an initiation of a new behavior (Roberts *et al.*, 2015). Recording of stereotypic
186 behaviors was considered in terms of bouts of behavior, i.e. regardless of the number of
187 weaves produced, each single bout of weaving was recorded as one behavioral initiation.

188 BIR recording was repeated over three consecutive days in the same manner, allowing a
189 mean BIR/30minutes to be calculated for each horse.

190

191 *2.5 Statistical Analysis*

192 A PCA was carried out with varimax rotation on all questionnaire items. Components with
193 eigenvalues ≥ 1 were retained. Component loadings of ≥ 0.4 within each component were
194 considered significant (McGrogan *et al.*, 2008) and checked for PCA suitability with the
195 Kaiser-Myer-Olkin (KMO) statistic. The Anderson-Rubin method for standardising component
196 scores was applied to ensure that all component scores were directly orthogonal. Once
197 component scores had been calculated for every horse for each temperament component,
198 these were then correlated with the horses' mean SBR and BIR utilising a Spearman Rank
199 Correlation Coefficient, similar to that conducted previously utilising both behavioral and
200 questionnaire measures (Lloyd *et al.*, 2007). Mean SBR and BIR values were also calculated.
201 A second PCA was conducted to investigate SBR and BIR as contributory towards
202 component structure i.e. if for example SBR contributed towards a particular temperament
203 component. To examine if sex, breed and usage had an influence on temperament and
204 dopamine correlate data, Kruskal-Wallis with post-hoc pairwise comparisons and Bonferroni
205 correction, or Mann-Whitney U tests where appropriate, were undertaken. To decipher
206 whether median or mean-rank was presented, visual inspection of the box-plots produced via
207 SPSS were utilised. Where distributions were similar median values were presented, though
208 when distributions were dissimilar, median-ranks were utilised. Breeds were categorised into
209 pony/cob types (14.2hh and under), sport horse types (light breeds e.g. Thoroughbreds
210 14.3hh and over) and draught horse types (heavy breeds e.g. Irish Draught 14.3hh and over).
211 Uses were categorised as leisure, so called traditional 'sports' disciplines (dressage, show

212 jumping and cross-country jumping) or polo dependent on the horse's primary purpose. The
213 significance level was set at $p < 0.05$. All statistical analyses were conducted in IBM SPSS
214 version 22.

215

216 **3.0 Results**

217 *3.1 PCA Data*

218 A 99% return rate was achieved from the questionnaires, only animals with which
219 temperament data were available were utilised for subsequent analysis, giving a total of $n=99$.
220 Initially, all 41 temperament variables were utilised to perform the PCA. Five temperament
221 traits (Timidity, Sociable, Protective, Subordinate and Permissive) were deemed unreliable
222 following examination of the KMO statistic and were consequently removed from further PCA
223 analysis. When the PCA was conducted with the remaining 36 temperament descriptions,
224 nine components were extracted accounting for 72.4% of the total variance (see Table 1).
225 The names of the components were derived from examination of the individual temperament
226 definitions which contribute towards a component (Table 2). Previous research was also
227 taken into account (Momozawa *et al.*, 2003; Momozawa *et al.*, 2005; Lloyd *et al.*, 2007; Nagy
228 *et al.*, 2010; Ijichi *et al.*, 2013; See Appendix 1). As such, the components were named as
229 follows, in descending order of percentage variance explained; 'Anxiety', 'Trainability',
230 'Excitability', 'Docility', 'Inquisitiveness', 'Irritability', 'Self-Reliance', 'Horse-Horse Interaction'
231 and 'Horse-Human Interaction'.

