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Determining the influence of socio-psychological factors on the adoption of individual 'best practice' parasite control behaviours from Scottish sheep farmers.

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ABSTRACT

Since 2003, the Sustainable Control Of Parasites in Sheep (SCOPS) group have provided the UK sheep farming industry with guidance on ways to mitigate the development and dissemination of anthelmintic resistance (AR). However our empirical understanding of sheep farmers' influences towards such 'best practice' parasite control approaches is limited, and therefore requires further assessment and evaluation to identify the potential factors influencing their implementation. In 2015, a telephone questionnaire was conducted in order to elicit Scottish sheep farmers' attitudes and behaviours regarding the SCOPS recommended practices, as well as gauging farmers' general attitudes to gastrointestinal nematodes (GIN; term roundworm used in questionnaire) control. A quantitative structural equation modelling (SEM) approach was employed to determine the influences of socio-psychological factors and the uptake of individual anthelmintic resistance mitigating practices including: the implementation of a quarantine strategy for parasite control and the use of parasite diagnostic testing for monitoring faecal egg counts (FEC) and detecting AR. The proposed models established a good fit with the observed data and explained 61%, 54% and 27% of the variance in the adoption of AR testing, FEC monitoring, and quarantine behaviours respectively. The results presented highlight a number of consistent and distinct factors significantly influencing the implementation of selected SCOPS recommended practices. The negative influences of topography and farmer experience was frequently demonstrated in relation to multiple GIN control practices, as well as the positive influences of social norms, worm control knowledge, AR risk perception and positive attitudes to the services provided by the veterinary profession. Factors that were shown to have the greatest relative effects on individual parasite control practices included: the perceived expectation of others (i.e. Social norms) for implementing a quarantine strategy, farmer's suspicions to the presence of AR on the holding for instigating AR testing and the confirmation of AR for adopting FEC monitoring. Determining the influences of behaviour-specific factors on farmers' decision making processes will help to identify and address positive and negative influences concerning implementation of AR mitigating practices, as well as contribute to the development of more evidence based intervention strategies in the future.

1. Introduction

Endemic disease of livestock costs the industry millions of pounds in lost revenue due to health and welfare factors such as lost productivity and mortality (Charlier et al., 2020; Seegers et al., 2003). Successful control of endemic diseases relies on uptake and application of best practice recommendations. Arguably, one of the economically important disease syndromes of sheep is parasitic gastroenteritis caused by

Abbreviations: AR, Anthelmintic resistance; FEC, Faecal Egg Count; GIN, Gastrointestinal Nematode; SEM, Structural Equation Modelling; TPB, Theory of Planned Behaviour; HBM, Health Belief Model.

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gastrointestinal nematodes (GIN). The control of GIN is being hampered by the development of resistance to the available anthelmintic compounds used in the therapeutic and prophylactic treatment of animals. As cases of anthelmintic resistance (AR) increase in number in herds and flocks (Rose Vineer et al., 2020) it is important to evaluate means of promoting sustainable GIN control strategies to mitigate further treatment failure and reduce the dissemination of resistant parasites. In the UK industry recommendations for responsible anthelmintic usage in sheep are developed by the industry led group Sustainable Control Of Parasites in Sheep (SCOPS; scops.org.uk). The group has encouraged 'best practice' approaches to parasite control since 2003 (Abbott et al., 2004; Abbott et al., 2012; Stubbings et al., 2020). The recommendations provide sheep producers and animal health advisors with background information and strategies for managing parasites at the individual farm level. The general ethos for these recommendations is for a more considered approach to parasite management and particularly the timing and application of anthelmintics, with an emphasis on long-term solutions that will ultimately help to sustain the efficacy of parasite treatments.

The formal and informal dissemination of the recommendations has relied on a variety of information platforms including the internet, farming press and direct consultancy (either individually, at group meetings and at agricultural events) providing high accessibility to potential users. However, the variable uptake of good practice guidelines recommendations on areas such as biosecurity (Garforth et al., 2015; Brennan and Christley, 2013), lameness and mastitis (Bell et al., 2006) and GIN control (Bartley, 2008; Melville et al., 2021b) demonstrates that many of these guidelines are implemented at variable rates by the general farming community. Recommendations for the control of GIN, that have been shown to have poor uptake include the high proportion of surveyed farmers using visual weight assessments for determining anthelmintic treatment doses (Sargison and Scott, 2003; McMahon et al., 2013), lack of uptake of effective quarantine administrations (Bartley, 2008; Morgan et al., 2012; Melville et al., 2021b) as well as the lack of farmers' employing parasite diagnostic testing for identifying AR (Sargison and Scott, 2003; Easton et al., 2018; Claerebout et al., 2020; Charlton and Robinson, 2020; Melville et al., 2020a, 2021b); or for monitoring parasite burdens (Vande Velde et al., 2015). The apparent detachment of many farmers from the practices concerning AR risk management therefore necessitates the need to explore the possible motives influencing farmers' parasite control behaviours, and particularly those relating to practices that mitigate the development of AR.

The field of implementation science (i.e. the study of methods to promote the uptake of research findings into routine practice) has been increasingly developed for investigating farmer behaviours relating to biosecurity (Garforth, 2015), management based strategies for infectious disease prevention and control (Review by Ritter et al., 2017), and examining a range of different social, psychological and economic influencing factors (Edwards-Jones, 2006; Wauters and Rojo-Gimeno, 2014). It is thought that many processes may be involved, from the development of ideas or innovations to their implementation in real life scenarios (Richens et al., 2018). Within the implementation process it is thought that there are a number of fundamental factors involved; the nature of the guidance (complexity, flexibility etc.), the characteristics of individual users (knowledge, motivations etc.) the local support organisation (existing network/structures, resources, priorities etc.) and the interventions used (training, leadership etc.; Livesey and Noon, 2007). In terms of the individual user, the influence of attitudes towards a recommendation or regulations (Ajzen, 1991) or information knowedge base (Toma et al., 2013) have been acknowledged as an important influencer in the decision making process, and therefore has significant implications on behavioural adoption. A number of model frameworks have been developed to help identify the range of potential influences of specific behaviours including; The Theory of Planned Behaviour (TPB; Ajzen, 1991), Technology Acceptance Model (TAM; Davis et al., 1986; cited in Lee et al., 2003), Health Belief Model (HBM; Rosenstock et al., 1988) and Normalisation Process Theory (NPT; May et al., 2009).

