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1 **ASSOCIATIONS BETWEEN COMMONLY USED APPARATUS AND CONFLICT BEHAVIORS**
2 **REPORTED IN THE RIDDEN HORSE IN AUSTRALIA**

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9 **Abstract**

10 Equestrian equipment is often used to maintain control of horses while riding, training or handling
11 them and therefore to optimize human and horse safety. However, equipment that has been
12 incorrectly selected or inappropriately used may result in horses exhibiting conflict-related behavior.
13 Characterising associations between apparatus use and unwelcome horse behavior could benefit both
14 horse welfare and human safety by elucidating the ontogeny of undesirable equine responses and
15 promoting the ethical use of equipment. The current study explored associations between commonly
16 used apparatus and the reported behaviors of the ridden horse, using an online survey that attracted
17 1101 Australian respondents. Chi-square tests of association revealed thirteen (9.1%) significant
18 relationships between any unwanted behavior and single items of apparatus used during riding.
19 Analysis of combinations of apparatus that impose aversive stimuli (e.g. harsh bits for deceleration,
20 and spurs for acceleration) revealed that 37.19% of combinations of such items were significantly
21 related to unwanted/conflict equine behaviors. Additional analysis demonstrated no significant
22 difference in the unwanted behavior of horses ridden in bitless versus bitted bridles. This study has
23 demonstrated associations between unwanted ridden behaviors and type of apparatus used,
24 particularly when multiple items are used to apply opposing aversive stimuli. Whilst these results do
25 not imply causation, they may be used to better inform equestrians' choice and ethical use of
26 apparatus.

27

28 **Keywords:** equine; welfare; tack; gear; bit; whip

29

30 **Introduction**

31 The role of the domestic horse has evolved with the advance of civilisation. Once used for
32 locomotion and agricultural power, horses now more commonly play roles in sport, leisure and
33 companionship (McGreevy et al., 2018b). The empirical study of horse handling, training and riding is
34 central to the nascent discipline of equitation science (McGreevy, 2007) and, as the impact of human
35 interventions on domestic horse welfare is being scrutinized (McGreevy et al., 2018a), the exploration
36 of what constitutes ethical equitation (Jones and McGreevy, 2010; Randle and Waran, 2019) is
37 increasingly important.

38 Horse-riding involves the rider establishing stimulus control over the horse's locomotory responses
39 (McLean and McLean, 2008) commonly using equipment, such as bits, bridles, whips and spurs, to
40 train the horse to respond in a particular way via negative reinforcement (NR). In NR, the horse learns
41 locomotory responses to these pressure cues (historically called aids) because they are associated
42 with the cessation of aversive stimuli. In correct NR, pressure cues should rapidly shrink to light signals
43 (the discriminative stimuli), and light cues should precede any stronger pressure (McGreevy et al.,
44 2018a). Whilst horses are skilled at responding to NR (McLean and Christensen, 2017), human error
45 in the application and removal of pressure, such as poor and/or inconsistent timing, can lead to
46 training-related stress, confusion, poor training outcomes, and compromised welfare. Simultaneous
47 application of acceleration and deceleration pressures of similar intensity increases the likelihood of
48 overshadowing and, ultimately, habituation to the least salient pressure (McGreevy et al., 2018b). The
49 simultaneous application of contradictory cues, e.g. that trigger both acceleration and deceleration is
50 contraindicated (McLean and McLean, 2008).

51 To cope with stressors, animals may attempt to remove themselves from discomfort, confront the
52 stressors, or adapt to them (Moberg and Mench, 2000). If unable to resolve conflicting or unrelenting

53 stimuli, horses may exhibit behavior indicative of a state of conflict or ultimately habituate to the
54 stimuli (McLean and McGreevy, 2010b). Mills and Marchant-Forde (2010) describe conflict behaviour
55 as “a category of stress-induced behavior changes that arise from conflicting motivations”. In the
56 ridden horse these may manifest as body tension, rearing, bolting, bucking or shying. Both conflict-
57 related behaviors and inadvertent habituation are undesirable in the context of the human-horse
58 relationship. In many competitive equestrian disciplines, such responses are associated with poor
59 performance and many directly attract penalties.

60 Doherty et al. (2017c) suggested some indicators of a horse’s pain, stress or fear go unnoticed by the
61 rider. Behaviors such as shying may also be misinterpreted as disobedience or a merely reflection of
62 the horse’s temperament, particularly in the context of equitation. Known conflict related behaviors,
63 such as rearing and bucking, may be clearly recognisable, but interpretation of both these behaviors
64 and their etiology is complex because their presentation may be influenced by numerous factors,
65 including rider/handler perception (Williams and Tabor, 2017). Behavioral responses to stimuli reflect
66 inter-individual differences in reactivity and sensitivity that are influenced by both genetic (Le Sclan
67 et al., 1997; Hausberger and Muller, 2002) and environmental factors or context (Søndergaard and
68 Ladewig, 2004; Hausberger et al., 2004).

69 Clinical indicators of relatively subtle pain responses, such as teeth-grinding, reluctance to perform
70 required movements and/or gait changes, muscular tension or atypical body posture may go
71 undiagnosed and minor problems may potentially escalate into more serious welfare issues (Hall et
72 al., 2013; Randle and Waran, 2017). Many common items of apparatus used in equitation, such as bits
73 and nosebands, are designed to apply aversive pressure to control and direct horses’ movement.
74 Other equipment, such as martingales or auxiliary reins, can use mechanical principles, such as
75 leverage, to amplify or redirect the pressure already being applied with the intention of preventing
76 the horse from evading the original pressures (McGreevy et al., 2018b). Even the most seemingly
77 innocuous equipment that are commonly considered ‘basic’ and even ‘kind’, such as the snaffle bit,
78 can be a source of abuse if used to apply pressure inappropriately, excessively or inconsistently. In

79 equitation, the human is responsible for the force and duration of aversive pressure applied. However,
80 studies of the direct impact of apparatus-related pressure upon horse behavior are in their infancy
81 (Doherty et al., 2017a; Randle et al., 2017). That said, numerous behaviors exhibited by the horse
82 under saddle are seldom observed outside the ridden context and should be valued among other
83 potential animal-based indicators of poor welfare (Randle and Waran, 2017). Increased interest in
84 animal welfare has drawn attention to potentially questionable ethics around some aspects of horse
85 use in sport and recreation (McLean and McGreevy, 2010a, McLean and McGreevy, 2010b) and public
86 scrutiny is intensifying with regard to social license to operate within racing (McGreevy and McManus,
87 2017) and many other sectors of the equine industry. Within this context, many training methods and
88 items of equipment, some of which have justifications based chiefly on tradition, are now being
89 questioned more deeply than ever.

90 Equestrian apparatus may, by design, be intrinsically aversive particularly when making physical
91 contact with extremely sensitive areas of the horse. Possibly exacerbated by selective breeding,
92 individual horses show considerable variation in sensitive loci. For example, some horses are
93 extremely 'head-shy' or 'girth-shy' while other individuals are seemingly oblivious to tactile contact in
94 these regions (McGreevy et al., 2018b). Most of the equipment used on horses has been designed to
95 benefit humans, providing comfort, stability and a means of controlling the ridden horse. All items
96 designed to transmit pressure in equitation can be sources of abuse if deployed inappropriately,
97 excessively or inconsistently.

98 Paleopathological studies have identified effects of horse-riding apparatus in ancient skeletal remains
99 of horses, including bit-wear on the jaw and teeth (Anthony and Brown, 2015) and abnormalities of
100 the postcranial skeleton indicative of the effects of riding and traction (Levine et al., 2000). There is
101 growing evidence that contemporary equipment used to control horses can inadvertently harm them
102 (Mata et al., 2015; Crago et al., 2019; Uldahl and Clayton, 2019; Weller et al., 2020).

103 In a survey of equestrian apparatus use in Australia, Hill et al. (2015) noted the use of milder bits,
104 designed to be less aversive than average, was associated with a reduction in the use of devices used

105 to accelerate the horse, notably whips and spurs. Correspondingly, relatively severe bits such as curbs,
106 designed specifically to apply stronger deceleration pressures, were often used in conjunction with
107 these accelerator devices. These findings raise questions about the use of such apparatus with opposing
108 effects, notably those designed to amplify pressures for either acceleration or deceleration, being
109 used simultaneously. When operator error, such as the delayed release of pressure, habituates horses
110 to pressure cues, then escalating the aversiveness with more severe items of gear offers only a short-
111 term solution at best. Unless the riders' errors are remediated, the perceived need for yet more severe
112 gear will eventually emerge.