232

233

Table 1. The total variance explained by the 9 extracted components

Component Name	Component Number	Total	Initial Eigenvalues		235
			Variance (%)	Cumulative (%)	
Anxiety	1	11.415	31.708	31.708	236
Trainability	2	4.058	11.274	42.981	
Excitability	3	2.418	6.716	49.697	237
Docility	4	2.027	5.631	55.329	
Inquisitiveness	5	1.596	4.433	59.762	238
Irritability	6	1.302	3.617	63.379	
Self-Reliance	7	1.131	3.143	66.522	238
Horse-Horse Interaction	8	1.073	2.981	69.503	
Horse-Human Interaction	9	1.049	2.913	72.415	

239

240 The mean (\pm SEM) SBR/30 min was found to be 547.72 ± 15.66 , whilst the mean (\pm SEM)
 241 BIR/30 min was 24.94 ± 2.30 . The lowest value for SBR/30 min was 243, whilst the highest
 242 was 1140, whereas the smallest value for BIR/30 min was 1 though the highest was 133. The
 243 Spearman rank correlation coefficient analyses determined that the temperament component
 244 'Anxiety' was positively correlated with SBR ($r_s(97) = 0.202$, $p = 0.045$) and 'Docility' was
 245 negatively correlated with SBR ($r_s(97) = -0.215$, $p = 0.032$). There were no significant
 246 correlations between temperament traits and BIR.

Table 2. The component loadings for each of the 9 extracted components. Component 1, Anxiety; Component 2, Trainability; Component 3, Excitability; Component 4, Docility; Component 5, Inquisitiveness; Component 6, Irritability; Component 7, Self-Reliance; Component 8, Horse-Horse Interaction; Component 9, Horse-Human Interaction.

Temperament Trait	Component								
	1	2	3	4	5	6	7	8	9
Nervousness	.820								
Concentration		.647							
Self_reliance			-.434				.644		
Trainability		.793							
Excitability	.528		.499						
Friendliness_people									.859
Friendliness_horse								.777	
Curiosity	-.452				.402				
Memory		.816							
Panic	.768								
Cooperation		.636							
Inconsistent	.481						.582		

Stubbornness				.665	
Docility			.766		
Vigilance	.440			.421	
Patience	.406		.588		
Competitiveness					-0.632
Skittishness	.687				
Active		.595			
Impulsive	.447		.675		
Apprehensive	.767				
Confident	-.660				
Eccentric		.583			
Equable	-.416		.522		
Fearful	.855				
Irritable				.536	
Opportunistic				.556	
Playful				.752	
Popular					.550
Slow			.708		
Solitary					.812
Tense	.686				
Suspicious	.776				
Reliable	.417				
Hardworking	.775				
Intelligent	.706				

248

249 Whilst the second PCA resulted in the dopamine correlates contributing to their own
 250 component, analysis of the KMO statistics revealed that neither SBR nor BIR were suitable
 251 for PCA ($p < 0.05$). The PCA was disregarded due to the unreliability of SBR and BIR as
 252 contributory variables to overall temperament components.

253

254 3.2 Effect of Sex

255 Distributions of temperament traits and dopamine correlates were similar as assessed by
 256 visual inspection. Median 'Anxiety' score for mares ($n=44$; -0.54) versus geldings ($n=55$; 0.05)
 257 were significantly different ($U = 1534$, $z = 2.282$, $p = 0.023$). Furthermore, median
 258 'Inquisitiveness' scores for mares (-0.23) was significantly lower than geldings (0.09) ($U =$

259 1489, $z = 1.965$, $p = 0.049$). Likewise, median 'Horse-Human Interaction' scores were
260 significantly lower for mares (-0.13) than geldings (0.39) ($U = 1654$, $z = 3.127$, $p = 0.002$). No
261 other significant differences were observed between mares and geldings for temperament
262 components or dopamine correlates.

263

264 3.3 Effect of Breed

265 Distributions of temperament and dopamine correlates were not similar for pony/cob types
266 ($n=33$), sport horse types ($n=60$) and draught types ($n=6$) as assessed by visual inspection
267 of the box-plot, thus mean-ranks are provided. SBR ($\chi^2 (2) = 6.872$, $p = 0.032$), 'Anxiety' (χ^2
268 ($2) = 8.665$, $p = 0.013$) and 'Excitability' ($\chi^2 (2) = 12.916$, $p = 0.002$) scores were significantly
269 different between the three breed categories when corrected for ties. Pairwise comparisons
270 with Bonferroni correction revealed significant differences in SBR between pony/cob types
271 (39.35) against sports horse types (55.61; $p = 0.027$) though no difference was found between
272 draught types (52.50) against either pony/cobs ($p = 0.907$) or sport horses ($p = 1.000$).
273 Similarly, pony/cob types demonstrated a significantly lower mean rank 'Anxiety' score
274 (39.36) than sport horse types (56.85; $p = 0.015$). No difference was observed between
275 draught types (40.00) compared to pony/cob types ($p = 1.000$) or sport horse types ($p =$
276 0.512). A significantly lower 'Excitability' mean rank for pony/cob types (38.58) compared to
277 sport horse types (58.23; $p = 0.005$) was also observed. There was no difference between
278 draught types (30.50) with either pony/cob types ($p = 1.000$) or sports horse types ($p = 0.072$)
279 and no further differences were observed for BIR nor any of the remaining seven
280 temperament components.