The TPB model consists of three main concept beliefs that are assumed to have either a direct impact on behaviour or an indirect impact via behavioural intention (Ajzen, 1991). The first of these belief predictors is 'attitude' towards a behaviour that assesses the individual's positive or negative beliefs regarding the outcome of the specific behaviour. The second predictor is 'social norms' which refers to the wider social environment and the perceived expectation of significant others towards adopting behaviours. The third predictor is 'perceived behavioural control' which reflects the individual's perceived ability to perform the specific behaviour based on factors believed to facilitate or hinder it such as cost, labour or facilities. Other such models have also focused on factors relating to preventive health behaviours such as the HBM (Rosenstock et al., 1988). The HBM shares some comparable factors to the TPB with predictors including perceived benefits/barriers, as well as self-efficacy i.e. perceived confidence in ones own ability to perform behaviours. Additional factors within this model include 'cues to action', 'perceived susceptibility/severity' and 'modifying variables'. The first of these factors proposes that a prompt or trigger, which may be internal (e.g. pain) or external (e.g. media) is necessary to spark engagement in a health behaviour. The second set of factors relate to the perceived level of risk, which comprises of susceptibility i.e. likelihood of an event occurring, as well as severity i.e. the impact of the event occurring. The final component 'modifying factors' incorporates various alternative individual characteristics believed to indirectly influence behaviour, which include demographics, psychosocial and structural variables. Demographics include aspects such as age, gender, education etc. Socio-psychological variables include features such as personality, peer/group pressure, social class and structural variables relate to an individual's knowledge and experience of the condition of interest.

The objective of this study, conducted with a questionnaire designed using the TPB and HBM frameworks and administered in 2015 to Scottish sheep farmers (Jack et al., 2017), was to determine influences on adoption behaviours of best management practices in GIN control. Identification of these influences will aid in the development of future extension programmes to target influencers of farmer behaviour to encourage the use of sustainable parasite control approaches.

2. Materials and methods

2.1. Survey background

The questionnaire was designed to assess both Scottish sheep farmers' attitudes towards GIN control as well as GIN control practices in connection with the SCOPS 'best practice' guidelines. This paper is limited to presenting survey items pertaining to the analysis with full details presented in Table 1. The full questionnaire can be found in Appendix A. The survey sample used for data collection (n = 400) was proportionally weighted based on the overall number of Scottish sheep holdings (approx. 14,900; National statistics) within each of the six broad geographical regions (South-East, South-west, Central, North-East, North-West and Islands). Contact details were obtained from the Scottish Government (Rural and Environment Science and Analytical Services Division; RESAS) by the use of a stratified simple random sampling method applied to the agricultural census data. The sampling frame was calculated by RESAS from the original target population by assuming a likely positive response rate of 30%, and aiming to achieve an overall failure rate of 0.001. The resulting sampling frame included 1930 holdings.

The data collection was performed using a computer-assisted telephone survey method conducted by an external telecommunications company using a quota sampling representative of the six geographic regions. A confidentiality/data protection agreement was agreed by all parties before the relevant contact details (names and telephone numbers) were released via an encrypted copy. All prospective survey

Table 1
Descriptive statistics (median and interquartile range; IQR) of observed variables included in 'Quarantine strategy', 'AR test' and 'FEC test' models. N = 400.

Indicator directory	Question	Indicators	Categories (code)					*N* =	Median	IQR
Section 1 (demographics and farm characteristics)	1	What is your age	18–35 (1)					35	3	1
			36–50 (2)					110		
			51–65 (3)					176		
			> 65 (4)					101		
	2	Did you attend a place of further education?	No further education (0)					196	0	1
			Agricultural college (1)					59		
	3	How many years have you been earning a living as a farmer	10 years or less (1)					31	4	2
			11–20 (2)					44		
			21–30 (3)					90		
			31–40 (4)					112		
			41–50 (5)					73		
			51 and over (6)					50		
	10	Is your farm designated as lowland, upland or hill?	Lowland (1)					96	2	1
			Upland (2)					153		
			Hill (3)					151		
Section 2 (general GIN (roundworm) control/AR attitude items)	103	How would you classify the occurrence of roundworm problems in your flock?	Low (1)					306	1	0
			Moderate (2)					87		
			High (3)					7		
			*SD	D	U	A	SD	***N* =**	**Median**	**IQR**
	32	Working out a roundworm control strategy with my vet is cost effective	8	19	78	131	163	400	4	2
	33	Working out a roundworm control strategy with my vet ensures I get reliable advice	8	12	51	127	202	400	4	1
Section 3 (open-ended knowledge items)	29 (a, b, c|)	Knowledge score	–					–	1	1
Section 4 (Quarantine strategy items)	45	I don't have time to quarantine incoming animals on my farm	168	106	24	20	5	323	1	1
	46	I don't have the facilities to separate incoming stock from the main flock	176	100	14	20	12	323	1	1
	47	I find the quarantine advice for roundworm control is too complicated	108	106	68	32	9	323	2	2
	48	Advice is conflicted regarding best quarantine practice	69	83	103	60	8	323	3	1
	92	They would expect me to have a quarantine strategy against roundworms	14	43	61	116	89	323	4	2
	93	Their opinion of my quarantine strategy is important to me	12	39	46	142	84	323	4	2
	40	Returning or new sheep pose a risk of introducing wormer resistance onto my farm	5	31	27	125	135	323	4	1
	41	I am worried about bringing wormer resistance onto my farm	17	67	51	96	92	323	4	3
Section 4 (AR test items)	50	Unless I saw an impact on productivity, I would not feel the need to test for wormer resistance	35	65	73	164	63	400	4	2
	51	Unless I saw scouring or ill thrift, I would not feel the need to test for wormer resistance	43	85	58	155	59	400	4	2
	94	They would advise me to test my flock for wormer resistance	12	43	90	153	102	400	4	2
	95	They would expect that I should know the wormer resistance status of my flock	10	65	96	157	72	400	4	1
	23	Wormer resistance is a problem in my region	39	129	121	82	29	400	3	2
	24	Wormer resistance is a threat to my farming business	42	126	72	112	48	400	3	2
	109	Do you suspect you have any resistance on your farm?	Yes					43	0	0
			No					337		
			Don't know					20		
Section 4 (FEC test items)	59	Monitoring worm egg counts can improve animal productivity	1	4	65	199	131	400	4	1
	60	Monitoring worm egg counts can optimise treatment timings	1	7	70	198	124	400	4	1
	62	Collecting samples for worm egg counts is too time consuming	82	125	75	97	21	400	2	2
	63	It isn't practical to collect faecal samples from my flock for worm egg counts	108	155	65	51	21	400	2	2
	97	They would want me to monitor worm egg counts before treating animals	27	70	82	137	84	400	4	1
	98	Their opinion of my treatment strategy is important to me	6	28	51	200	115	400	4	1
Section 5 (GIN; Roundworm) control practice items)	106	Do you drench incoming sheep brought onto the farm?	Yes					291	†2	1
			Yes, occasionally					12		
			No					20		
	107	Do you withhold incoming sheep from pasture?	Yes					221		
			No					102		
	110	Have you ever tested for drug resistance?	Yes					51	0	0
			No					349		
	105	Do you monitor worm egg counts?	Yes, more frequently					49	0	1
			Yes, once or twice					89		
			No					262		