113 Hockenhull and Creighton (2013) investigated the use of items of apparatus, with a focus on so-called
114 artificial aids, such as martingales, spurs and whips, in relation to owner-reported prevalence of ridden
115 behavior problems in a sample of UK leisure horses (n=1,326). Ninety-one percent of the horses were
116 reported as displaying unwanted behavior when ridden in the week preceding data submission.
117 Furthermore, 78% of respondents reported using one or more artificial aids when riding or handling
118 the horse on the ground (Hockenhull and Creighton, 2013). The widespread reported use of these
119 artificial aids is of concern if they escalate force without requiring optimal operation that avoids
120 excessive force and poor timing. While not inferring a direct causal relationship between apparatus
121 and behavior, Hockenhull and Creighton (2013) proposed that behavioral conflict may be exacerbated
122 by owners' attempts to address behavioral issues with apparatus that increases the intensity of
123 controlling signals.

124 The complex etiology of conflict behavior must be considered in the context of human-horse
125 relationships (McGreevy et al., 2009), most notably those associated with training and performance.

126 In addition, the collection of valid, reliable and scientifically robust data is difficult, being complicated
127 by numerous dynamic, confounding variables that exist within the horse-human dyad. It is worth
128 considering that unwanted behaviors may cluster together suggesting inter-relatedness. It is therefore
129 plausible that they may be triggered by, or result from, the use of similar items of apparatus. Indeed,
130 it is also possible that clusters of locomotory behaviors may trigger corresponding clusters of reactions

131 from riders that may include the use of items of gear that amplify pressure. Researchers and
132 practitioners alike are now questioning whether, in the absence of owners' having a thorough
133 understanding of the consequences of using increasingly aversive stimuli, behavioral conflict may be
134 exacerbated by use of such equipment (Hall et al., 2013; Heleski et al., 2009). Statistical testing can be
135 used to identify direct associations between apparatus use and horse behavior. If significant
136 associations between items of apparatus and undesirable horse behaviors exist, identification of these
137 relationships can benefit both horse welfare and human safety by informing owners about the range
138 of effects and consequences items of apparatus can have and providing information about its ethical
139 use.

140 The effect of bit pressure on the horse is complex, with multiple physical outcomes from increased
141 rein tension, beyond pressure on the tongue and diastema (Doherty et al., 2017b). Despite researchers
142 such as Cross et al., (2017) positing the physical effect of bit operation can be inferred from laboratory
143 testing, multiple variables may potentially affect the physical impact on the horse, including the bit
144 itself, the rider's hands and the anatomy of the horse's mouth. Meanwhile, arguments for bitless
145 bridles appear frequently in industry and practitioners' media (Cook and Mills, 2009), with the
146 suggestion that they are inherently more ethical than their bitted counterparts (Mellor and Beausoleil,
147 2017). Hence, the relationships among bitted bridles and unwanted horse behaviors may be of
148 particular interest. The current study investigated possible relationships among conflict behaviors
149 reported in the ridden horse in Australia and associations with commonly used apparatus.

150 **Materials and methods**

151 The raw data were collected by Hill et al. (2015) via an online questionnaire designed to audit
152 apparatus used to apply aversive stimuli to ridden horses and ponies in Australia. The study was
153 approved by the University of Sydney Research Ethics Committee (approval number 12396); the
154 questionnaire was available between 20th July 2012 and 26th September 2012. Further details and
155 preliminary results of this study have previously been published (Hill et al., 2015). A copy of the survey
156 is available as supplementary material.

157 The questionnaire asked for details of riding style and equipment used. A further set of data about
158 horse behaviors that were exhibited when ridden were collected using the same instrument. Since the
159 relationships between apparatus used and occurrence of unwanted/undesirable behaviors were not
160 analysed by Hill et al. (2015), the current study analysed data relating to ridden behavior and
161 accompanying apparatus to identify associations among them.

162 *Horse ridden behavior*

163 Respondents were asked about their horses' ridden behavior and provided with five possible options
164 for each response. The 11 ridden behavior statements provided were: *this horse pulls its head forward*
165 *and down when you are riding, this horse gets excited when he anticipates cantering, this horse never*
166 *bolts, this horse never bucks, this horse never rears, this horse never shies, this horse is very sensitive*
167 *to my leg cues, this horse needs strong leg cues to get into canter, this horse is very easy to steer, this*
168 *horse stops very easily, and this horse loves to jump obstacles.* Respondents were asked to use a 5-
169 point Likert response scale (from 0-4, where 0=never, 4=always) to indicate the frequency with which
170 the horse expressed the 11 listed behaviors. A "not applicable" option was also provided to reduce
171 the possibility of a non-response. To facilitate analysis, low, nominal values were merged and these
172 data recoded to binary responses (rankings 0 and 1 became 'no', and rankings 2, 3 and 4 became
173 'yes'). Responses left blank were excluded from the analysis.

174 *Apparatus applied*

175 Apparatus-related data included the broad range of equipment commonly used during equitation
176 activities. Respondents were asked about 13 categories of common apparatus and the type of
177 apparatus used within each category was recorded. (The number of options are shown in
178 parentheses.) Apparatus categories and type were: bit style (n=4); bit thickness (n=5); bit material
179 (preliminary analysis identified n=57 variations of bit material composition); bit mouthpiece type
180 (n=15); shank length (n=7); number of reins (n=3); chain or lip strap (n=6); noseband type (n=35);
181 auxiliary reins (n=5); martingale type (n=5); other auxiliary equipment (n=7); spur type (n=9) and whip
182 type (n=7). In any instance where the respondent gave more than one response, the item of apparatus

183 considered most aversive/restrictive according to criteria defined by McGreevy et al. (2018a) was
184 recorded. Responses that did not provide information on the type of apparatus used in each category
185 were eliminated from the analysis. Bridle use was also recorded as either bitted (n=729 respondents)
186 or bitless (n=132 respondents).

187 *Statistical analysis*

188 Using data shown in Figure 1 and Table 2, categories of responses detailing behavior (n=11) and
189 apparatus (n=13) were tabulated into 143 2 × 2 contingency tables using Minitab Statistical Software
190 version 18 (Minitab, LLC, State College, Pennsylvania, USA). Chi-square tests of association were
191 conducted on all variables. Initial analysis revealed no associations between any behavior and single
192 item of apparatus. Data on types of apparatus were then combined to reduce the number of variables
193 in each category, whilst still meeting validity requirements for chi-square tests. These then became
194 the following 13 factors: bit style (n=3: bitless, snaffle, double/Pelham); bit thickness (n=3: thin,
195 medium, thick); bit material (n=2: metal, other); bit mouthpiece type (n=3: jointed, no joint, other);
196 shank length (n=2: shank, no shank); number of reins (n=2: one pair, more than one pair); chain or lip
197 strap (n=2: either chain or strap, none); noseband type (n=3: halter, cavesson, other); auxiliary reins
198 (n=2: draw reins, other); martingale type (n=2: standing martingale, other); other auxiliary equipment
199 (n=2: martingale only, other); spur type (n=2: smooth, other) and whip type (n=2: dressage whip,
200 other). A further series of chi-square tests were run on these modified 143 contingency tables. To
201 investigate the possibility of an association between bitted *versus* bitless bridle use and behavior, chi-
202 square tests were conducted using a total of 861 responses; the apparent shortfall being attributed to
203 237 participants (21.6%) not providing data in response to the question of bitted/bitless bridle use.

204 The next analysis explored any associations between the expression of ridden behavior and apparatus
205 applying opposing aversive stimuli when used in combination. Apparatus categories were
206 concatenated to include accelerator devices (n=2), specifically whips and spurs, used concurrently
207 with decelerator devices (n=11), such as bits, nosebands, martingales and auxiliary reins (draw reins,
208 side reins, Whitaker reins, Pessoa® Training System, Market Harborough, tie-down, Chambon).

209 Contingency tables (n=121) were created relating behaviors (n=11) to apparatus that allows riders to
210 apply opposing aversive stimuli (n=11) and chi-square tests were performed on these behavior and
211 (concatenated) apparatus data. Significance was set as $P < 0.05$ *a priori*.

