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Attitudes towards worm egg counts and targeted selective treatment against equine cyathostomins

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1 **Attitudes towards worm egg counts and targeted selective**
2 **treatment against equine cyathostomins**

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15

16 **Abstract**

17 Gastrointestinal nematodes present a major threat to the health and welfare of
18 equids worldwide. Anthelmintic resistance (AR) is increasingly reported and
19 challenges effective control in horses and ponies in many regions. The use of faecal
20 worm egg counts (FECs) to support targeted treatment (FEC-TT) and targeted
21 selective treatment (FEC-TST) has been promoted as an effective deworming
22 strategy that may prolong the useful life of anthelmintics and reduce the costs
23 associated with parasite control. However, treatment applied at set intervals or on
24 pre-determined dates remains common. A structural equation model was developed
25 to identify factors influencing the uptake of FEC-directed treatment strategies, based
26 on well-established socio-psychological theories of intentional health-related
27 behaviours: the Theory of Planned Behaviour and the Health Belief Model. More
28 than 850 valid responses were received from horse owners in the UK via an online
29 survey. The intention to use FECs prior to deworming was not influenced by the
30 perceived risk of anthelmintic resistance or that of gastrointestinal nematode
31 infection but was positively influenced by a negative attitude towards anthelmintics, a
32 positive attitude towards FECs, an increase in social pressure (e.g. significant others
33 think the respondent should use FECs) and an increase in perceived control over
34 their deworming programme. The results were consistent with a similar study
35 conducted on FEC-TT in cattle in Belgium. An increase in respondents' self-
36 perceived level of knowledge significantly increased the intention to use FECs via
37 mediating factors. These results suggest that knowledge transfer activities aimed at
38 increasing awareness and understanding of sustainable nematode control practices
39 may be more effective at encouraging behavior change than emphasising the

40 dangers of nematodes and AR, which had limited influence on behaviour intention in
41 this study population.

42

43 **Keywords:** equine cyathostomins; faecal egg count; structural equation model;
44 theory of planned behavior; health belief model

45 ¹

¹ **Abbreviations:**

UK – United Kingdom

GB – Great Britain

AR – Anthelmintic Resistance

GIN – gastrointestinal nematode

FEC – faecal worm egg count

HBM – Health Belief Model

TPB – Theory of Planned Behaviour

EFA – Exploratory factor analysis

CFA – Confirmatory factor analysis

SEM – structural equation model

CFI – Comparative Fit Index

TLI – Tucker-Lewis Index

RMSEA – Root Mean Square Error of Approximation

SRMR – Standardised Root Mean Residual

46 **Introduction**

47 Gastrointestinal nematodes present a major threat to the health and welfare of
48 equids worldwide, and anthelmintic resistance (AR) increasingly compromises
49 control efforts in horses and ponies (Corning, 2009; Matthews and Lester, 2015).
50 The problem of AR in grazing ruminants (Rose et al., 2015) has been addressed by
51 recommending more discriminant application of anthelmintic treatments at group and
52 individual levels (Charlier et al., 2014). In horses, the use of faecal worm egg counts
53 (FECs) to support targeted treatment (FEC-TT) and targeted selective treatment
54 (FEC-TST) has been promoted as an effective deworming strategy that may prolong
55 the useful life of anthelmintics and reduce the costs associated with parasite control
56 (Matthews and Lester, 2015). In Denmark, anthelmintics can only be prescribed for
57 individual horses when supported by parasitological diagnosis such as high faecal
58 egg counts (Nielsen et al., 2006). Elsewhere, however, the use of FECs to inform TT
59 and TST is voluntary, although it does form a key part of new guidelines for the
60 responsible prescription and use of anthelmintics in horses in the UK (AHDA, 2015).
61 Seventy-six percent of respondents to a recent survey of horse owners in the UK
62 (primarily owners in the south of England) reported that they already use FECs to
63 target treatment (Easton et al., 2016). Despite this relatively high self-reported
64 uptake of FEC-TT, the survey indicates that treatment applied at set intervals or on
65 pre-determined dates remains relatively common in the equine industry in the UK.
66 Furthermore, a survey of French veterinarians found that almost half of practitioners
67 never performed FECs prior to treatment (Salle and Cabaret, 2015). Identifying the
68 knowledge, attitudes and practices of horse owners and managers to nematode
69 infections, AR, diagnosis and control will help identify barriers to the uptake of
70 sustainable GIN control strategies such as FEC-TT and FEC-TST.