*SD= Strongly disagree (1), D = Disagree (2), U= Unsure (3), A= Agree (4), SA= Strongly agree (5); †Median and IQR figures calculated from score of combined quarantine measures implemented; GIN gastrointestinal nematodes; AR, anthelmintic resistance; FEC, faecal egg count.

recipients were sent a letters two weeks prior to the survey implementation detailing the purpose and content of the interview, predicted length of time required, data confidentiality measures, as well as to offer the option to opt-out from data collection. The surveys were conducted between January and February of 2015, as this was anticipated to be the most suitable period that farmers could be reached and have the time to conduct the interviews. Those farmers who conducted the survey were not sent the question list beforehand. Further details of questionnaire implementation and data collected can found in Jack et al. (2017).

The survey design was based around five main components which were included in the following order: 1) Socio-demographics (including respondents: age, education, number of years earning as a farmer) and enterprise characteristics (Farm topography i.e. lowland, upland or hill); 2) General attitudes towards GIN control and anthelmintic resistance; 3) Open-ended GIN control knowledge questions; 4) Attitudes towards SCOPS related GIN control practices and 5) Self-reported parasite control practices.

All attitudinal items were assessed using statements relating to various topics and measured on a 5-point Likert scale from: Strongly disagree (1), Disagree (2), Unsure (3), Agree (4) and Strongly agree (5). The collated survey data was coded in Microsoft Excel as well as formatted into SPSS (Statistical Package for the Social Sciences, IBM version 25.0).

2.2. Survey analysis

2.2.1. Structural equation modelling

For the purposes of analysing statistical models comprising of considerable numbers of individual variables, a Structural Equation Modelling approach (SEM) was adopted. This particular modelling method comprises of two steps, a) defining the measurement model and b) imputing the structural model.

2.2.2. Measurement model

The measurement model involves creating a smaller set of 'latent' (unobserved) factors from a selection of observed measures (i.e. manifest variables). Before the measurement model is assigned, an exploratory factor analysis and reliability analysis was initially conducted on the ordinal Likert scale items relating to each best practice model. Factor loadings (correlation coefficients) were used to assess the strength of covariation observed between items based on procedures described by Hair et al. (2006). Using a principal component analysis method of extraction with an orthogonal factor rotation method (Varimax) to interpret the extracted factors, a minimum threshold of $\pm$ 0.30 factor loading was set to ensure statistical significance for each value at a statistical power of 80%, corresponding to the study sample size. Accordingly, all factor loadings below $\pm$ 0.30 were omitted from further analysis, in addition to cases where significant loadings were observed across more than one factor (i.e. cross loading). Once suitable factors were identified, an internal reliability measure (Cronbach alpha) was performed with a minimum threshold set at 0.60. Factors demonstrating both acceptable factor loadings and reliability measures were used in the subsequent structural model.

The multiple-indicators latent variables included in this paper established acceptable factor loadings with their underlying constructs (i.e. >0.70), as well as suitable measures of collinearity as indicated by Cronbach alpha analysis (α = >0.60), with the exception of 'AR risk' (α = 0.59). Factor loading and Cronbach alpha values are detailed individually for each model within Appendix B (Tables S1 – S3) and C (Tables S4 - S6).

The resulting latent factors included within each model are described in the results section, with details of the factor loadings included in appendices A, B and C.

2.2.3. Structural model

The second step of the SEM analysis is to assign a structural model which examines the relationships between the model constructs in a multiple regression. The resulting regression coefficients represent the change in the dependent variables for one unit change in the independent variable. The results described in *'Results of structural equation models'* represent the standardised coefficients (β values) which allow direct comparisons to be made between each of the predictor variables and their relative effects on other variables. The statistical package used for the SEM analysis was LISREL 8.80 (Jöreskog and Sörbom, 2007). A Diagonally Weighted Least Squares (DWLS) method for estimating the model parameters was chosen due to the non-normally distribution of the variable data used. The assessment for model fit was evaluated using the following model fit indices: Root Mean Square Error of Approximation (RMSEA), Standardised Root Mean Residual (SRMR), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Goodness of fit (GFI), Adjusted Goodness of Fit Index (AGFI) and Normed Fit Index (NFI). The reference values used to assess the goodness-of-fit indices were obtained from Hair et al. (2006).

2.2.4. Model frameworks

Three parasite control behaviour models were developed in connection to three SCOPS guideline associated practices: 1) Quarantine strategy for anthelmintic resistance 2) Testing for anthelmintic resistance and 3) Monitoring faecal egg counts (FEC).

All attitudinal Likert scale data were initially assessed for normality using the Kolmogorov-Smirnov statistical test. Bivariate Spearman correlation were used to assess correlation between observed (measured) variables and the associated dependent variables. Based on the correlations observed and their empirical relevance to the individual practices, the proposed three models were established and are discussed further hereon.