212

213 *Binary logistic regression*

214 A series of binary logistic regression models were constructed to identify risk factors associated with
215 the reporting of specific undesirable behaviors during ridden work. The variables to be fitted in the
216 multivariable models were first assessed using univariate analysis of binary response variables: *pulls-*
217 *head-forward-down*: yes or no, *very-sensitive-to-leg-cues*: yes or no, *needs-strong-canter-cues*: yes or
218 no, *gets-excited-anticipates-canter*: yes or no, *shies*: yes or no, *easy-to-steer*: yes or no, *easy-to-stop*:
219 yes or no, and *loves-to-jump-obstacles*: yes or no. A variable with an alpha value of < 0.10 was
220 considered eligible for use in building the multivariable models (Bailey et al., 1997). No significant
221 factors were related to the behaviors *pulls-head-forward-down*, *shies* or *easy-to-steer*, so five
222 multivariate models were built (Model A: *Very-sensitive-to-leg-cues*; Model B: *Needs-strong-canter-*
223 *cues*; Model C: *Gets-excited-anticipates-canter*; Model D: *Easy-to-stop*; Model E: *Loves-to-jump-*
224 *obstacles*; see Table 1). Each model was fitted using a backward stepwise process that excluded
225 variables with a likelihood ratio test significance of $P < 0.05$ (Parkin et al., 2006; Smith et al., 2018). For
226 each step in the multivariate model building process, the effect of removal of variables was assessed
227 using a likelihood ratio chi-square test of model coefficients ($P < 0.05$) to check that the new model
228 was an improvement on the baseline model (Williams et al., 2013; Smith et al., 2018). This ensured
229 that variables with a significant impact on the model were not excluded from further analysis. Hosmer-
230 Lemeshow goodness-of-fit tests ($P > 0.05$) were also used to evaluate the fit of the model (Williams et
231 al., 2013; Smith et al., 2018). The predictive ability of the final model was investigated using receiver
232 operating characteristic (ROC) curve analysis (Williams et al., 2013; Smith et al., 2018). The risk of the
233 behavior in question for each model being reported at an increased prevalence was compared using
234 the odds ratio (OR) and associated 95% confidence intervals (CI).

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Table 1: Multivariate models assessing the presence of specific undesirable behaviors during ridden work. Five multivariate models were built (Model A: *Very-sensitive-to-leg-cues*; Model B: *Needs-strong-canter-cues*; Model C: *Gets-excited-anticipates-canter*; Model D: *Easy-to-stop*; Model E: *Loves-to-jump-obstacles*)

Model	Factors taken forward to the final model ($P < 0.1$)
Model A: Very-sensitive-to-leg- cues	<p>Noseband type - Headcollar/halter (1- reference), Plain cavesson (2), Other (3)</p> <p>Noseband type and whip - Headcollar/halter (1- reference), Plain cavesson (2), Other (3), Whip (4), Headcollar/halterWhip (5), Plain cavessonWhip (6), OtherWhip (7)</p>
Model B: Needs-strong-canter-cues	<p>Lipstrap or chain or None - Yes chain or strap (1- reference), Neither chain or lip strap(2),</p> <p>Spur type - Smooth spurs(1- reference), Other(2)</p> <p>Other Auxiliary equipment and spurs – spurs (1 - reference), Martingale only(2), Other(3)</p>
Model C: Gets-excited-anticipates- canter	<p>Shank length and spurs – shank (1- reference), No shank(2), spurs(3), shankspurs(4), No shankspurs(5),</p> <p>Martingale type and spurs - spurs(1- reference), Standing martingale(2), Other martingale(3), Standing martingalespurs (4), Other martingalespurs (5)</p> <p>Other auxiliary equipment and spurs - spurs(1- reference), Martingale only(2), Other(3)</p> <p>Bit thickness and spurs – Any thickness bit no spurs (1- reference), Thin + spurs(2), Medium+spurs(3), Thick+spurs(4)</p>
Model D: Easy-to-stop	<p>Bit style and spurs - Any bit no spurs(1- reference), Snaffle+spurs(2), Double/Pelham +spurs(3),</p> <p>Number reins used and spurs - Only one(1 - reference), One setspurs(2), one or morespurs(3)</p>
Model E: Loves-to jump-obstacles	<p>Noseband type and spur</p> <p>Bit style and whip - snaffle (1 – reference), double/pelham (2), Bitless (3), snaffle + whip (4), double/pelham + whip (5), bitless+whip (6), whip (7)</p>

	Chain/lip strap and whip – neither chain, lip strap or whip (1-reference), neither chain or lip strap (2), whip (3), chain or strap (4), chain strap or whip (5)
	Aux reins and whip - draw reins (1-reference), draw reins and whip(2), whip (3), other whip (4), other (5)
	Martingale type and whip - standing martingale (1 – reference), standing martingale + whip (2), whip (3), other martingale (4), other martingale + whip (5)

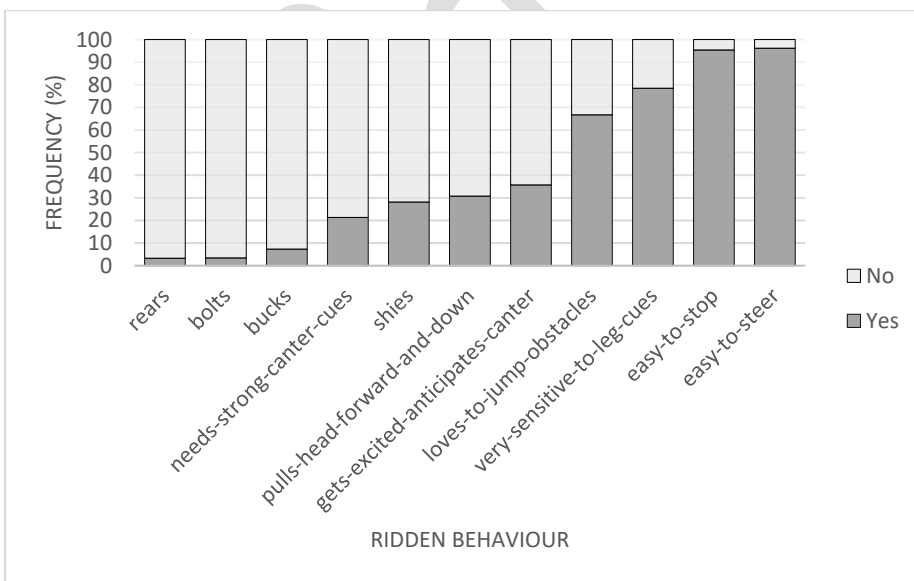
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243 **Results**

244 Data used for this study were derived from a total of 1101 survey responses by respondents
 245 over 18 years of age: 82.6% females (n=910), 17.1% males (n=188) and 0.3% (n=3) who did not disclose
 246 gender. The questionnaire collected details of main riding discipline and equipment/apparatus used
 247 and included a set of 11 behaviors horses exhibit when ridden.

248 *Horse ridden behavior*

249 Of the 1101 respondents, the majority (n=997) reported at least one problematic ridden behavior.
 250 Responses from the remaining 4 respondents were not used in further analysis. Horse ridden behavior
 251 frequency adjusted to binary responses are shown in Figure 1.



252

253 **Figure 1.** Frequency of horse ridden behaviors reported by 1101 respondents

254 *Apparatus applied*

255 The number of apparatus variables for both preliminary and secondary analyses are shown in Table 2,
 256 along with number of responses to each category of apparatus. Table 2 also shows the percentage of
 257 non-responses recorded as “no data”.

258 **Table 2.** Types of apparatus reported by 1101 respondents. Preliminary analyses were conducted on all variables
 259 using raw data from Hill et al. (2015). Data on types of apparatus were subsequently combined to reduce the
 260 number of levels and secondary analysis conducted. For example, in the preliminary analysis, variable bit style
 261 included 4 levels (bitless; snaffle; Weymouth/double bridle and curb/shank (Pelham)) and in the secondary
 262 analysis due to combining categories, variable Bit style had only 3 variables (bitless, snaffle and double
 263 bridle/Pelham).

Apparatus = VARIABLE	Number of levels in preliminary analysis	Number of levels in secondary analysis	Responses	Responses (%)	*(no data)	*(% of no data)	Total responses
Bit style	4	3	861	78.42	237	21.58	1098
Bit thickness	5	3	737	68.24	343	31.76	1080
Bit material	57	2	740	68.52	340	31.48	1080
Bit mouthpiece type	15	3	742	68.70	338	31.30	1080
Shank length	7	2	581	53.80	499	46.20	1080
Number reins used	3	2	614	56.85	466	43.15	1080
Chain or lip strap	6	2	599	55.46	481	44.54	1080
Noseband type	35	3	652	59.38	446	40.62	1098
Auxiliary reins	5	2	78	7.09	1022	92.91	1100
Martingale type	5	2	197	17.91	903	82.09	1100
Other auxiliary equipment	7	2	74	6.73	1026	93.27	1100
Spur type	9	2	355	32.27	745	67.73	1100
Whip type	7	2	499	46.12	583	53.88	1082

264

265 *Statistical data analysis – behaviors associated with a single item of apparatus*

266 Preliminary analysis revealed no associations between any behavior and any single item of apparatus.

267 Secondary analysis (i.e. with combined response categories) revealed 13 (9.1%) significant
 268 associations between an identified behavior and a single item of apparatus used during riding
 269 (P<0.05), as shown in Figure 2.

270 Of the 11 surveyed behaviors, only 4 (36.36%): *pull-head-forward-and-down; very-sensitive-to-leg-*
 271 *cues; needs-strong-canter-cues and loves-to-jump-obstacles*, showed significant associations with the
 272 use of a single item of apparatus.

