

# 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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#### 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 worm egg counts (FECs) to support targeted treatment (FEC-TT) and targeted 20 selective treatment (FEC-TST) has been promoted as an effective deworming 21 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 infection but was positively influenced by a negative attitude towards anthelmintics, a 31 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 their deworming programme. The results were consistent with a similar study 34 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

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#### <sup>1</sup> 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 control efforts in horses and ponies (Corning, 2009; Matthews and Lester, 2015). 49 50 The problem of AR in grazing ruminants (Rose et al., 2015) has been addressed by recommending more discriminant application of anthelmintic treatments at group and 51 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). Seventy-six percent of respondents to a recent survey of horse owners in the UK 61 62 (primarily owners in the south of England) reported that they already use FECs to target treatment (Easton et al., 2016). Despite this relatively high self-reported 63 uptake of FEC-TT, the survey indicates that treatment applied at set intervals or on 64 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 never performed FECs prior to treatment (Salle and Cabaret, 2015). Identifying the 67 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.

Risk management behaviour in animal owners, such as the use of FECs, may be 71 driven by a range of factors including their perception of disease risk, whether they 72 consider the behaviour to be effective, their underlying knowledge of the risks and 73 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

attitude towards the behaviour, their perceived control over whether or not they
perform the behaviour, and peer/societal influences (Ajzen, 1991). The Health Belief
Model (HBM; Rosenstock et al., 1988) shares common elements with the TPB but
extends the inclusion of potential barriers to performing a behaviour, e.g. positive
attitudes towards the risky behaviour, and includes the evaluation of perceived risk
(Valeeva et al., 2011; Vande Velde et al., 2015).

Although these models are rooted in studies of human health, they have been
applied to evaluate animal health management and identify factors influencing
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.

# 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
121	
125	The structural model comprised constructs evaluating the intention to use
125 126	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs),
125 126 127	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs), attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e.
125 126 127 128	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs), attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e. FECs) prior to treatment and subjective norms, as described by Vande Velde et al.
125 126 127 128 129	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs), attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e. FECs) prior to treatment and subjective norms, as described by Vande Velde et al. (2015). In addition, a perceived risk construct evaluated perceived susceptibility to
125 126 127 128 129 130	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs), attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e. FECs) prior to treatment and subjective norms, as described by Vande Velde et al. (2015). In addition, a perceived risk construct evaluated perceived susceptibility to infection and AR (i.e. the perceived likelihood of infection or developing AR), and
125 126 127 128 129 130 131	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs), attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e. FECs) prior to treatment and subjective norms, as described by Vande Velde et al. (2015). In addition, a perceived risk construct evaluated perceived susceptibility to infection and AR (i.e. the perceived likelihood of infection or developing AR), and perceived severity of infection and AR. The framework was also extended to include
125 126 127 128 129 130 131 132	The structural model comprised constructs evaluating the intention to use diagnostics (i.e. FECs) prior to treatment, attitudes towards diagnostics (i.e. FECs), attitudes towards anthelmintics, perceived control over the use of diagnostics (i.e. FECs) prior to treatment and subjective norms, as described by Vande Velde et al. (2015). In addition, a perceived risk construct evaluated perceived susceptibility to infection and AR (i.e. the perceived likelihood of infection or developing AR), and perceived severity of infection and AR. The framework was also extended to include the horse owners' perceived knowledge as a construct which may directly or

7

#### 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 Equine Database in 2012. Therefore, a randomised survey design was not possible 147 148 and horse and pony owners were surveyed using a self-selecting online survey 149 (SurveyMonkey Inc., Palo Alto, California, USA, <u>www.surveymonkey.com</u>) 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.

#### 159 External validation

To verify the external validity of the survey, commercial respondents' characteristics (type of horse owner/establishment) were compared against characteristics of the UK equine industry (Lantra, 2011). It was not possible to validate the ratio of private 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 UK was compared against the distribution of commercial equine establishments in 167 168 the UK (Lantra, 2011) by Chi Square analysis in R 3.2.2 (R Core Team, 2015). The county of origin of each respondent was extracted from the latitude and longitude 169 170 coordinates and the Ordnance Survey's Boundary Line<sup>™</sup> 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).