2.2.5. Quarantine strategy model

Overall seven factors were included in the Quarantine model based on their significant effect on the outcome behaviour. Five multiple-indicator latent variables were formulated from 10 indicators as detailed in Appendix B; Table S1. The multiple-indicator latent variables consisted of the following factors: 'Vet service pros', 'AR risk', 'Quarantine resources',' Quarantine advice' and 'Quarantine social norms' (Fig. 1). Explanations of these factors will be discussed hereon.

The factor 'Vet service pro' refers to the positive attitudes towards veterinary services particularly regarding reliability and cost-effectiveness. 'Quarantine social norms' which derives from the TPB and refers to respondents perceived social pressures from significant

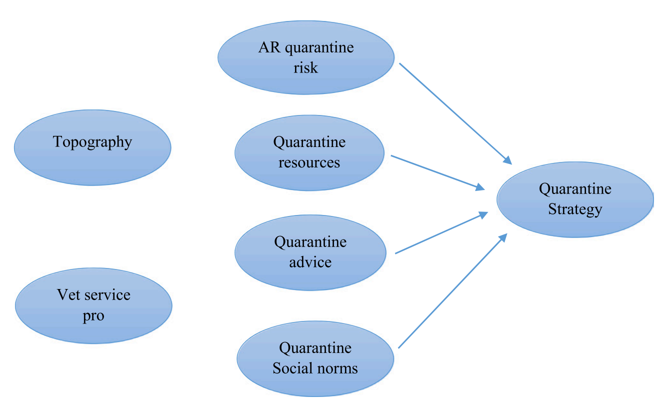

Fig. 1. Model framework for uptake of quarantine practices ('Quarantine strategy').

others associated with implementing quarantine measures. Other mediating variables include 'Quarantine advice' which represents negative association with quarantine advice including conflicting information and complexity. 'Quarantine resources' refers to the perceived demands that quarantining animals requires on both time and facilities, which corresponds with the perceived behavioural control factors proposed within TPB model. The variable 'Quarantine AR risk' refers to the perceived AR risk posed specifically by the introduction of new or returning animals onto the farm and measures both the cognitive and affective perceptions towards quarantine AR risk.

The two single-indicator variables included in the quarantine model consist of 'Topography' i.e. the physical farm setting which classifies whether the farming system is a predominantly lowland, upland or hill farm, and the outcome variable 'Quarantine strategy'. The dependent variable 'Quarantine strategy' was formulated into an ordinal measure by attributing a score to each of the following quarantine related behaviours: 'Do you drench incoming animals brought onto the farm' and 'Do you withhold incoming animals from pasture'. This was required due to the nature of the attitudinal questions that were directed at the overall quarantine strategy rather than individual aspects. The final sample total used to assess the quarantine model was 323, which included only respondents that introduce new sheep onto their farms i.e. open flocks.

2.2.6. AR testing model

Overall, 11 factors were included in the AR testing model based on their significant effect on the outcome behaviour. Five multiple-indicator latent variables were formulated from 10 indicators shown in Appendix B; Table S2. The multiple-indicator latent variables consisted of the following factors: 'Experience', 'Vet service pros', 'AR risk', 'Cues to action' and 'Social norms' (Fig. 2). Explanations of these factors will be discussed hereon.

The latent factor 'Experience' is based on two observed items: the respondents age and number of years earning a living as a farmer. The remaining latent factors include: respondents perceptions towards the level of risk associated with AR ('AR risk'), respondents current belief concerning presence of AR on their premises ('Suspect AR'), 'Cues to action' which evaluates the impetus that clinical signs associated with anthelmintic (term wormer used in questionnaire) failure may have on AR testing behaviour and lastly, respondents level of social conformity connected to testing for AR 'AR test social norm'. Both the 'AR risk' and 'Cues to action' constructs were adopted from the HBM as proposed influences towards health related behavioural change.

The six single-indicator variables included 'Topography', 'Education', 'Occurrence of worm problems', 'Worm control knowledge', 'Suspect AR' and the outcome variable 'AR test'.

The variable 'Roundworm control knowledge' was formulated from a set of three open-ended parasite control questions. Each question response was classified as correct or incorrect based on the authors' judgment. A score was devised based on the number of correct responses to the three questions. For the variable 'Education' all categories other than 'agricultural college' were considered to have little influence on agricultural practice and were therefore combined into a dichotomous variable (agricultural college vs. other). The variables 'Worm control knowledge' and 'Occurrence of worm problems' are both connected with the HBM as structural variables which relate to a pre-existing knowledge and previous experience of a disease. The dependent variable 'AR test' classified whether the respondent had or had not previously tested for AR. The total number of observations included in this sample was 400.

2.2.7. FEC test model

Overall, 11 factors were included in the FEC testing model based on their significant effect on the outcome behaviour (Fig. 3). Six multiple-indicator latent variables were formulated from 12 indicators shown in Appendix C; Table S3. The multiple-indicator latent variables consisted of the following factors: 'Experience', 'FEC pros', 'FEC cons', 'AR risk', 'Social norms' and 'Vet service pros' (Fig. 3). The factor 'FEC pros' is in connection to positive attributes for using FEC monitoring, namely improving animal productivity and timing of treatments. 'FEC cons' conversely denotes negative attributes associated with FEC monitoring, specifically regarding the perceived practicality and time required to collect samples. The five single-indicator variables included 'Topography', 'Occurrence of worm problems', 'Worm control knowledge', 'AR confirmation' which reflects whether respondents had previously confirmed AR in their flock, and the final outcome variable 'FEC test'. The dependent variable 'FEC test' was formulated into dichotomous variables which classified whether the respondent had or had not previously conducted FEC testing in their flock. The total number of observations included in this sample was 400.