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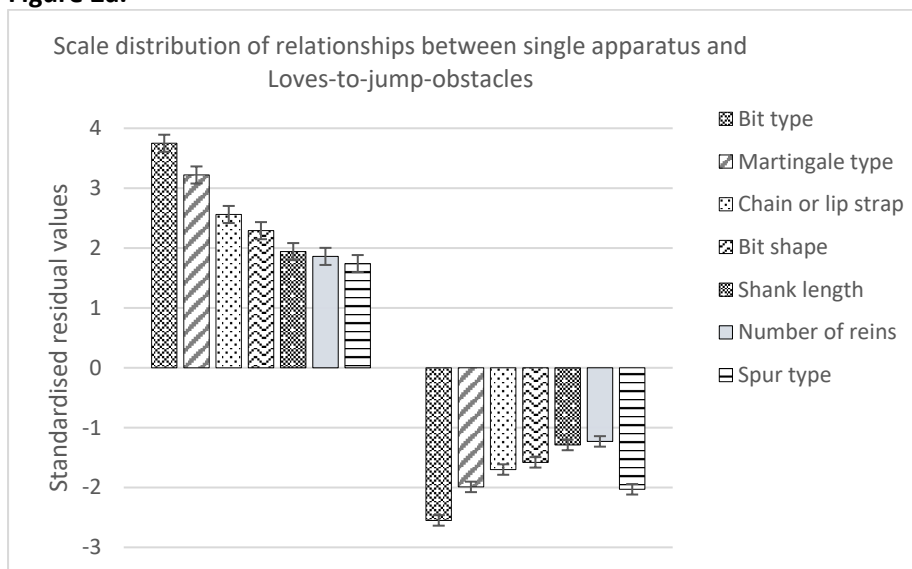
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278 **Figure 2a.**

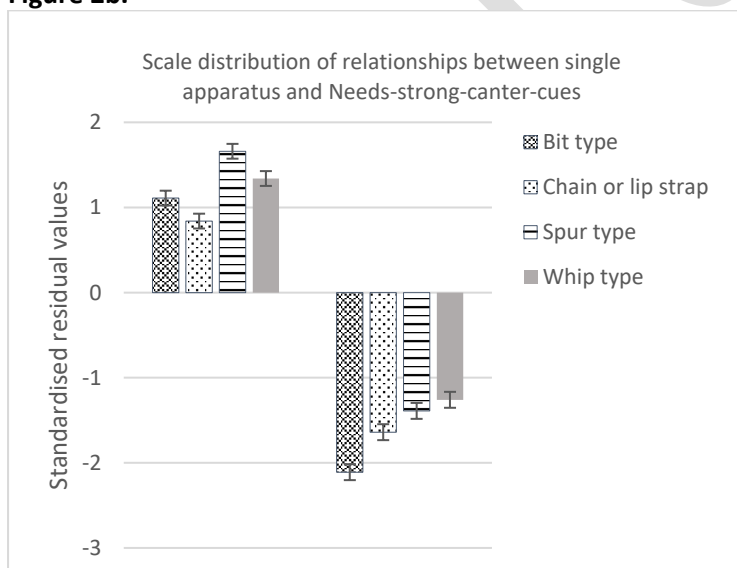


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280 Example, *Love-to-jump-obstacles*/chain or lip strap: more horses do not *Love-to-jump-obstacles* with a chain or
281 lip strap than expected (SR = 2.56), fewer horses *Love-to-jump-obstacles* with a chain or lip strap than expected
282 (SR = -1.70)

283

284 **Figure 2b.**



285

286 Example, *Need-strong-canter-cues*/whip type: more horses *Need-strong-canter-cues* with other type whip than
287 expected (SR = 1.34), fewer horses *Need-strong-canter-cues* with a dressage whip than expected (SR = -1.27)

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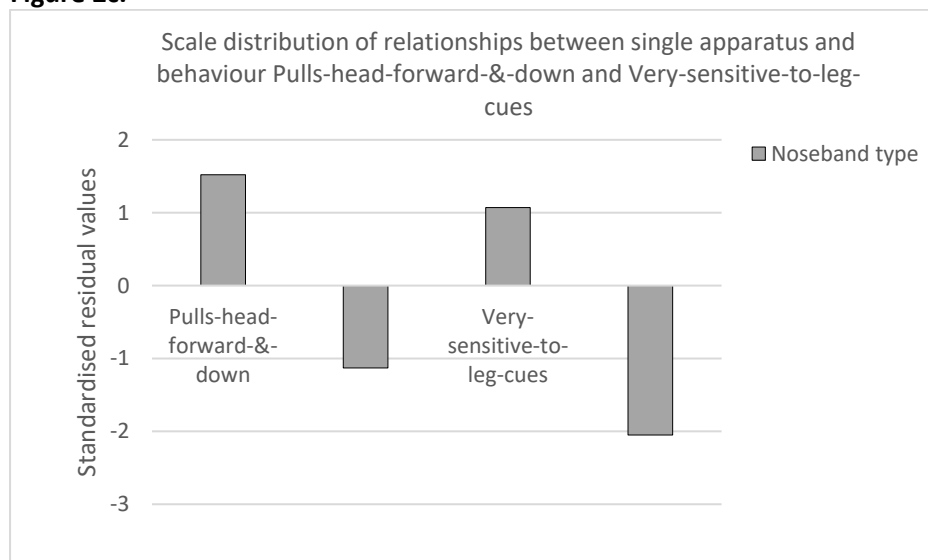
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Figure 2c.



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Example, *Pulls-head-forward-and-down/noseband type*: more horses *Pull-head-forward-and-down* in other noseband than expected (SR = 1.52), and fewer horses *Pull-head-forward-and-down* in a Cavesson than expected (SR = -1.13).

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Figure 2. Significant associations ($P < 0.05$) between identified behavior and single items of apparatus. Graphs depict positive and negative standardised residual (SR) values for each significant behavior/apparatus category, indicating the direction of association for each. Behaviors are: Figure2a) *Loves-to-jump-obstacles*, Figure2b) *Needs-strong-cues-to-canter*, Figure3c) *Pulls-head-forward-and-down* and *Very-sensitive-to-leg-cues*

309

Statistical data analysis - Bitted vs bitless bridles and influence on horse ridden behavior

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There were no significant associations between bridle type (i.e. bitted or bitless) and any single unwanted ridden behavior.

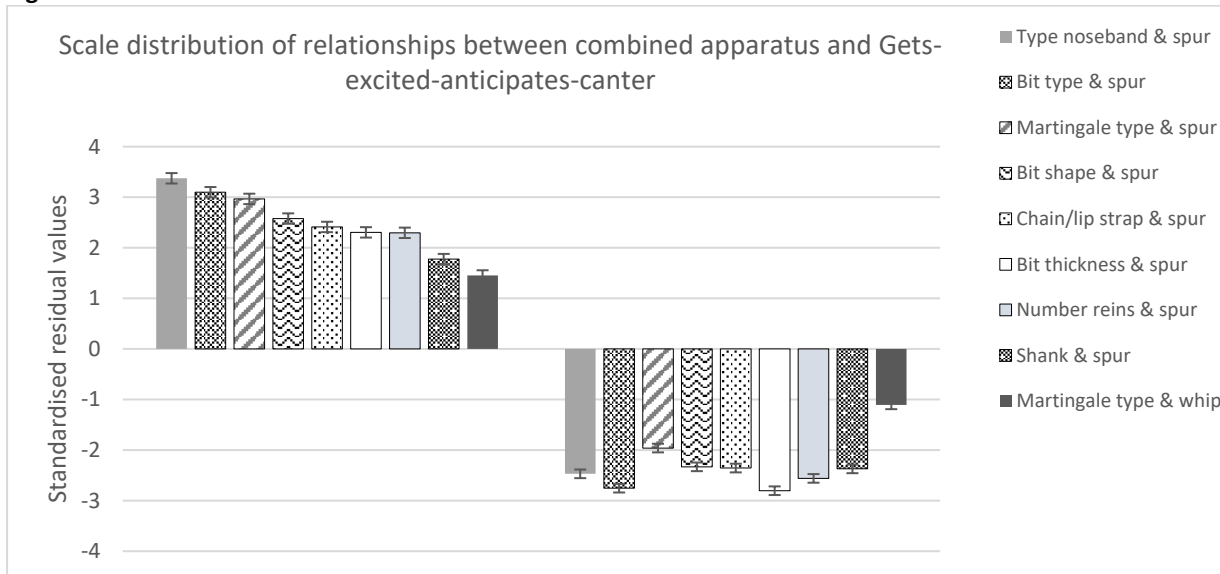
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Statistical data analysis – associations among behavior and combinations of apparatus responses