281

282 3.4 Effect of Use

283 Distributions of temperament and dopamine correlates were similar for leisure (n=56),
284 traditional sports discipline (n=27) and polo (n=19) horses as assessed by visual inspection
285 of the box-plot, thus median values are provided. 'Anxiety' (χ^2 (2) = 9.418, p = 0.009),
286 'Excitability' (χ^2 (2) = 8.138, p = 0.017) and 'Inquisitiveness' (χ^2 (2) = 6.002, p = 0.05) were
287 significantly different between the three use categories when corrected for ties. Pairwise
288 comparison with Bonferroni correction highlighted that the leisure animals demonstrated a
289 lower median 'Anxiety' score (-0.21) compared to sport discipline horses (0.50; p <0.009).
290 No significant difference was observed for median 'Anxiety' score between polo horses (-
291 0.01) and leisure (p = 0.335) nor traditional sports discipline animals (p = 1.000). Leisure
292 animals demonstrated a lower median 'Excitability' score (-0.36) compared to traditional
293 sports discipline horses (0.49; p = 0.019). Polo animals median score (-0.30) showed no
294 significant difference between either leisure (p = 1.000) or sports discipline horses (p = 0.112).
295 Furthermore, leisure animals demonstrated an increased median 'Inquisitiveness' score
296 (0.06) compared to polo horses (-0.51; p = 0.049), though no difference was apparent
297 between traditional sports discipline horses (0.09) and leisure (p = 1.000) or polo animals (p
298 = 0.130). No other temperament traits, SBR or BIR were found to demonstrate statistical
299 significance between uses.

300

301 4.0 Discussion

302 The combined PCA and correlational analysis supported the hypothesis that one known
303 measure of inferred DA activity (SBR) is correlated with the two temperament components
304 'Anxiety' and 'Docility', a finding not yet reported in the equine literature, although the range
305 of SBR data gathered is roughly in-line with our previous work (Roberts *et al.*, 2015). SBR is

306 correlated with striatal DA levels, with increases indicating higher, and decreases lower,
307 levels of production and release of DA (Kaminer *et al.*, 2011). Therefore, our data suggest
308 that SBR may not only be a potentially useful predictor of central dopamine function in relation
309 to behavioral output and as a risk factor for onset of pathology, but also as a proximate
310 predictor tool. Furthermore, given that SBR does not appear to contribute to temperament
311 traits themselves, this could indicate the suitability of SBR as a potential measure of
312 underlying temperament components as opposed to being a direct causal factor.
313 Temperament and personality have previously been cited as highly influential for horse
314 purchase and breeding, and a need to incorporate an objective temperament assessment
315 identified by Graf *et al.* (2013). Thus the use of SBR as part of pre-purchase veterinary
316 examination may allude to the temperament of the animal and be beneficial to the horse
317 owning population. Indeed, improved understanding of equine temperament prior to purchase
318 could benefit human safety, given that unanticipated horse behavior was highlighted as a
319 contributory factor in 61% and 39% of injuries in children under 15 and adults above 15
320 respectively (Northey, 2003).

321

322 4.1 'Anxiety' and Dopamine

323 Due to the causal links between stress and DA (Cabib *et al.*, 1998), it is possible that anxious
324 horses are more sensitive to environmental stressors, such as restricted feeding or social
325 isolation; common stressors faced by stabled horses (McAfee *et al.*, 2002; Ninomiya *et al.*,
326 2007). Underlying this increased responsiveness to stress, the anxious individuals may have
327 elevated striatal DA in comparison to less anxious animals kept under the same
328 environmental conditions. This could allow the initiation of active coping in an attempt to gain
329 control over the environment, similar to the elevated dopamine levels observed in the active

330 coping DBA mouse strain (Cabib & Bonaventura, 1997; Cabib & Puglisi-Allegra, 2012). A
331 similar process could be occurring with the anxious horses, as evidenced by the elevation in
332 SBR in these individuals.