3. Results

3.1. Survey implementation

The telecommunications company used the full sample set supplied

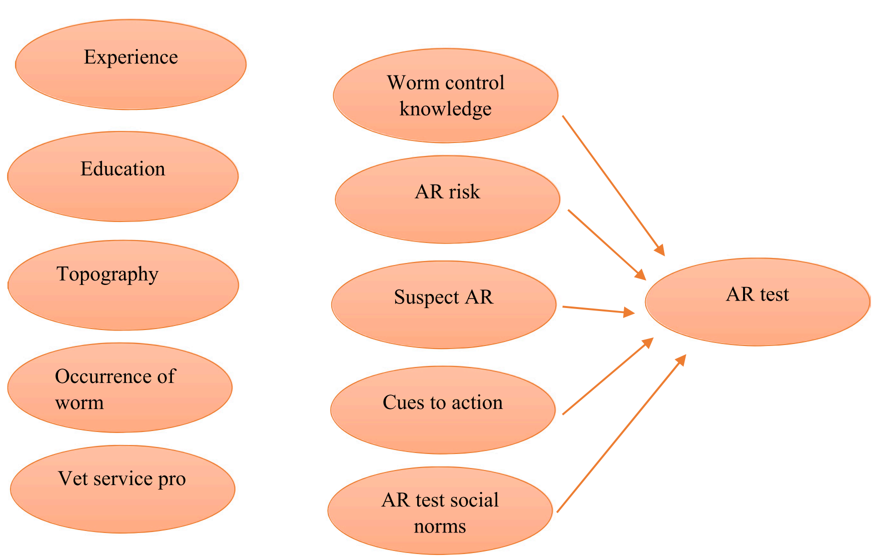

Fig. 2. Model framework for uptake of anthelmintic resistance testing ('AR test').

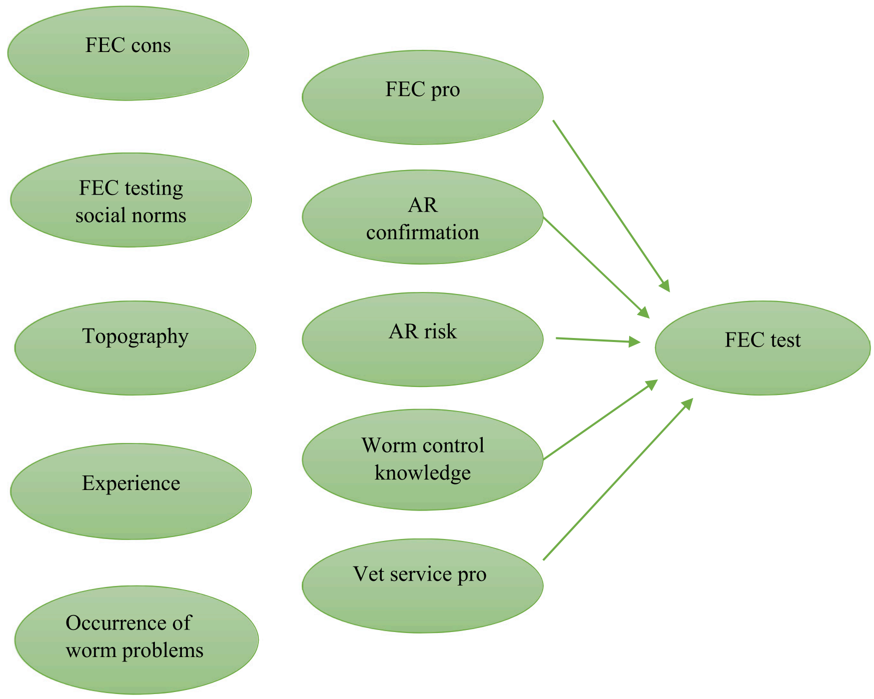

Fig. 3. Model framework for uptake of faecal egg count monitoring ('FEC test').

that had not opted out when invited to participate (n = 1503). In order to reach the quotas required interviewers attempted to make initial contact with all names on the list. Because of the approach used and challenges involved in contacting prospective interviewees the interviewers often scheduled appropriate time for administering the questionnaire. Data on non-response rates was not collected as interviewers stopped collecting data from a region once the quota was reached, however initial opt-out rate prior to conducting the survey was (n = 427; 22%).

3.2. Descriptive results of model indicators

From the results presented in Table 1, question items which demonstrated the highest levels of agreement overall (Median = 4) included those regarding: positive veterinary service attitudes (Q32, 33), quarantine AR risk (Q40, 41), social norms (Q92, 93, 94, 95, 97, 98), AR testing cues to action (Q50, 51) and positive FEC attitudes (Q59, 60). Conversely, question items which demonstrated the higher levels of disagreement overall (Median = 1) included items concerning quarantine resource requirements i.e. time and facilities (Q45, 46). In regards to items receiving an overall moderate level of disagreement these included items such as: complexity of quarantine advice (Q47) and negative FEC sampling attitudes (Q62, 63). Attitudinal items which indicated uncertainty (Median =3) among respondents included: conflicting quarantine advice (Q48) and AR risk questions (Q23, 24).

In terms of variability of attitudinal items, an equivalent proportion of items demonstrated a relative low level of variability (n = 10; IQR= 1) as well as moderate variability (n = 10; IQR=2). The only item that demonstrated a greater variability was regarding respondents concerns of introducing anthelmintic resistance onto their farm (Q41; IQR=3).

With regards to the non-attitudinal questionnaire items, of the GIN control behaviours included, responses indicate that quarantine behaviours were the most readily employed (Median = 2). Whereas, in regards to respondents' parasite diagnostic testing behaviour this indicated a minimal level of adoption, especially concerning testing for resistance (Median = 0, IQR = 0). In conjunction, respondents responses concerning suspecting AR on their farms was comparably low (Median = 0, IQR = 0). The classification of GIN problems from respondents would indicate an overall perceived low level of concern towards GIN control problems (Median = 1). The median for respondents' knowledge scores was 1 (Q29: A, B, C).

3.3. Results of Structural equation models

All three models reflected a goodness of fit with the observed data as indicated by the following model fit indices as according to Hair et al. (2006). The model fit values as shown in Table 2, were below the maximum threshold of 0.10 for RMSEA, and at the 0.08 threshold for SRMR. For the subsequent fit indices (i.e. CFI, IFI, GFI, AGFI and NFI) values above 0.90 give an indication of acceptable fit, all of which were established above the required threshold. Significance was established for all relationships at a 0.05 level, with significant standardised coefficients (total effects) of each model detailed in Tables 3, 4 and 5. Illustrated versions of the structural models are presented in Figs. 4, 5 and 6.