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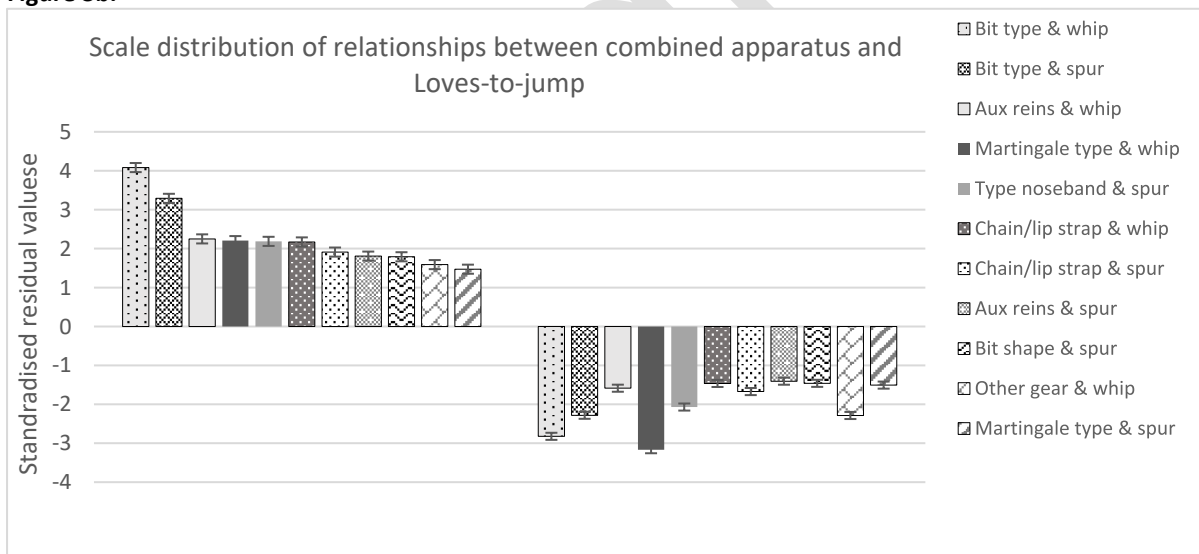
The 121 tables of behavior and concatenated apparatus returned 45 significant results showing that 37.19% of chi-square tests of combinations of apparatus that apply opposing stimuli were significantly associated with certain behavioral reports. Significant results are shown in Figure 3. A copy of statistical data analysis in tabulated form is available as supplementary material.

318 **Figure 3a.**



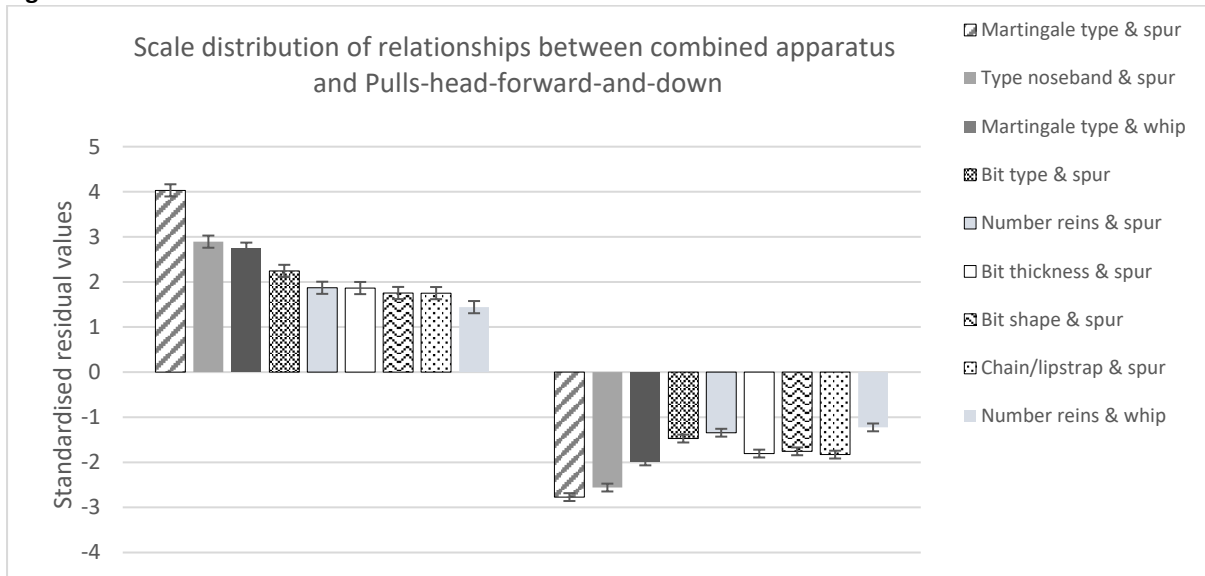
319 Example, *Gets-excited-anticipates-canter/bit type & spur*: more horses *Get-excited-anticipates-canter* with
 320 snaffle only (no spurs) than expected (SR = 3.10) and fewer horses *Get-excited-anticipates-canter* with snaffle &
 321 spurs than expected (SR = -2.75)
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324 **Figure 3b.**



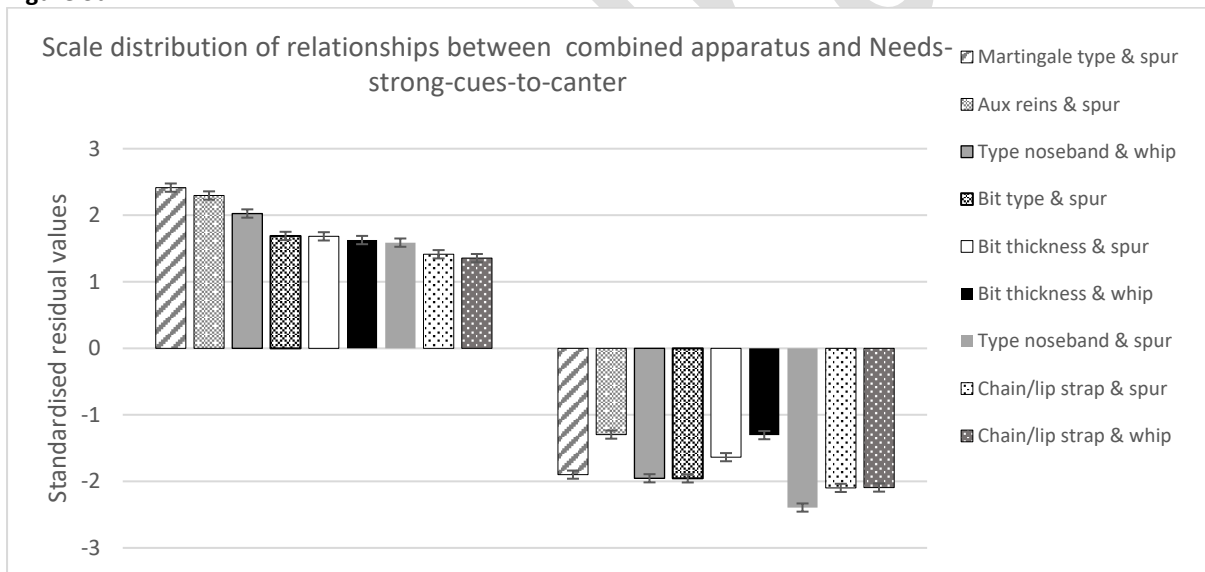
325 Example, *Loves-to-jump/martingale type & spur*: more horses do not *Love-to-jump* with standing martingale &
 326 spurs than expected (SR = 1.47) and fewer horses do not *Love-to-jump* with other martingale & spurs than
 327 expected (SR = -1.51)
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341 **Figure 3c.**



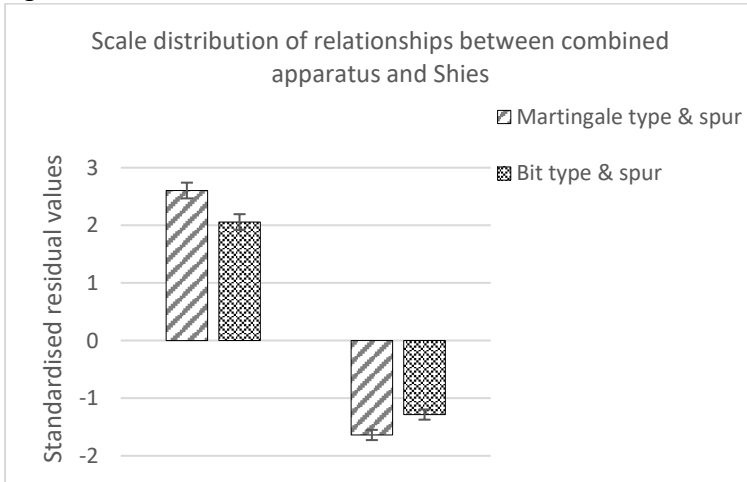
342 Example, *Pulls-head-forward-and-down*/bit thickness & spur: more horses *Pull-head-forward-and-down* with
 343 medium thickness bit only (no spurs) than expected (SR = 1.86) and fewer horses *Pull-head-forward-and-down*
 344 with a medium thickness bit & spurs than expected (SR = -1.81)
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347 **Figure 3d.**