71 Risk management behaviour in animal owners, such as the use of FECs, may be
72 driven by a range of factors including their perception of disease risk, whether they
73 consider the behaviour to be effective, their underlying knowledge of the risks and
74 management options, access to trusted information on the subject, socio-
75 demographic factors and physical attributes of the farm/stables which may limit the
76 possible behaviours (Garforth et al., 2013; Toma et al., 2013; Alarcon et al., 2014).
77 Adopting new technology or strategies to manage animal health, and other
78 constructive behaviour change, requires animal owners to assess the current level of
79 risk and risks associated with adopting/not adopting the new technology or strategy,
80 sometimes based on uncertainty and incomplete knowledge. By identifying the
81 factors driving and preventing the adoption of risk management behaviours, it may
82 be possible to target and address these factors to increase uptake and behaviour
83 change.

84 Various model frameworks have been proposed to describe the factors driving risk
85 management behaviours. The Theory of Planned Behaviour (TPB; Ajzen, 1991)
86 describes the intention to perform a behaviour as a function of the individual's
87 attitude towards the behaviour, their perceived control over whether or not they
88 perform the behaviour, and peer/societal influences (Ajzen, 1991). The Health Belief
89 Model (HBM; Rosenstock et al., 1988) shares common elements with the TPB but
90 extends the inclusion of potential barriers to performing a behaviour, e.g. positive
91 attitudes towards the risky behaviour, and includes the evaluation of perceived risk
92 (Valeeva et al., 2011; Vande Velde et al., 2015).

93 Although these models are rooted in studies of human health, they have been
94 applied to evaluate animal health management and identify factors influencing
95 farmer behaviour. For example, a survey of pig fattening farms in the Netherlands

96 based on the HBM concluded that emphasising the efficacy of risk management
97 strategies such as biosecurity measures and animal health plans may prove more
98 effective than focussing on farmers' perceived risk of disease (Valeeva et al., 2011).
99 The TPB has been used to identify drivers of disease control by English pig
100 producers (Alarcon et al., 2014), and drivers of and barriers to the reduced use of
101 antibiotics by British dairy cattle farmers (Jones et al., 2015). The TPB and HBM
102 have also been combined to evaluate English sheep and pig farmers' attitudes to
103 disease risk management (Garforth et al., 2013) and to identify factors driving the
104 adoption of sustainable GIN control practices on Belgian cattle farms (Vande Velde
105 et al., 2015). The latter were the first to adapt these models to evaluate the use of
106 diagnostics (including FECs) and parasite control behaviour, providing a framework
107 that can be replicated for different livestock sectors and parasites. Here, the
108 framework developed by Vande Velde et al., (2015) was adapted to reflect
109 differences in potential factors influencing behaviour in horse owners compared with
110 cattle farmers and used to identify barriers to the uptake of FEC-TT and FEC-TST by
111 commercial and private equine owners and managers in the UK.

112

113 **Methods**

114 *Theoretical framework*

115 The theoretical framework was based on the work of Vande Velde et al., (2015) on
116 the use of diagnostics before treatment for GINs in dairy cattle in Belgium, and is a
117 combination of elements in the Theory of Planned Behaviour (TPB) and the Health
118 Belief Model (HBM; Figure 1). The model framework is made up of a structural
119 model (Figure 1; Appendix A), comprising factors, or latent variables, which may
120 influence the intention to use FECs before treatment (referred to as constructs). The
121 constructs in the structural model are evaluated using a set of questions, or
122 observed variables (referred to as items) which form the measurement model. These
123 variables are referred to hereafter as items x_1 to x_{40} and are described in full in
124 Appendix A.

125 The structural model comprised constructs evaluating the intention to use
126 diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs),
127 attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e.
128 FECs) prior to treatment and subjective norms, as described by Vande Velde et al.
129 (2015). In addition, a perceived risk construct evaluated perceived susceptibility to
130 infection and AR (i.e. the perceived likelihood of infection or developing AR), and
131 perceived severity of infection and AR. The framework was also extended to include
132 the horse owners' perceived knowledge as a construct which may directly or
133 indirectly affect behaviour intention (Figure 1).

134

135 *Survey design*

136 Survey questions for the structural model were based on validated constructs and
137 items used by Vande Velde et al., (2015) which followed the general guidelines for
138 conducting surveys using socio-cognitive models such as the TPB (Francis et al.,
139 2004). Respondents were also asked about their characteristics e.g. type of horse
140 owner and number of horses under their control, in order to describe the sample
141 population and perform external validation. A detailed list of constructs and items
142 forming the measurement model is provided in Appendix A.

143

144 *Data collection*

145 Although a passport is a legal requirement for all equids in the UK, no central
146 database of horses nor horse owners exists since the removal of the UK National
147 Equine Database in 2012. Therefore, a randomised survey design was not possible
148 and horse and pony owners were surveyed using a self-selecting online survey
149 (SurveyMonkey Inc., Palo Alto, California, USA, www.surveymonkey.com) between
150 18/12/2015 and 31/01/2016.