3.4. Quarantine strategy model

The quarantine model explained 27% of the variance in the outcome quarantine behaviours. The illustrated path diagram of the model results are presented in Fig. 4. Of the six overall significant factors identified as influencing quarantine behaviours, three factors demonstrated direct

Table 2
Structural Equation Model (SEM) fit indices measures for 'Quarantine strategy', 'AR test' and 'FEC test' models.

SEM model	Goodness-of- fit indices						
	RMSEA	SRMR	CFI	IFI	GFI	AGFI	NFI
Quarantine	0.027	0.045	0.99	0.99	0.99	0.99	0.98
AR test	0.0063	0.057	1.00	1.00	0.98	0.98	0.96
FEC test	0.031	0.065	0.99	0.99	0.98	0.97	0.96

RMSEA, Root Mean Square Error of Approximation; SRMR, Standardised Root Mean Residual; CFI, Comparative Fit Index; IFI, Incremental Fit Index; GFI, Goodness of Fit Index; AGFI, Adjusted Goodness of Fit Index; NFI, Normed Fit Index; AR, anthelmintic resistance; FEC, faecal egg count.

Table 3
Standardised total effects on AR test model latent variables.

	Total (direct and indirect) effects on effector variables				
Determinants	'Quarantine strategy'	'AR quarantine risk'	'Quarantine resources'	'Quarantine advice'	'Quarantine social norms'
'Topography'	0.05 *	–	-0.20 * *	0.05	-0.02
'Vet service pro'	0.26 * *	0.39 * *	-0.24 * *	-0.28 * *	0.50 * *
'AR quarantine risk'	0.17 *	NA	–	-0.30 * *	0.10 * *
'Quarantine resources'	-0.33 * *	–	NA	0.66 * *	-0.22 * *
'Quarantine advice'	-0.10 *	–	–	NA	-0.33 * *
'Quarantine social norms'	0.29 * *	–	–	–	NA
R-square	0.27	0.13	0.09	0.40	0.44

*t-stat significant at 0.05; * *t-stat significant at 0.01; AR, anthelmintic resistance; Vet, veterinarian

Table 4
Standardised total effects on AR test model latent variables.

	Total (direct and indirect) effects on effector variables					
Determinants	'AR test	'Worm control knowledge'	'AR risk'	'Cues to action'	'Social Norms'	'Suspect AR'
'Experience'	-0.11 *	-0.29 * *	–	–	–	-0.07 *
'Topography'	-0.07 *	-0.17 *	–	–	–	-0.04 *
'Education'	0.21 * *	–	0.39 * *	-0.08 *	0.31 * *	0.23 * *
'Vet service pro'	0.17 * *	–	–	-0.12 * *	0.47 * *	0.02
'Occurrence of worm problems'	0.11 *	–	0.41 * *	–	–	0.23 *
'Worm control knowledge'	0.39 * *	NA	–	–	–	0.23 *
'AR risk'	0.26 * *	–	NA	–	–	0.56 * *
'Cues to action'	-0.31 * *	–	–	NA	–	-0.20 *
'AR testing social norms'	0.37 * *	–	–	-0.26 * *	NA	0.05
'Suspect AR'	0.46 * *	–	–	–	–	NA
R-square	0.61	0.12	0.34	0.06	0.31	0.43

*t-stat significant at 0.05; * * t-stat significant at 0.01; AR, anthelmintic resistance; Vet, veterinarian.

Table 5
Standardised total effects on FEC test model latent variables.

	Total (direct and indirect) effects on effector variables					
Determinants	'FEC test'	'Worm control knowledge'	'AR risk'	'Vet service pro'	'FEC pro'	'AR confirmation'
'Experience'	-0.13 * *	-0.25 * *	-0.22 *	–	–	-0.23 * *
'Topography'	-0.11 * *	-0.17 *	-0.22 *	–	–	-0.19 * *
'FEC con'	-0.37 * *	–	–	–	–	–
'Social Norms'	0.13 *	–	–	0.61 * *	0.49 * *	–
'Occurrence of worm problems'	0.13 *	–	0.46 * *	–	–	0.24 *
'Worm control knowledge'	0.25 * *	NA	–	–	–	0.46 * *
'AR risk'	0.29 * *	–	NA	–	–	0.52 * *
'Vet service pro'	0.05 *	–	–	NA	0.18 *	–
'FEC pro'	0.27 * *	–	–	–	NA	–
'AR confirmation'	0.55 * *	–	–	–	–	NA
R-square	0.54	0.09	0.32	0.37	0.26	0.53

*t-stat significant at 0.05; * * t-stat significant at 0.01; FEC, faecal egg count; AR, anthelmintic resistance; Vet, veterinarian.

influence on the behavioural outcome. Positive direct effects were associated with the factors 'AR quarantine risk' and 'Social norms', with 'Social norms' attitudes i.e. regarding the expectation of significant others, demonstrating the greatest positive influence on the quarantine behaviours assessed (β = 0.29), followed by attitudes to AR quarantine risk (β = 0.15). The factor 'Quarantine advice' was the only negative influence on Social norm perceptions (β = −0.33).

The factor 'AR quarantine risk' also demonstrated a moderate negative effect on negative attitudes to 'quarantine advice' (β = −0.30). Direct negative effects on quarantine behaviours were associated with the factor 'Quarantine resources' which demonstrated a moderate influence on behaviour (β = −0.26) as well as a high positive effect on 'quarantine advice' attitudes (β = 0.66).

Exogenous factors i.e. whose role is to explain other variables or outcomes in the model, which were shown to have indirect influence on quarantine behaviour through mediating factors include 'Topography' and 'Vet service pro'. Both of these factors had negative effects on the factor 'Quarantine resources' (β = −0.20; −0.24). Positive attitudes to veterinary services (i.e. 'Vet service pro') demonstrated positive effects on perceived 'AR quarantine risk' (β = 0.39) in addition to social norm attitudes (β = 0.41). Increasing topography demonstrated positive effects towards 'quarantine advice' attitudes (β = 0.18).