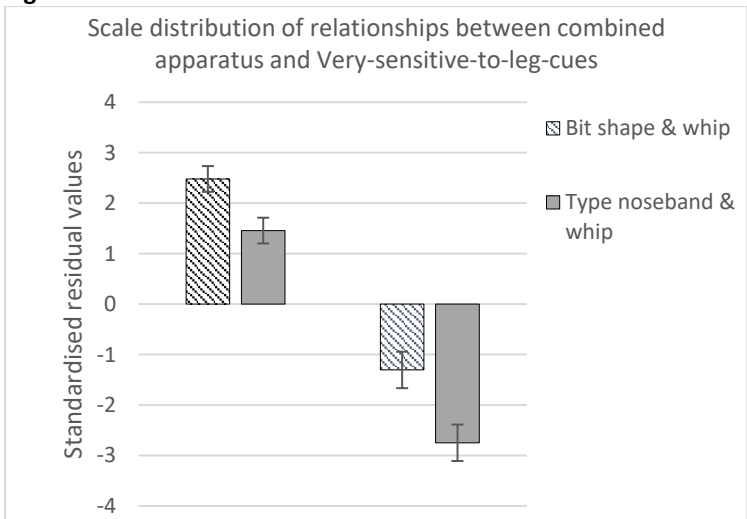
348 Example, *Needs-strong-cues-to-canter*/bit thickness & whip: more horses *Need-strong-cues-to-canter* with thin
 349 bit & whip than expected (SR = 1.63) and fewer horses *Need-strong-cues-to-canter* with only a bit (no whip) than
 350 expected (SR = -1.31)
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364 **Figure 3e.**



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366 Example, *Shies*/martingale type & spur: more horses *Shy* with martingale only (no spurs) than expected (SR =
367 2.60) and fewer horses *Shy* with spurs only (no martingale) than expected (SR = -1.64)

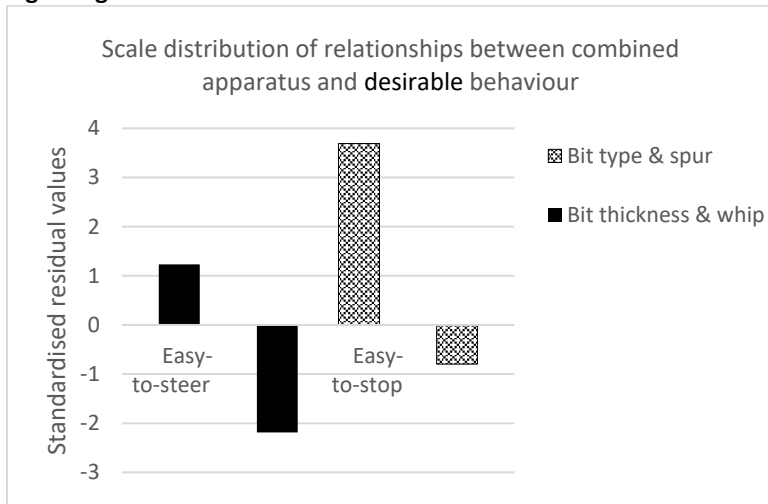
368
369 **Figure 3f.**



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371 Example, *Very-sensitive-to-leg-cues*/bit shape & whip: more horses are not *Very-sensitive-to-leg-cues* with
372 complex (roller, key etc) bit & whip than expected (SR = 2.48) and fewer horses are *Very-sensitive-to-leg-cues*
373 with complex (roller, key etc) bit & whip than expected (SR = -1.30)

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392 **Figure 3g.**



393 Example, *Easy-to-steer*/bit thickness & whip: more horses are not *Easy-to-steer* with only one aversive than
394 expected (SR = 1.23) and fewer horses are not *Easy-to-steer* with medium thickness bit & whip than expected
395 (SR = -2.19)
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397
398 **Figure 3.** Significant associations ($P < 0.05$) between ridden horse behavior and combinations of apparatus that
399 apply opposing stimuli. Graphs depict positive and negative standardised residual (SR) values for each significant
400 behavior/apparatus combination, indicating the direction of association for each.

401 Behaviors are: Figure 3a) *Gets-excited-anticipates-canter*, Figure 3b) *Loves-to-jump*, Figure 3c) *Pulls-head-*
402 *forward-and-down*, Figure 3d) *Needs-strong-cues-to-canter*, Figure 3e) *Shies*, Figure 3f) *Very-sensitive-to-leg-*
403 *cues*, Figure 3g) *Easy-to-steer*; *Easy-to-stop*

404
405 The behavior *pulls-head-forward-and-down* in association with combinations of apparatus generated

406 9 significant associations with items of gear in combination: 7 when decelerating apparatus (bit type,
407 bit thickness, bit shape, number of reins, lip strap/chain, type noseband and martingale type) were

408 combined with spurs and 2 when decelerating apparatus (martingale type and number of reins) were
409 combined with whips. Equine responses to riders' leg cues generated 12 significant results. *Very-*

410 *sensitive-to-leg-cues* showed significant associations with both noseband type and bit mouthpiece
411 type (decelerating devices) when these were combined with whips (accelerating devices). In contrast,

412 the behavior *needs-strong-canter-cues* generated 10 significant associations: 6 when items of
413 decelerating apparatus were combined with spurs and 4 when items of decelerating apparatus were

414 combined with whips.

415 The behavior *gets-excited-anticipates-canter* generated 9 significant associations with items of gear in
416 combination: 8 when items of decelerating apparatus were combined with spurs and 1 when items of

417 decelerating apparatus were combined with whips. *Shying* showed two significant associations with

418 spur use: one relating to spur and martingale use and one relating to spur and bit type. *Ease-of-*
419 *steering* was associated with combined bit thickness and whip use and *ease-of-stopping* was
420 associated with bit style and spur combinations. *Loves-to-jump-obstacles* showed 11 significant
421 associations: 6 when items of decelerating apparatus were combined with spurs and 5 when
422 decelerating apparatus were combined with whips.

423 *Multivariate analysis*

424 *Model A: Very-sensitive-to-leg-cues*

425 Type of head gear ($P = 0.01$) and noseband type and whip ($P = 0.05$) were significantly associated with
426 increased sensitivity to leg cues. Horses wearing a plain cavesson or other forms of head gear were
427 3.8 times ($P = 0.009$; CI: 1.39 – 10.40) and 4.5 times ($P = 0.002$; CI: 1.69-11.76) more likely to be
428 sensitive to the leg cues than those wearing headcollars or a halter. Horses wearing another head gear
429 type and whip were 4.4 times more likely ($P = 0.02$; CI: 1.30-14.56) to be extra sensitive to leg cues
430 than horses in headcollar / halters. Hosmer Lemeshow goodness-of-fit statistics confirmed that the
431 model showed a good fit ($P > 0.05$). The likelihood ratio chi-square test of model coefficients revealed
432 a significance level of $P \leq 0.05$ at each step. ROC curve analysis indicated that the predictability of the
433 final model to determine risk factors associated with decreased sensitivity to the leg cues was average
434 (ROC: 0.52).

435 *Model B: Needs-strong-canter-cues*

436 Horses ridden with smooth spurs were 3.07 times more likely ($P = 0.005$; CI: 1.41-6.68) to require
437 stronger canter cues than those not ridden with spurs. The presence of other auxiliary equipment was
438 significantly associated with horses requiring stronger canter cues ($P = 0.002$); horses ridden in a
439 martingale were 0.17 times less likely ($P = 0.0004$; CI: 0.06-0.45) to require stronger canter cues than
440 horses ridden with spurs. Hosmer Lemeshow goodness-of-fit statistics ($P > 0.05$) and likelihood ratio
441 chi-square test of model coefficients ($P < 0.05$) confirmed that the model showed a good fit. ROC curve
442 analysis indicated that the predictability of the final model to determine risk factors associated with
443 reduced canter cues was moderate (ROC: 0.62).