151 The survey was pilot tested on two private horse owners, one lay person and one
152 owner of a commercial equine establishment before online publication. The survey
153 was promoted via social media (Twitter, equine-related Facebook groups and
154 forums). To encourage complete responses, respondents were offered the chance to
155 enter a prize draw for a £100 Amazon.co.uk voucher by entering their email address
156 on the final page of the survey. The winner was selected by assigning valid
157 responses random numbers and selecting the lowest number.

158

159 *External validation*

160 To verify the external validity of the survey, commercial respondents' characteristics
161 (type of horse owner/establishment) were compared against characteristics of the
162 UK equine industry (Lantra, 2011). It was not possible to validate the ratio of private
163 and commercial respondents as no data exist for comparison.

164 The distribution of respondents was not tested for complete spatial randomness as
165 no spatial datasets were available to correct for the distribution of the horse
166 population. The distribution of commercial respondents at a county level within the
167 UK was compared against the distribution of commercial equine establishments in
168 the UK (Lantra, 2011) by Chi Square analysis in R 3.2.2 (R Core Team, 2015). The
169 county of origin of each respondent was extracted from the latitude and longitude
170 coordinates and the Ordnance Survey's Boundary Line™ dataset using the 'Point
171 sampling tool' in QGIS 2.8.1-Wien (QGIS Development Team, 2015).

172

173 *Internal validation*

174 The validity of the measurement model was assessed in several ways. First,
175 Cronbach's alpha was used to test for internal consistency of constructs using the
176 *alpha* function of the *psych* R package (Revelle, 2015) where $\alpha > 0.7$ is good and
177 $\alpha > 0.6$ is acceptable (Vande Velde et al., 2015).

178 Maximum likelihood exploratory factor analysis (EFA) was then conducted on
179 exogenous items in R using the *factanal* function of the *lavaan* package (Rosseel,
180 2012) with an oblique promax rotation (thus allowing for correlation between factors;
181 Costello & Osbourne, 2005) to evaluate whether the items making up the constructs
182 were consistent with the theoretical constructs on which they were based. Methods

183 followed best practice guidelines for EFA (Costello & Osbourne, 2005). Due to the
184 multi-level structure of the proposed model EFA was conducted twice: once using
185 items x_1 - x_6 underlying the 'perceived knowledge' construct, and again using items x_7 -
186 x_{37} which form the intermediate constructs that are exogenous to 'behaviour
187 intention' (Table 1; Figure 1).

188

189 *Structural equation modelling (SEM)*

190 Structural equation modelling was performed in R using the *sem* function in the
191 *lavaan* package. Regression equations were based on the proposed structural model
192 (Figure 1) and covariance between the constructs relating to perceived risk.

193 Subjective norms and perceived behavioural control were also allowed to covary due
194 to the potential crossloading identified in the EFA. Item variances were fixed to 0 if
195 negative variances were computed and the variance was not significantly different
196 from 0. Although the Likert and bipolar 7-point scales generate ordinal items, the
197 *lavaan* package treats these data as numeric and therefore no further adjustments
198 were necessary.

199 Model fit can be evaluated using a χ^2 test on the observed and expected covariance
200 matrices. However, model performance was evaluated primarily based on an
201 assessment of misclassification of the structural model as described by Saris et al.,
202 (2009) using the *modificationIndices* function in the *lavaan* package. The function
203 provides an estimated modification index (MI) between endogenous and exogenous
204 variables, and between factors. If the MI is greater than 3.84 (equivalent to the χ^2
205 critical value corresponding to one degree of freedom at $p < 0.05$) then the model may
206 be improved by respecifying the parameter in the model (Whittaker, 2012). To

207 determine the need for respecification and model modification the context of the
208 change is considered (i.e. is the modification theoretically plausible?) in combination
209 with the expected parameter change (EPC). The EPC indicates the size of the
210 misspecification and therefore, like the MI values, higher EPC values are of greater
211 concern (Whittaker,2012). The strength, direction and significance of relationships
212 between constructs and between covariance terms were assessed using the
213 regression coefficients (β) and p-values.

214 Mediation analysis (Iacobucci et al., 2007) was used to evaluate indirect effects of
215 perceived knowledge on behaviour intention, mediated by the other constructs.

216 Intercepts obtained from the SEM output provide a general idea of the sample
217 population's response to the questions included in the final model, where 7 is
218 strongly agree on the Likert scale or the most positive response on the bipolar scales
219 and 1 is strongly disagree on the Likert scale or the most negative response on the
220 bipolar scales. An intercept of 1-3 would therefore indicate a negative response, 4 a
221 neutral response and 5-7 a positive response.