3.5. AR test model

The AR test model explained 61% of the variance in the outcome behaviour 'AR test'. The illustrated path diagram of the model results are presented in Fig. 5. Of the four significant factors demonstrating a direct influence on AR testing behaviour, three were shown to have positive influences including: 'Worm control knowledge', 'AR suspicion', and 'Social norms' factors. The greatest positive determinant of AR testing behaviour was 'AR suspicion' (β = −0.46), followed by comparable effects between 'Social norms' (β = 0.29) and 'Worm control knowledge' (β = −0.28). Significant negative influence on testing behaviour was demonstrated by the factor 'Cues to action' (β = −0.22).

The factor 'AR suspicion' was shown to be positively and negatively

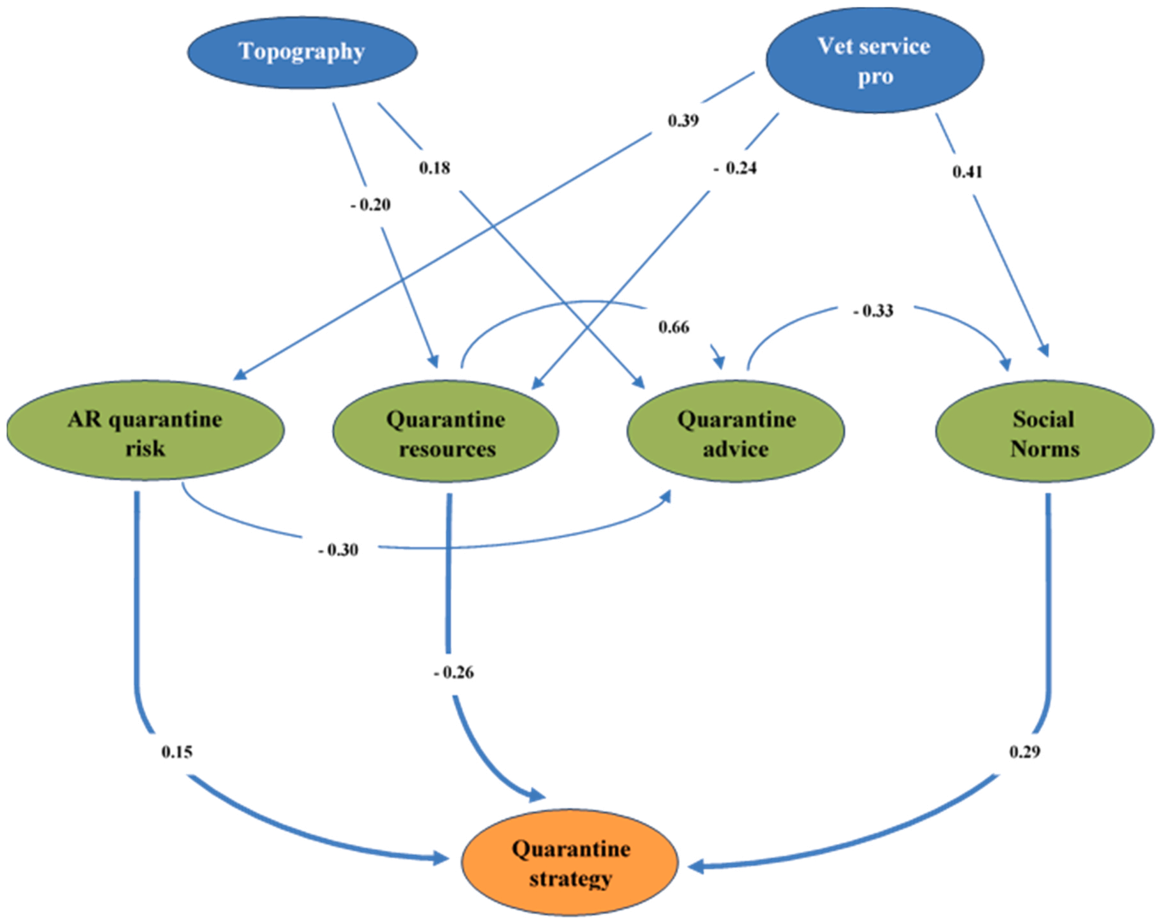

Fig. 4. Quarantine strategy uptake structural model (standardised solution). Bold arrows represent the total (direct/indirect) influences of latent variables on the behavioural latent 'Quarantine strategy', with non- bold arrows representing the total effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

influenced by three other mediating factors with 'AR risk' having the greatest positive effect (β = 0.56) followed by 'Worm control knowledge' (β = 0.23). Significant negative influence on 'AR suspicion' was demonstrated by 'Cues to action' (β = −0.20). The factor was 'Social norms' was shown to have a significant negative influence on 'Cues to action' (β = −0.25).

With regard to exogenous factors positively influencing mediating factors, 'Education' demonstrated moderate positive influences on both 'AR risk' (β = 0.39) and 'Social norms' (β = 0.31) factors. The factor 'Occurrence of worm problems' was also shown to have a positive effect on the factor 'AR risk' and 'Vet service pro' also demonstrated positive influence on 'Social norms'. The only exogenous factors demonstrating a negative influence on mediating factors were associated with increasing levels of experience and topography, which both demonstrated a negative effect on 'worm control knowledge' (β = −0.29, −0.17).

3.6. FEC test model

The FEC test model explained 54% of the variance in the outcome behaviour 'FEC test'. The illustrated path diagram of the model results are presented in Fig. 6. Three factors demonstrated direct influence on FEC testing behaviour, with 'AR test' having the strongest positive influence overall (β = 0.55), followed by 'FEC con' with the greatest negative direct influence on behaviour (β = −0.37) and 'FEC pro' with a moderate positive influence on FEC testing behaviour. Mediating factors shown to influence the aforementioned factors include 'AR risk' and 'Worm control knowledge' which both demonstrated strong positive influence on 'AR test' factor (β = 0.52, 0.46). In addition, 'Vet service pro' demonstrated a positive influence on 'FEC pro' (β = 0.18).

Exogenous factors shown to have positive effects on behaviour mediating variables include 'Occurrence of worm problem' with a strong influence on 'AR risk' perception' (β = 0.46) and 'Social norms' with a strong influence on 'Vet service pro' (β = 0.61) and a moderate influence on 'FEC pro' factors (β = 0.38). Factors demonstrating negative effects on mediating factors included 'Experience' and 'Topography' where increasing levels were associated with negative influence on 'AR risk' perception (β = −0.22, −0.22) and 'Worm control knowledge' (β = −0.25, −0.17).