444 *Model C: Gets-excited-anticipates-canter*

445 Horses ridden with spurs and a bit with a shank were 1.6 times more likely to anticipate canter than
446 horses ridden in a bit with no shank and spurs ($P = 0.04$; CI: 1.01-1.71). Horses wearing a martingale
447 only or wearing a martingale and ridden with spurs were 8.5 times ($P = 0.03$; CI: 1.20-60.44) and 8.6
448 ($P = 0.013$; CI: 1.57-47.42)] more likely, respectively, to anticipate canter than horses ridden in spurs
449 alone. The use of other auxiliary equipment was significantly associated with increased anticipation of
450 canter ($P = 0.002$), with horses ridden in a martingale or other equipment (draw reins, side reins,
451 Whitaker reins, Pessoa® Training System, Market Harborough, tie-down, Chambon) being less likely
452 to anticipate canter than horses ridden with spurs, only (0.06 times, $P = 0.003$, CI: 0.10-0.38; 0.21
453 times, $P = 0.0004$; CIs: 0.09-0.50, respectively). Hosmer Lemeshow goodness-of-fit statistics ($P > 0.05$)
454 and likelihood ratio chi-square test of model coefficients ($P < 0.05$) confirmed that the model showed
455 a good fit. ROC curve analysis indicated that the predictability of the final model to determine risk
456 factors associated with reduced anticipation to canter was moderate (ROC: 0.66).

457 *Model D: Easy-to-stop*

458 Horses ridden in a bit and with spurs were 1.9 times more likely to stop easily than horses ridden in a
459 bit alone ($P = 0.05$; CI: 1.00-3.62). Meanwhile horses ridden in double reins were 0.28 times less likely
460 to stop easily than horses ridden in single reins ($P = 0.03$; CI: 0.08-0.92). Hosmer Lemeshow goodness-
461 of-fit statistics ($P > 0.05$) and likelihood ratio chi-square test of model coefficients ($P < 0.05$) confirmed
462 that the model showed a good fit. ROC curve analysis indicated that the predictability of the final
463 model to determine risk factors associated with reduced anticipation to canter was moderate (ROC:
464 0.68).

465 *Model E: Loves-to-jump-obstacles*

466 Using a martingale type and a whip were significantly associated with horses who were reported as
467 loving to jump obstacles ($P = 0.002$); whereas horses ridden with just a whip were 0.2 times less likely
468 to be reported as loving to jump than those ridden in a standing martingale ($P = 0.004$; CI: 0.064 to
469 0.602). Although associations between the reported love of jumping and noseband-and-spur use in

470 combination were non-significant ($P = 0.09$), the combination was retained as it improved model fit.
471 Hosmer Lemeshow goodness-of-fit statistics ($P > 0.05$) and likelihood ratio chi-square test of model
472 coefficients ($P < 0.05$) confirmed that the model showed a good fit. ROC curve analysis indicated that
473 the predictability of the final model to determine risk factors associated with reduced anticipation to
474 canter was moderate (ROC: 0.65).

475 **Discussion**

476 Due to the omnipresence of NR via physical apparatus in horse riding and handling, it is critical
477 that equestrians recognise the potential aversive nature of pressure-applying devices such as bits,
478 reins, whips and spurs and learn to use them optimally. This study of Australian horse-owners' use of
479 gear and their reports of their horses' behavior permitted an exploration of associations among
480 apparatus commonly used in equitation and the occurrence of apparent conflict behavior whilst being
481 ridden. Eleven horse behaviors exhibited when ridden were considered. Of these, two behaviors, *easy-*
482 *to-steer* and *easy-to-stop* are typically desirable in the ridden horse. The remaining nine are behaviors
483 commonly considered undesirable in equitation, including three, *rearing*, *bolting* and *bucking*,
484 considered extreme displays of conflict (McGreevy et al., 2018b). While not inferring causation, the
485 current results reveal correlational associations among commonly used apparatus and some ridden
486 behavior. The study has shown that the use of numerous combinations of both accelerator (whips and
487 spurs) and decelerator devices (bits, reins, chain/lip strap, nosebands, martingales and auxiliary
488 equipment), both in combination and separately, are associated with various unwelcome behaviors in
489 horses. Multivariate modeling also suggests that choice of apparatus may indeed reflect rider
490 perception of the horses' ridden responses. For example, a less reactive horse may prompt the rider
491 to select a whip or spurs to motivate locomotory response.

492 Whilst the expression of ridden behavior cannot be specifically linked to a single item of apparatus,
493 multiple items of apparatus applying opposing stimuli used in conjunction can influence behavior in
494 the ridden horse. The significant relationships among them will be discussed separately.

495

496 *Ridden horse behavior*

497 The current study revealed behaviors (n=9) that may be indicative of discomfort, conflict or
498 habituation (McGreevy et al., 2018b) and potentially reflect welfare issues. For example, the behaviors
499 *very-sensitive-to-leg-cues* and *gets-excited-and-anticipates-canter* may be manifestations of hyper-
500 reactivity and may indicate that the horses affected are hyper-vigilant to pressure cues on the thorax
501 or abdomen. Horses that show anticipation of accelerator cues may motivate their riders to select
502 strong decelerator cues to match. The combination of strong accelerator and strong decelerator
503 devices may detract from the horse's *telos* and may contribute to learned helplessness (Hall et al.,
504 2008). *Loves-to-jump-obstacles* may be used to euphemistically describe horses that rush fences, and
505 so horses described this way may be showing a hyper-reactive response (McGreevy et al., 2018b).
506 *Shying* is also a hyper-reactive response reflecting tendencies to favour turning to one direction
507 (McGreevy, 2012; McLean and McLean, 2008), with *ease-of-steering* being a manifestation of the
508 converse (McLean and McLean, 2008). The behavior *needs-strong-canter-cues* may be an indication
509 of habituation to accelerating stimuli (McGreevy, 2012). Interestingly 78.45% of respondents
510 described their horses as *very-sensitive-to-leg-cues*. That said, riders' perception of horse sensitivity
511 may be subjective. Some riders consider this a desirable trait and so observations of this trait may be
512 affected by reporting bias.

513 A less subjective behavior, *pull-head-forward-and-down*, was reported by 30.74% of respondents. This
514 may be of concern as this behavior could be a flawed response to rider deceleration cues and/or
515 restriction of the mouth/head/neck and is certainly classed as an unwelcome response to stimuli
516 (McGreevy et al., 2018b).

517 Interestingly, behaviors considered to be extreme displays of conflict, *rearing*, *bolting* and *bucking*
518 were reported to occur at least sometimes by 3.31%, 3.41% and 7.34%, respectively. As these three
519 conflict behaviors are potentially dangerous, animals displaying them tend to not make desired riding
520 horses (Hawson et al., 2011; Oddie et al., 2014; McGreevy et al., 2015) and may be culled from the
521 more general riding horse population (Thomson et al., 2014). Culling of horses with dangerous traits

522 may account for the relatively low numbers in this survey and should be considered when interpreting
523 results.

524 *Apparatus used*

525 The number of apparatus options offered in the original survey was extensive. This is an authentic
526 reflection of the diverse choices possible in the saddlery market (Doherty et al., 2017b). For example,
527 the categories for bit composition (n=57) and noseband type (n=35) indicate the vast array of
528 apparatus available to the modern equestrian. Choice of apparatus is influenced by discipline (Hill et
529 al., 2015) and by other multiple factors, such as fashion and peer pressure, relating to the rider
530 (Williams and Tabor, 2017). However, there remains only limited scientifically validated information
531 available to help riders make informed choices when selecting bits for their horses. Subjective opinions
532 among riders have been proposed as the main determinant in bit selection, but equine oral anatomy,
533 individual horse sensitivity and past experiences should be also be considered (Manfredi et al., 2007).
534 The naïve horse seems to find oral pressures from bits aversive but may habituate quickly (Christensen
535 et al., 2011). Over the course of a working life, the cumulative effect on horses of strong rein tension
536 and a restrictive noseband may magnify bit pressure, cause discomfort and/or pain consequently
537 affecting behavior and compromising welfare (McGreevy et al., 2012; Weller et al., 2020).

538 Manfredi et al. (2009) used lateral fluoroscopic imaging to investigate intra-oral behaviors in six horses
539 wearing three different snaffle bits, with and without rein tension of 25N. Behaviors indicative of
540 discomfort, such as resistance to stopping and turning and pulling-head-forward-and-down, are
541 readily apparent to most informed observers (Dyson and Pollard, 2020) while other subtle intra-oral
542 behaviors that are not observable externally, may also indicate discomfort and/or stress. Manfredi et
543 al. (2009) detected significant increases in tongue movements in response to static bilateral rein
544 tension of 25 ± 5 N but behavioral responses were specific to individual horses, rather than to bit type.

545 A large variety of bits are available to riders, with many marketed towards resolution of oral,
546 behavioral and training problems (McGreevy et al., 2014). These anecdotal beliefs may account for
547 the high degree of variation found in the current respondents' answers to bit-specific questions.

548 Snaffle bits were the predominant reported bit type used. This was expected as snaffles are a basic bit
549 design but the reported use of these bits incorporated many variations in mouthpiece style,
550 composition and thickness, and therefore severity.