## 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 from 0. Although the Likert and bipolar 7-point scales generate ordinal items, the 196 197 lavaan package treats these data as numeric and therefore no further adjustments 198 were necessary. 199 Model fit can be evaluated using a  $\chi^2$  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  $\chi^2$ critical value corresponding to one degree of freedom at p<0.05) then the model may 205 be improved by respecifying the parameter in the model (Whittaker, 2012). To 206

207 determine the need for respecification and model modification the context of the change is considered (i.e. is the modification theoretically plausible?) in combination 208 209 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 ( $\beta$ ) and p-values. 214 Mediation analysis (laccobucci 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 A subject to item ratio of 10:1 (i.e. 10 respondents for each question in the survey) 224 225 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.

#### 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 incomplete and were removed from further analysis. Respondents were allowed to 236 237 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 finder (http://www.gridreferencefinder.com/postcodeBatchConverter/), which was 250 251 unable to find 15 postcodes. Ten of these were found to be valid postcodes for Northern Ireland and the Channel Islands after further searches. The remaining 5 252 253 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).

# 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	$x_{31} \mbox{ and } x_{32}  underlying the subjective norms (norms) construct loaded weakly (factor$
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 $x_{19}\mathchar`-x_{24}$ 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

structural model (Figure 1), and a split model whereby the perceived severity of AR
and perceived severity of infection constructs were divided to account for potential
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 as covariances. Therefore the model was considered correctly specified. Specifically, 303 304 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

- relating to perceived knowledge (range 4.5 6.2). On average, respondents had only

- a slightly positive response to the questions regarding perceived susceptibility to AR 332 (range 4.54 - 4.57; i.e. they only slightly agreed that they were susceptible to the 333 334 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 threat to horse health and performance). 336 337 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
- 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

improved (AIC(full) = 83737, AIC(split) = 80499) but the split model was rejected in
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 evidence base. The framework described here, based on the Theory of Planned 386 387 Behaviour and the Health Belief Model, captures these issues by measuring perceived risk, attitudes towards FECs and the use of anthelmintics, subjective 388 389 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 influences and emotion, habits and the translation of intention into behaviour 393 394 (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 therefore be framed as a part of a bigger picture, the static and more rational part of 396 397 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).

'Perceived risk' was evaluated using constructs measuring 'perceived susceptibility 406 to AR' and 'perceived severity of AR' as described by Vande Velde et al., (2015). 407 408 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 infection (susceptibility and severity) in addition to the perceived risk of AR (Figure 413 414 1). Additional items evaluating 'perceived severity of infection' and 'perceived severity of AR' in the context of horse performance were also included to reflect the 415 potentially divergent priorities of different sectors of the equine industry. These four 416 417 constructs were allowed to covary as they are components of the shared perceived 418 risk measure.

Similar studies on livestock have shown that the farmer's assessment of the efficacy
of the strategy in question is an important consideration (Valeeva et al., 2011;
Garforth et al., 2013), that access to sufficient, trusted information may influence
farmer behaviour with regards to biosecurity and animal health (Toma et al., 2013),
and that knowledge and awareness of practices may influence behaviour intention
(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 $\chi^2$ 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 $\chi^2$ 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

in the context of both horse health and performance, was surprisingly not associated
with the intention to use FECs. Therefore, the initial assumption that perceived risk
levels may drive the adoption of FECs is not supported. Vande Velde et al., (2015)
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.

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

It is interesting to note that, overall, respondents thought that their horses were not susceptible to disease caused by GINs but agreed that GIN infection was a threat to horse health and performance. The low perceived risk of GIN infection may be due to the chronic nature of the majority of clinical infections and lack of awareness of 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, 2010; Morgan et al., 2012) and could possibly be addressed inexpensively by regular 466 467 monitoring of pre- and post-treatment FECs to demonstrate the local status and risks of infection and AR. However, the results here suggest that failure to adequately 468 469 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. There was a mildly positive overall attitude towards the use of anthelmintics to 471

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 liveries
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.

Greater perceived control of deworming strategy was also strongly associated with a 498 greater intention to use FECs prior to treatment. This, in contrast to the lack of effect 499 of perceived risk, demonstrates the importance of self-efficacy and control in health 500 501 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' perceived control of behaviours associated with limiting exposure to pesticides 510 (Arcury et al., 2002). Arcury et al., further suggest that education and demonstrations 511 aimed at increasing self-efficacy would lead to behaviour change. On the other hand, 512 513 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. The importance of education and awareness in empowering behaviour change is 516 517 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

were for and that they knew enough about worms and deworming to decide on an 523 appropriate worm control strategy, but were less confident in their knowledge of the 524 525 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 to users. They may also reflect a wider problem of companies offering potentially 536 537 inaccurate FEC services based on inadequate faecal samples, damaging the credibility of FEC-based deworming strategies as some respondents communicated 538 539 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.

#### 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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