222

223 *Target sample size*

224 A subject to item ratio of 10:1 (i.e. 10 respondents for each question in the survey)
225 can be used as a rule of thumb for determining the sample size needed for EFA,
226 although 20:1 is preferable to minimise misclassification of items on the wrong factor
227 (Costello and Osbourne, 2005). Therefore, a minimum sample size of 400 valid
228 responses was required for EFA in this survey. There appears to be no consensus
229 on sample size and power calculations for SEMs. Weston and Gore (2006) suggest
230 a minimum sample size of 200.

Commented [FV1]: Theory trumps statistics, so you should always consider this first. But if it's not intervening, you can modify the model using the MI, although not too much.

231

232 **Results**

233 *Description of the population*

234 A total of 1451 responses were recorded between the 18th December 2015 and 31st
235 January 2016; 873 were retained for further analysis. 422 (29.08%) responses were
236 incomplete and were removed from further analysis. Respondents were allowed to
237 complete the survey multiple times to account for individuals that own or are
238 employed at several premises. Therefore, responses with the same IP address (i.e.
239 completed on the same computer or mobile device) were checked to ensure the
240 responses pertained to different premises or owners and were not simply duplicate
241 entries. One duplicate entry was removed from analysis as the respondent had
242 completed all mandatory questions on both occasions but had only completed
243 additional optional questions in one response. The full response was retained in this
244 instance. The time spent completing the survey was checked for each remaining
245 respondent to eliminate potential automated responses. The survey should have
246 taken approximately 5-10 minutes to complete. A total of 149 responses were
247 removed due to implausibly short completion times of less than one minute and
248 consistent selection of the midpoint of the Likert and bipolar scales throughout the
249 survey. Finally, postcodes were checked for validity using the UK grid reference
250 finder (<http://www.gridreferencefinder.com/postcodeBatchConverter/>), which was
251 unable to find 15 postcodes. Ten of these were found to be valid postcodes for
252 Northern Ireland and the Channel Islands after further searches. The remaining 5
253 responses had either invalid or missing postcodes and were excluded from further
254 analysis.

255 Most respondents (93.58%) were private horse or pony owners (Table 1).
256 Respondents reported a median of 2 horses and/or ponies (range 1-70) under their
257 care and were distributed throughout the UK and Channel Islands (Figure 2).
258

259 *External validation*

260 The activity structure of the commercial respondents and the UK equine industry was
261 not significantly different from that reported in the Lantra equine business survey
262 (Lantra, 2011; $\chi^2 = 42$, d.f. = 36, $p = 0.227$). The regional distribution of commercial
263 respondents and the distribution of UK equine businesses reported by Lantra (2011)
264 was not significantly different ($\chi^2 = 12$, d.f. = 9, $p = 0.213$). The distribution of
265 respondents was broadly comparable with the distribution of horse owners in Great
266 Britain in 2011 (Boden et al., 2012). However, quantitative comparison with this
267 dataset was not possible.

268

269 *Internal validation*

270 All constructs were found to have good internal consistency with $\alpha > 0.7$ but three
271 factors could be improved by deleting items x_9 , x_{16} and x_{33} (Appendix B, Table B1).
272 These items were removed from subsequent analysis.

273 Validity of the perceived knowledge and behaviour intention constructs was
274 confirmed using EFA specifying a single factor (Appendix B, Table B2 and B4). Items
275 x_{31} and x_{32} underlying the subjective norms (norms) construct loaded weakly (factor
276 loading < 0.3) onto several factors (Appendix B, Table B3). Furthermore, items x_{10} - x_{15}
277 underlying the perceived severity of anthelmintic resistance construct loaded onto
278 two factors, and items x_{19} - x_{24} underlying the perceived severity of infection construct
279 showed some weaker cross-loading onto several factors, suggesting a split between
280 responses to the questions on the perceived severity of AR and infection in the
281 context of horse health (x_{10} - x_{12} and x_{22} - x_{24}) and performance (x_{13} - x_{15} and x_{19} - x_{21}).
282 Therefore, subsequent analyses compare the full model based on the proposed

283 structural model (Figure 1), and a split model whereby the perceived severity of AR
284 and perceived severity of infection constructs were divided to account for potential
285 differences in responses to questions regarding animal health and performance.

286

287 *Structural equation modelling (SEM)*

288 SEM regression equations for the full model followed the structural model in Figure
289 1. Additional covariance terms were introduced between the constructs measuring
290 perceived risk, and between construct measuring perceived control and subjective
291 norms (Appendix C). SEM regression equations for the split model were the same as
292 for the full model except that the perceived severity of AR and perceived severity of
293 infection constructs were divided into two constructs each for reasons described
294 above (Appendix C). Constructs were defined using the measurement model
295 described in Appendix A.