333

334 From a mechanistic standpoint, when DA agonists are administered, there is a partnership
335 between the elevation of DA levels and the emergence of behaviors characteristic of anxiety
336 (McCullough & Salamone, 1992; Cancela *et al.*, 2001). This DA elevation appears to result
337 from GABA disinhibition at the level of the midbrain i.e. the ventral tegmental area (VTA)
338 (Biggio *et al.*, 1990; Nikulina *et al.*, 2005). A similar progression could also be apparent in
339 environmentally induced anxiety. For example in rodents chronic stressors such as restricted
340 feeding, social isolation and restricted locomotion are known to induce mu-opioid proliferation
341 (Nikulina *et al.*, 2005), and therefore resulting in GABA disinhibition, in addition to
342 sensitisation of the dopaminergic pathways (Cabib *et al.*, 1998). Combined, this could indicate
343 a relationship between mu-opioid receptor proliferation and GABAergic disinhibition, perhaps
344 giving rise to elevated DA. These chronic stressors are strikingly similar to those faced by the
345 stabled horse, and induce similar neural adaptations. For example, dopaminergic pathways
346 are suggested to be sensitised within stress-linked conditions of the horse including oral
347 (McBride & Hemmings, 2005) and locomotor stereotypy (Roberts *et al.*, 2015). Further
348 research indicates mu-opioid receptor density is significantly elevated within horses
349 displaying oral stereotypy at the VTA, as well as dorsal and ventral striatal regions (Hemmings
350 *et al.*, 2006). Thus, it is possible that in the more anxious animals, mu-opioid receptor
351 sensitisation and GABAergic disinhibition giving rise to DA elevation has occurred, or is well
352 underway. This could well be a perpetuating issue given that DA elevation within the
353 amygdala, a structure which also receives dopaminergic input from the VTA and is
354 characteristic for its fear gating and anxiety inducing functions, potentiates anxiety in both

355 rodent and human models (Kienast *et al.*, 2008). Additionally, this elevation in dopamine
356 effectively removes inhibitory control of the medial prefrontal cortex over amygdala function
357 (de la Mora *et al.*, 2010) giving rise to prolonged 'Anxiety' type responses. This could therefore
358 provide a mechanism by which elevated 'Anxiety' is observed in this population of horses
359 presenting with raised SBR.

360

361 Importantly in rodents, persistent DA elevation is the final step to instigate active coping,
362 leading to stereotypy manifestation in stressed, captive animals (Cabib & Bonaventura,
363 1997). The emergence of an elevated 'Anxiety' type temperament in the horse could similarly
364 be indicative of significant underlying neural adaptations which pre-date stereotypy
365 development. Timely removal of key stressors could prevent progression to the stereotypic
366 behavioral end-point in this regard. Indeed, as neural sensitisation of DA appears to be
367 permanent (or at least recalcitrant) where rodent species are concerned, prophylaxis rather
368 than remediation is recommended (Cabib *et al.*, 1998). This latter point is particularly
369 important given the proposed habitual mechanisms of crib-biting behavior (Hemmings *et al.*,
370 2007; Parker *et al.*, 2009; Roberts *et al.*, 2015), and also with the highly motivated (albeit non-
371 habitual) phenotype thought to contribute to weaving behavior (Roberts *et al.*, 2015). Also of
372 interest with regard to environmentally induced stereotypy is that under improved
373 management regimes, which reduce chronic stress and potentially the normalisation of DA
374 levels within the neural circuitry, the high 'Anxiety' horses may then become more biddable
375 in the context of training and management. Indeed, the performance of increasingly anxious
376 type behavior is a part of the prodromal phase of schizophrenia (Park *et al.*, 2016) a hyper-
377 dopaminergic phenomenon. As such, the use of increasing anxiety is currently under
378 investigation as a potential predictor of an oncoming schizophrenic episode (Park *et al.*,

379 2016). In light of this evidence, it is plausible then that the more anxious horses are presenting
380 as such due to consistently elevated levels of the neurotransmitter DA.