551 *Ridden horse behavior in relation to single items of apparatus*

552 In the current study preliminary analysis to identify significant relationships between behavior and
553 apparatus using broad category parameters exposed no associations between any behavior/single
554 apparatus combinations. Secondary analysis revealed 13 significant associations between *ridden horse*
555 *behavior and single items of apparatus*. Of these, 4 (30.77%) were between apparatus and the
556 behavior *needs-strong-canter-cues*. Two of these relationships involved bit type and chain/lip strap
557 and the other 2 involved the accelerating devices, whips and spurs. This suggests that riders used
558 these devices to address issues of habituation and to augment signals from their legs. There were 7
559 significant associations (53.85%) between apparatus and the behavior *loves-to-jump-obstacles*. This
560 suggests that the behavior labelled *loves-to-jump-obstacles* has more than one cause and its origins
561 may be obscured by subjective interpretations. It also indicates that the relationships among gear and
562 appearing to enjoy jumping are especially complex. It will be important that further studies of this
563 perceived attribute trait are designed to unpick its different manifestations.

564 *Bitted versus bitless bridles and horse ridden behavior*

565 Whilst it may appear convenient that the equine mouth can accommodate a bit, allowing for
566 directional and speed control via pressure, it did not evolve to accommodate a bit nor to facilitate NR
567 (McGreevy et al., 2014). Bitless bridles appear to be gaining popularity, particularly among leisure and
568 endurance riders, whose choice of apparatus is not restricted by current competition rules (Hill et al.,
569 2015). Riders may choose this equipment as they perceive the bitless bridle to be less aversive to the
570 horse than bitted bridles or they may not feel the need to ride with the constraints currently required
571 in many competition arenas. There is also the more recent view that bits may interfere with the
572 natural seal of the horse's mouth during respiration, affecting athletic performance (Mellor and
573 Beausoleil, 2017). The design of bitless bridles varies, as does their ability to apply pressure to sensitive

574 structures of the head/nose and their degree of aversiveness. For example, even though it is bitless,
575 the hackamore bridle incorporates lever action to apply amplified, potentially severe, rein pressure to
576 the nasal bones and mandible. In contrast, the bitted bridle applies pressure to sensitive oral
577 structures of the mouth; the hard palate, tongue, bars and lips. The potential deleterious impact of
578 any bridle on the horse is therefore not only influenced by its design but also its operation. Any bit
579 style improperly fitted or used in ridden horses can potentially cause oral trauma such as bone spurs,
580 ulceration, and tongue lacerations (Mata et al., 2015).

581 The current indirect investigation into the anecdotal assumption that bitless bridles are less aversive
582 than bitted bridles revealed interesting results. Analysis found the use of bitted or bitless bridles had
583 no significant association with the prevalence of conflict behaviors. Scofield and Randle (2013)
584 compared the effects of bitted and bitless bridles on behavior in a pilot study. Results suggested the
585 occurrence of conflict behavior was similar with both types of equipment and the current study
586 appears to support these findings. However, in the absence of specific details of bitless bridle design
587 and their corresponding mechanisms, further investigations are warranted.

588 *Behavior versus combinations of equipment*

589 The current study revealed a series of significant relationships between behavior and the use of items
590 of apparatus. Items that deliver opposing stimuli revealed differing results to that of single apparatus
591 use. Applying the same behavior and apparatus categories used for single apparatus, apparatus
592 designed to amplify pressures for acceleration or deceleration were then combined and 37.19% of
593 these relationships were significant. The use of items of apparatus that apply opposing stimuli in
594 combination may be both counterproductive and unethical (McLean and McGreevy, 2010a).

595 Habituation is not the only potential consequence of the use of simultaneous, opposing cues. Horses
596 may become either difficult to stop or sensitive to leg signals, therefore, cues applied as light versions
597 of the original stimulus, and thus horsemanship in general, are compromised. All other conflict or
598 discomfort behaviors in response to opposing stimuli that the horse cannot resolve reflect serious
599 insults to welfare.

600 It should be recognised that nosebands and bits are not used in isolation in the ridden horse. Previous
601 studies have suggested wearing a noseband or bit in the absence of rein tension, regardless of bit
602 type, is sufficient to produce a stress response in naïve horses (Manfredi et al., 2009; McGreevy et al.,
603 2012). By design, restrictive nosebands inhibit oral movements (Fenner et al., 2016; Doherty et al.,
604 2017a). In a bid to find comfort, horses fight against this constraint; a response that may cause the
605 structural changes in nasal bones and mandibles that have recently been reported at the site of
606 restrictive nosebands (Perez-Manrique et al., 2020). There is evidence that the additional impact of
607 rein tension and other auxiliary equipment, such as martingales and draw reins, may further amplify
608 pressures applied by the bridle, noseband and bit (McGreevy et al., 2014). The additional
609 complications of the physical influence of the rider on the horse, rider skill level and experience and
610 decisions affecting apparatus choice, further confound the effect of apparatus upon horse behavior
611 (Williams and Tabor, 2017).

612 Restrictive apparatus applied to the mouth and other parts of the head is primarily used to increase
613 control and to steer forward movement using pressure; and therefore to influence deceleration
614 through negative reinforcement. In contrast, whips and spurs are generally used to augment the cues
615 of the riders' legs to promote and achieve acceleration. The separate use of accelerating and
616 decelerating apparatus has been the focus of many previous studies (Heleski et al., 2009; McLean and
617 McGreevy, 2010a; Clayton et al., 2011; Doherty et al., 2017a; McGreevy et al., 2017) but studying the
618 concurrent use of two such opposing types of stimuli and the resultant effect upon behavior is novel.
619 Overuse of any apparatus that directs pressure onto animals can lead to habituation (McGreevy and
620 Boakes, 2011) and may easily become a welfare concern if, instead of improving their technique and
621 most notably their timing, riders escalate pressure (e.g., by using more severe apparatus) to elicit
622 desired behavior. Combined with the potential for intentional or accidental misuse by the rider, the
623 use of apparatus to apply opposing tactile stimuli to the ridden horse may result in significant welfare
624 compromises. The study indicates that no single item of apparatus is exclusively associated with the
625 expression of behavior issues in horses. However, it goes on to reveal associations among behaviors

626 and the apparatus issuing opposing aversive stimuli. This reminds us that one must consider numerous
627 factors when evaluating the aetiology of equine responses including rider application of stimuli, horse
628 sensitivity and general context.

629 *Limitations*

630 Cross-sectional surveys, such as the current one, cannot reliably identify casual relationships.
631 Additionally, differences in horse age, sex, learning history, and coping style may influence the
632 responses that emerge under saddle, and data on these were not collected by the current survey
633 instrument. The anonymity of internet surveys promotes self-disclosure and may consequently negate
634 the tendency for respondents to provide socially acceptable responses (Fricker and Schonlau, 2002).
635 Regardless, despite appropriate aspects of survey design and administration to minimise sanitised
636 reporting, the prospect that some respondents offered responses perceived as desirable must still be
637 noted as a potential limitation.

638 In the absence of a comprehensive ridden behavior ethogram to facilitate accurate behavioral
639 definition, the current responses may have been skewed as a function of respondents' interpretation
640 of their horses' behavior (Pierard et al., 2019). Respondents' interpretation of some behaviors may
641 reflect subjectivity and anthropomorphism, and this should be considered when interpreting the
642 current results.

643 Riding horses displaying extreme displays of conflict, including *rearing*, *bolting* and *bucking* may be
644 misrepresented in this study. Further investigation into longitudinal associations between hazardous
645 behaviors and apparatus is warranted. Additionally, for the purpose of interpretation, the availability
646 of an unambiguous, detailed ethogram to enable the recording of behavioral observations in relation
647 to behavior indicative of a state of conflict would assist the evaluation of apparatus, training and rider
648 influence and allow comprehensive inferences to be drawn about the welfare of the horse (Hall and
649 Heleski, 2017).

650 Raw data analyzed in this study were collected by Hill et al. (2015). It should be considered that
651 responses may differ over time, and responses to a contemporary survey may yield different results.

652 **Conclusions**

653 The current study indicates that the use of a single specific item of apparatus cannot be fully
654 implicated in the expression or intensity of undesirable ridden horse behavior. Similarly, the use of
655 bitted or bitless bridle was shown to have no significant effect on the reports of ridden horse behavior.
656 However, significant non-causal associations were demonstrated among behaviors and apparatus that
657 imposes opposing aversive stimuli. This suggests multiple items of apparatus can influence behavior
658 when used simultaneously, particularly if these devices, when used in combination, amplify
659 contradictory stimuli simultaneously. Further investigation is required to identify all factors involved
660 in the ontogeny and expression of conflict behavior in ridden horses.

661

662 **Acknowledgements**

663 The authors thank the respondents to this survey and Hill et al. (2015) for access to the raw data.

664

665 **Conflicts of Interest**

666 The authors declare no conflicts of interest.

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812 **Appendices**



Hill et al. (2015)
Survey.pdf

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Statistical data
analysis, tabulated res

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