296 The full model was re-specified to remove covariance between the following
297 constructs as the covariances were not statistically significant (AppendixC):
298 subjective norms and behavioural control, perceived susceptibility to infection and
299 attitudes towards FECs, perceived severity of infection and attitudes towards
300 anthelmintics, and perceived severity of AR and attitudes towards anthelmintics.

301 Several MIs greater than the threshold value of 3.84 were identified, but in all cases
302 the EPC was low, and some of the modifications were already captured in the model
303 as covariances. Therefore the model was considered correctly specified. Specifically,
304 covariance between subjective norms and perceived susceptibility to infection
305 yielded a high MI of 15.767 but a low EPC of 0.221. Similarly, covariance between
306 subjective norms and attitudes towards FEC yielded a high MI and low EPC (MI =

307 16.029, EPC = 0.17). MIs suggested that perceived susceptibility to infection may be
308 dependent on the intention to use FECs (MI = 4.072, EPC = 0.123), subjective
309 norms (MI = 15.767, EPC = 0.165) and perceived behavioural control (MI = 7.593,
310 EPC = -0.278). However, the corresponding EPCs were low and therefore these
311 changes were not made. MIs also suggested that attitudes towards anthelmintics
312 may be dependent on perceived susceptibility to anthelmintic resistance (MI = 7.813,
313 EPC = 0.771), perceived severity of anthelmintic resistance (MI = 6.775, EPC =
314 0.270), perceived susceptibility to infection (MI = 7.672, EPC = 1.318), perceived
315 severity of infection (MI = 7.053, EPC = 0.209), and attitudes towards FECs (MI =
316 7.388, EPC = 1.470). These modifications were not made as the model either
317 already included terms for covariance between these variables or the covariances
318 were removed as described above due to non-significance, and the EPC was low in
319 all cases. A high MI suggested that attitudes towards FECs may be dependent on
320 subjective norms (MI = 16.029, EPC = 0.126) but the low EPC did not justify
321 modification of the model. Finally, high MIs suggested that subjective norms may be
322 dependent on perceived susceptibility to anthelmintic resistance (MI = 11.345, EPC
323 = 0.116), severity of anthelmintic resistance (MI = 7.583, EPC = 0.190), susceptibility
324 to infection (MI = 23.041, EPC = 0.177), severity of infection (MI = 12.457, EPC =
325 0.185) and attitudes towards FECs (MI = 20.621, EPC = 0.242), but again, EPC
326 values were low and therefore the modification was not justified. The full MI output is
327 provided in Appendix D.

328 The full SEM explained 50.6% of the variability in the intention to use FEC-TT/FEC-
329 TST ($R^2 = 0.506$; $X^2 = 6186$, $df=601$, $p<0.001$). Intercepts from the full SEM output
330 indicate that respondents had a moderately positive response to the questions
331 relating to perceived knowledge (range 4.5 - 6.2). On average, respondents had only

332 a slightly positive response to the questions regarding perceived susceptibility to AR
333 (range 4.54 - 4.57; i.e. they only slightly agreed that they were susceptible to the
334 development of AR), but gave a moderately positive response to questions regarding
335 the perceived severity of AR (range 5.51 – 5.88; i.e. they agreed that AR was a
336 threat to horse health and performance).

337 Respondents gave a slightly negative response to the questions regarding
338 susceptibility to infection (range 3.1-3.18; i.e. they slightly disagreed that their horses
339 were susceptible to disease caused by worms), but gave a moderately positive
340 response to questions regarding the severity of infection (range 5.48 – 5.77; i.e. they
341 agree that worms are a threat to horse health and performance).

342 Respondents reported slightly positive attitudes towards the use of anthelmintics
343 (range 4.87 – 4.89) and strong positive attitudes towards the use of FECs prior to
344 treatment (range 6.42 – 6.51). On average, there was only a slightly positive
345 response to the questions regarding subjective norms (range 4.04 – 4.75). They also
346 gave moderately positive responses to the questions regarding behavioural control
347 (range 5.96 – 6.2; i.e. they agreed that the decision to use FECs and treat their
348 horses was under their control and that they could obtain FECs). Finally, on
349 average, respondents reported a moderately positive response to the intention to
350 use FECs in future (range 5.29 – 5.63). The intercepts are detailed in the SEM
351 output in Appendix D.