381

382 However, when investigating the work completed by Nagy *et al.* (2010), an interesting
383 question arises. It was reported that crib-biting horses demonstrated a significantly lower
384 'Anxiety' score when compared to the control animals (Nagy *et al.*, 2010). Whilst this initially
385 appears to contradict what is being suggested here, the data reported by Nagy *et al.* (2010)
386 may in fact lend support. Crib-biting animals present as hypodopaminergic, as evidenced by
387 a significantly decreased SBR and significant reduction in caudate dopamine receptor
388 sensitivity (McBride & Hemmings, 2005; Roberts *et al.*, 2015). This is despite post-mortem
389 evidence of increased receptor sensitivity to dopamine within the nucleus accumbens
390 (McBride & Hemmings, 2005). This neural work supports the notion that SBR is a reflection
391 of midbrain DA transmission into the dorsal striatum (caudate nucleus) rather than the
392 ventrally sited nucleus accumbens (Taylor *et al.*, 1999). However, elevations in nucleus
393 accumbens DA are of significant behavioral relevance, and have been considered crucial to
394 the putative self-stimulatory stress reducing aspects of crib-biting. It may be that following the
395 onset of a stress coping function i.e. crib-biting performance, leads to the diminishing anxiety
396 in crib-biting animals as reported by Nagy *et al.* (2010). Indeed, recent evidence appears to
397 support the stress coping function of crib-biting (Freymond *et al.*, 2015). Overall then, it is
398 plausible that initial elevations in DA could manifest as increased 'Anxiety', though potentially
399 following the development of stereotypy as a part of the behavioral repertoire 'Anxiety' could
400 decrease, at least in crib-biting horses. Further research would be required to investigate
401 such an effect in weaving animals.

402

403 4.2 'Docility' and Dopamine

404 'Docility' was negatively correlated with SBR, and thus inferred levels of DA activity. A
405 comparative phenomenon is observed in the inbred mouse strain C57, whereby in response
406 to an inescapable stressor, a net reduction in DA transmission leads to reduced anxiety linked
407 behaviors such as locomotion (Cabib, 2006; Cabib & Puglisi-Allegra, 2012). Rather than the
408 often quoted pathological condition of learned helplessness, the depressed activity in the C57
409 strain is thought to signal a passive form of coping, which promotes energy thriftiness in the
410 face of insurmountable stress (Cabib & Puglisi-Allegra, 2012). The reduced SBR which
411 accompanies 'Docility' in the data reported herein, could well indicate a similar strategy is
412 adopted by the horse in response to persistent low level stressors such as restricted
413 locomotion and social isolation.

414

415 From a pathology prediction standpoint, in stark contrast to those with conditions
416 characterised by elevated DA such as schizophrenia and drug addiction, human patients with
417 PD typically present with personalities which are categorised as stoic, rigid and slow-
418 tempered (Dagher & Robbins, 2009). Novelty-seeking type behaviors are also reduced in PD,
419 with twin studies also demonstrating that individuals who later develop Parkinson's are more
420 self-controlled than their non-affected twin (Menza, 2000). It is thought that the emergence of
421 such traits are directly related to underlying degeneration of DA containing neurons (Kaasinen
422 *et al.*, 2001). When considering the individual temperament variables 'slow' and 'patient'
423 which contribute to the 'Docility' temperament trait in this cohort of horses (Table 2), it is
424 reasonable to propose that the more 'docile' horses are also more slow-tempered and self-
425 controlled. Parallels could be drawn between Parkinson's disease personality and conditions
426 of the horse which feature reduced DA such as PPID. Typically, PPID is suspected when