352 All specified covariances were statistically significant and all items were significantly
353 associated with the assigned constructs. Full output and standard fit indices are
354 reported in Appendix D. There was a significant, but weak, positive influence of the
355 perceived susceptibility of AR on the intention to use FECs before treating. None of
356 the other perceived risk constructs were significantly associated with intention to use
357 FECs. A more positive attitude towards anthelmintics was weakly associated with a
358 decrease in intention to use FECs. A more positive attitude towards FECs, an
359 increase in societal/peer influences (subjective norms) and an increase in perceived
360 control were strongly associated with an increased intention to use FECs (Table 2).

361 There was no direct effect of perceived knowledge on the intention to use FECs
362 before treating (Tables 2 and 3). However, there was a significant indirect influence
363 of perceived knowledge on behaviour intention via several mediating constructs
364 (Table 3). An increase in perceived knowledge was associated with a more negative
365 attitude towards anthelmintics (Table 2) which in turn led to an increase in the
366 intention to use FECs (Tables 2 and 3). However, the overall effect of perceived
367 knowledge on behaviour intention mediated by attitudes towards anthelmintics was
368 much weaker than for other mediating constructs. There were stronger, significant
369 positive influences of perceived knowledge on behaviour intention mediated by
370 attitudes towards FECs, subjective norms and perceived control (Tables 2 and 3).

371 The total indirect effect of knowledge on the intention to use FECs ($\beta = 0.76$, Odds
372 Ratio ($\exp(\beta)$) = 2.14; Table 3) was greater than the direct effect of any single
373 construct (Table 3).

374 The split SEM yielded an identical outcome to the full SEM, albeit with slightly
375 different coefficients (Appendix D). The standard fit indices and AIC were slightly

376 improved (AIC(full) = 83737, AIC(split) = 80499) but the split model was rejected in
377 favour of the more parsimonious full model.

378

379

380 **Discussion**

381 The adoption of new animal health management strategies and technology requires
382 animal owners to make complex risk assessments. Animal owners must also work
383 within the practical limitations of their particular management system and available
384 resources. Furthermore, as non-experts, animal owners must assess risk based on
385 incomplete knowledge of the health issue, management strategies and scientific
386 evidence base. The framework described here, based on the Theory of Planned
387 Behaviour and the Health Belief Model, captures these issues by measuring
388 perceived risk, attitudes towards FECs and the use of anthelmintics, subjective
389 norms and perceived control.

390 Socio-cognitive models such as the TPB and HBM are statistically testable
391 frameworks which can be used to determine which factors influence behavior.
392 However, all have their limitations, for example the exclusion of unconscious
393 influences and emotion, habits and the translation of intention into behaviour
394 (Sniehotta et al., 2014) and there is scope for factors not included in the model such
395 as emotion to influence the behaviour intention. These socio-cognitive theories can
396 therefore be framed as a part of a bigger picture, the static and more rational part of
397 behaviour (Vande Velde et al., 2017).

398 The intention of respondents to use FEC-TT or FEC-TST in future (i.e. conduct a
399 FEC prior to treating groups or individual horses, respectively) was evaluated as

400 'behaviour intention' in the framework. Attitudes towards diagnostics (FECs) and
401 anthelmintics were included as constructs to evaluate on the one hand the 'attitude
402 towards the behaviour' component of the TPB, and on the other hand the 'benefits –
403 barriers' component of HBM as described by Vande Velde et al., (2015). 'Subjective
404 norms' and 'perceived behavioural control' constructs were also evaluated as
405 described by Vande Velde et al., (2015).

406 'Perceived risk' was evaluated using constructs measuring 'perceived susceptibility
407 to AR' and 'perceived severity of AR' as described by Vande Velde et al., (2015).
408 However, many equids in the UK are considered companion animals and, as GIN
409 infection may lead to acute disease such as colic (Corning, 2009), it is possible that
410 fear of disease may drive horse owners to treat prophylactically regardless of cost or
411 future development of AR and to avoid selective treatment strategies. Therefore the
412 framework was extended to include additional constructs evaluating perceived risk of
413 infection (susceptibility and severity) in addition to the perceived risk of AR (Figure
414 1). Additional items evaluating 'perceived severity of infection' and 'perceived
415 severity of AR' in the context of horse performance were also included to reflect the
416 potentially divergent priorities of different sectors of the equine industry. These four
417 constructs were allowed to covary as they are components of the shared perceived
418 risk measure.

419 Similar studies on livestock have shown that the farmer's assessment of the efficacy
420 of the strategy in question is an important consideration (Valeeva et al., 2011;
421 Garforth et al., 2013), that access to sufficient, trusted information may influence
422 farmer behaviour with regards to biosecurity and animal health (Toma et al., 2013),
423 and that knowledge and awareness of practices may influence behaviour intention
424 (Garforth et al., 2013). Furthermore, an individual's knowledge and awareness may

425 affect the perceived credibility of peer and societal influences, and affect their
426 perceived control (how can one be in control of something that they do not
427 understand?). It therefore follows that a horse owner's intention to use FEC-TT or
428 FEC-TST may be driven in part by their knowledge and access to information. The
429 framework was therefore extended to include the horse owners' perceived
430 knowledge as a construct which may directly or indirectly affect behaviour intention
431 (Figure 1).

432 The significant χ^2 statistic obtained here was at odds with good model performance
433 in the structural evaluation and the model was therefore accepted. The SEM output
434 and subsequent conclusions were very robust to changes in the structural model
435 (indicated by the modification indices and comparison of the full and split models)
436 and were consistent with similar surveys conducted in other livestock sectors in
437 Europe (Vande Velde et al., 2015). This dual approach to model evaluation was
438 undertaken as the χ^2 test has been criticized for its sensitivity to large sample sizes
439 and susceptibility to type I errors (Weston and Gore, 2006; Barrett, 2007; Saris et al.
440 2009). Furthermore, it does not provide any indication of the suitability of the
441 structural model and misclassification errors. Therefore, evaluation of modification
442 indices has been suggested as an alternative method for model evaluation (Saris et
443 al., 2009).

444 The perceived risk of anthelmintic resistance and GIN infection, measured using
445 constructs related to perceived susceptibility and severity of resistance and infection
446 in the context of both horse health and performance, was surprisingly not associated
447 with the intention to use FECs. Therefore, the initial assumption that perceived risk
448 levels may drive the adoption of FECs is not supported. Vande Velde et al., (2015)
449 found a similar pattern in Belgian dairy cattle farmers' attitudes towards diagnosis

Commented [FV2]: Not sure if this is necessary, already well reported in Methods section.

450 before GIN treatment, but this was attributed to the relatively low levels of
451 anthelmintic resistance in dairy cattle in Western Europe. In contrast, anthelmintic
452 resistance is a common and well-publicised problem in UK horse populations, where
453 sub-optimal efficacy of all three classes of anthelmintics (macrocyclic lactones,
454 pyrantel and benzimidazoles) against cyathostomins has been detected (Relf et al.,
455 2014) and sub-optimal efficacy of fenbendazole has been detected on 100% of yards
456 tested (Lester et al., 2013; Relf et al., 2014; Stratford et al., 2014).

457 It is interesting to note that, overall, respondents thought that their horses were not
458 susceptible to disease caused by GINs but agreed that GIN infection was a threat to
459 horse health and performance. The low perceived risk of GIN infection may be due
460 to the chronic nature of the majority of clinical infections and lack of awareness of
461 acute larval cyathostominosis.

462 Similarly, the perceived severity of anthelmintic resistance was greater than the
463 perceived susceptibility to anthelmintic resistance, suggesting that respondents
464 thought that AR was a significant general issue but that they were less susceptible
465 than others. This attitude is also prevalent in sheep farmers (Morgan and Coles,
466 2010; Morgan et al., 2012) and could possibly be addressed inexpensively by regular
467 monitoring of pre- and post-treatment FECs to demonstrate the local status and risks
468 of infection and AR. However, the results here suggest that failure to adequately
469 assess risk of infection and AR are not barriers to the uptake of FEC-TT/FEC-TST
470 and therefore efforts may be better directed elsewhere.

471 There was a mildly positive overall attitude towards the use of anthelmintics to
472 prevent GIN infection. This suggests that horse owners consider prophylactic
473 treatment to be effective and perhaps explains the relatively low perceived

474 susceptibility to anthelmintic resistance regardless of the high prevalence of AR in
475 UK horse populations (Lester et al., 2013; Relf et al., 2014; Stratford et al., 2014).
476 Furthermore, a negative attitude towards the prophylactic use of anthelmintics was
477 weakly associated with greater intention to use FECs prior to treatment, suggesting
478 that owners wishing to move away from anthelmintic use for any reason (e.g. in
479 favour of using 'herbal' wormers) are more likely to use FECs.

480 Consistent with Vande Velde et al., (2015), a positive attitude towards diagnostics
481 (FECs) was strongly associated with a greater intention to use FECs prior to
482 treatment. Vande Velde et al., (2015) found that attitudes towards diagnostics were
483 more positive for dairy cows than calves, perhaps due to the ease of implementation
484 and lower costs of bulk milk tank ELISAs used in dairy cows compared with the
485 FECs used in calves. The current survey did not explore the motivations and
486 opinions underlying respondents' attitudes towards FECs and further work is
487 necessary to elucidate these factors.