427 overt symptoms, such as hirsutism and hyperhidrosis are observed in combination with
428 advancing age, at which point it is likely that the influence of elevated proopiomelanocortin
429 (POMC) peptide levels are already having a significant detrimental effect on health
430 (McFarlane, 2011). Indeed, ACTH is characteristically elevated in PPID horses prior to
431 pharmacological treatment, with this posing long term health issues leading to reduced
432 welfare status of the animal (Durham *et al.*, 2014). Early intervention with regards to PPID
433 development could be essential for prolonged quality of life and improved welfare (McFarlane
434 *et al.*, 2011). Despite this, there is a lack of peer reviewed publications specifying the early
435 indicators of PPID, which when treated earlier could significantly improve prognosis and
436 prevent life threatening consequences of the disease (McFarlane *et al.*, 2005). Therefore, our
437 finding that a decrease in SBR is correlated with higher 'Docility' could provide an important
438 early indicator for those at risk of PPID development. This is of significance given that
439 depression, lethargy and an apathetic outlook are observed following PPID diagnoses
440 (Bradaric *et al.*, 2013), and could therefore link towards a more 'docile' temperament. Thus,
441 should the horse demonstrate an uncharacteristic alteration in temperament by increasing in
442 'Docility', this may signify that there are alterations with regards to DA physiology that could
443 indicate the development of PPID. This is highly noteworthy, as previously McFarlane (2011)
444 suggested that observed docility was due to increased beta-endorphin circulation. In light of
445 the findings here however, it seems probable that increased 'Docility' is a reflection instead
446 of DA reduction. Taken together, should the owner notice elevated 'Docility' even in the
447 absence of PPID symptomology, an in-depth endocrine work up should certainly be
448 considered, but also proposes an interesting area for further research.

449

450 *4.3 Effect of Breed, Use and Sex*

451 Pony/cob types were found to have significantly reduced SBR, 'Anxiety' and 'Excitability'
452 scores than sports horses. In other studies (see Cabib & Puglisi-Allegra, 2012) utilising
453 rodents, decreased dopamine release is associated with a passive, less active stress coping
454 style. Decreased SBR, along with lower 'Anxiety' and 'Excitability' as observed here
455 constitutes evidence for a similar phenomenon in the horse. On the other hand, our data is
456 somewhat at odds with the work of Lloyd *et al.* (2008) who observed similar 'Anxiousness'
457 and 'Excitability' in both welsh ponies and cobs compared to Thoroughbreds and Arabs.
458 However, Lloyd *et al.* (2008) formed sample groups based on breed rather than the more
459 generalised type designation employed in this study, which may account for the discrepancy.

460
461 Interestingly, geldings scored significantly higher than mares for 'Anxiety', 'Inquisitiveness'
462 and 'Horse-Horse Interaction'. Duberstein and Gilkeson (2010) observed that mares were
463 more 'Anxious' than geldings, a finding directly opposing to the results presented here.
464 Whereas Le Scolan *et al.* (1997) previously found no significant difference between mares
465 and geldings with their study of equine temperament. It should be noted however, that both
466 of these previous studies utilised lower numbers of horses (n=18 and n=72 respectively)
467 which may account for the lack of inter-study agreement. Given the gender imbalance often
468 observed in some equine sporting disciplines (i.e. mares are generally favoured as polo
469 ponies) this area is certainly worthy of further investigation.

470
471 Finally, leisure animals were found to have significantly reduced 'Anxiety' and 'Excitability'
472 compared to those engaged in traditional sports disciplines, though had significantly elevated
473 'Inquisitiveness' scores than polo ponies. It could reasonably be postulated that polo ponies
474 and sport horses are more likely to be managed under environmental conditions (i.e. housing

475 and feeding regimen) that promote chronic stress potentially giving rise to the elevated
476 'Anxiety' and 'Excitability' along with the reduced 'Inquisitiveness' scores observed here.

477

478 **5.0 Conclusion**

479 This research is the first demonstration of a relationship between temperament and inferred
480 neural DA levels within the horse. Whilst this study cannot elucidate the precise underlying
481 mechanisms governing the DA and temperament relationship, extrapolation from previous
482 research provides a sound basis upon which to develop future work. The ability to utilise the
483 presentation of either increased 'Anxiety' or 'Docility' to indicate altered neural DA function at
484 an early stage could prove valuable for the welfare of at risk animals. The potential
485 ramifications of this work, and the group differences observed, therefore highlights this is an
486 area that warrants further research.

487

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491

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