488 Subjective norms were a strong driver of intention to use FEC-TT/FEC-TST,
489 indicating the importance of peers and advisers in the decision-making process. In
490 this respect, the recent release of equine anthelmintic prescribing protocols that
491 promote the use of FECs in the UK is a step in the right direction. Privately owned
492 horses and ponies are typically kept in small groups on private land, or on livery
493 where several owners keep their horses on the same yard and where the deworming
494 strategy of one owner directly affects the health of other horses on the yard.
495 Therefore, advocates for FEC-TT/FEC-TST on livery yards or shared grazing may
496 present an opportunity to encourage more widespread use of FECs through peer
497 influence.

498 Greater perceived control of deworming strategy was also strongly associated with a
499 greater intention to use FECs prior to treatment. This, in contrast to the lack of effect
500 of perceived risk, demonstrates the importance of self-efficacy and control in health
501 related behaviours – regardless of the perceived risk, an individual can only perform
502 a behaviour if they believe they have control over their circumstances and ability to
503 perform the behaviour. Access to suitable FEC services will undoubtedly play a key
504 role, but other fundamental barriers exist which limit perceived control. For example,
505 in some cases respondents commented that there was a lack of control over
506 deworming at the livery yard where their horse was kept. In other cases it may be
507 that a lack of understanding translates to a lack of perceived control. In a study of
508 pesticide safety behaviour in Mexican farmworkers in the US, which was also based
509 on the HBM framework, access to information on pesticide safety increased subjects'
510 perceived control of behaviours associated with limiting exposure to pesticides
511 (Arcury et al., 2002). Arcury et al., further suggest that education and demonstrations
512 aimed at increasing self-efficacy would lead to behaviour change. On the other hand,
513 livery yard managers that dictate yard worm control strategies could have a positive
514 role in co-ordinating deworming activities in co-grazing horses for the greater good,
515 to include considerations of sustainability.

516 The importance of education and awareness in empowering behaviour change is
517 reflected in the mediation analysis. Attitudes towards FECs and anthelmintics,
518 subjective norms and perceived control were all directly influenced by an increase in
519 perceived knowledge, which had a strong positive indirect effect on behavior
520 intention. Therefore, even small increases in the perceived knowledge of horse
521 owners could be beneficial to encourage sustainable nematode control practices.
522 Respondents were confident in the statement that they knew what worm egg counts

523 were for and that they knew enough about worms and deworming to decide on an
524 appropriate worm control strategy, but were less confident in their knowledge of the
525 limitations of worm egg counts and their ability to interpret worm egg counts without
526 the help of an adviser. Garforth et al., (2013) note that 'the fact that someone knows
527 about a measure and understands what it is designed to do does not make it more
528 likely that they will implement it' and that the comments of farmers in their survey
529 suggested that practicability and the ability to assess the efficacy of the measure are
530 important considerations.

531 In the present study, some horse owners commented on the quality, amount, and
532 impartiality of information available to them. Some horse owners also demonstrated
533 clear misunderstandings of gastrointestinal nematode biology, the epidemiology of
534 disease and the limitations of FECs, which further demonstrate the importance of
535 communicating the limitations of egg counts and other sustainable control strategies
536 to users. They may also reflect a wider problem of companies offering potentially
537 inaccurate FEC services based on inadequate faecal samples, damaging the
538 credibility of FEC-based deworming strategies as some respondents communicated
539 concerns and distrust with regards to the sampling methods used by commercial
540 providers.

541

542 **Conclusions**

543 Based on the results of this survey and the comments of respondents, knowledge
544 transfer activities focussing on increasing awareness and understanding, and
545 delivering training on the practical implementation of FECs, may improve the uptake
546 of sustainable parasite control practices such as FECs on equine holdings in the UK,

547 primarily by improving self-efficacy and perceived control. It is, however, important
548 that such activities are supported by targeted research on the opinions and attitudes
549 of horse owners to current information sources and methods of knowledge transfer,
550 as opinions of livestock farmers on the credibility of information sources and the
551 translation of scientific evidence underpinning animal health measures was reported
552 to be variable (Garforth et al., 2013). Furthermore, emphasising the dangers of the
553 *status quo*, in this case nematode infection and the development of AR, may not
554 encourage behaviour change. Knowledge transfer activities should therefore focus
555 on improving self-efficacy through improved knowledge of the system and available
556 nematode control options, as well as identifying and addressing potential barriers to
557 the uptake of sustainable nematode control strategies.

558

559 **Conflicts of interest**

560 HRV delivers training and knowledge exchange activities related to faecal egg
561 counting and sustainable nematode control in livestock and horses. The research
562 was conducted as part of a project aiming to develop automated parasite egg
563 counting technology to support targeted treatment of grazing livestock. Funding
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565

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571

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