4. Discussion

The SCOPS guidelines were designed to offer practical solutions to farmers to enable them to manage parasites effectively. The advice covers a wide range of aspects influencing sustainable GIN control strategies and slowing down the development of AR. This study aimed to contribute much needed evidence for improving our understanding of livestock producers' parasite control decision making processes. The models presented in this paper cover examples of key parasite management practices and factors influencing their adoption. Practice specific factors are identified, as well as several overarching themes which are discussed.

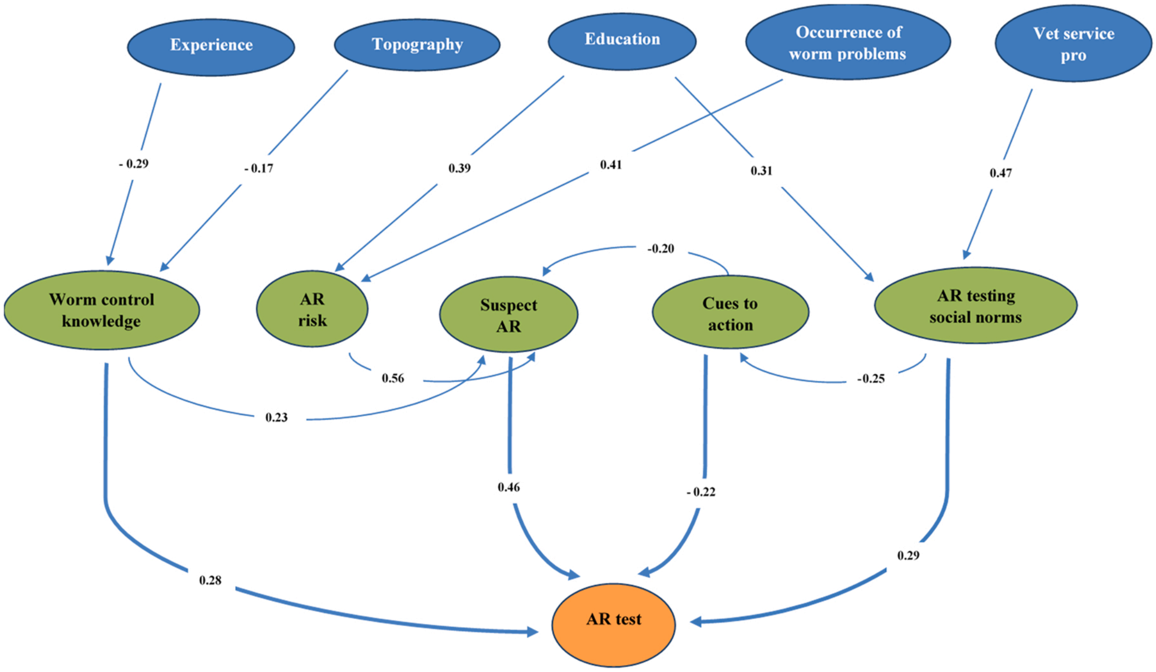

Fig. 5. AR testing uptake structural model (standardised solution). Bold arrows represent the total (direct/indirect) influences of latent variables on the behavioural latent 'AR test', with non- bold arrows representing the total effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

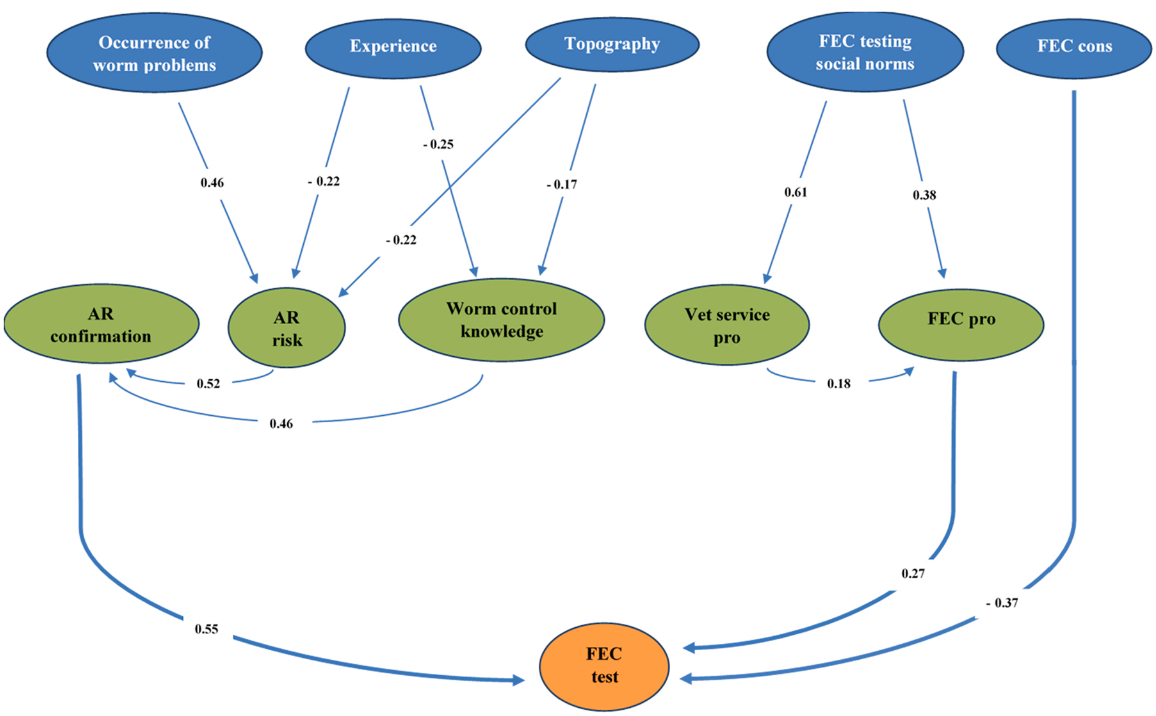

Fig. 6. FEC testing uptake structural model (standardised solution). Bold arrows represent the total (direct/indirect) influences of latent variables on the behavioural latent 'FEC test', with non- bold arrows representing the total effect influences on other latent variables. The corresponding numbers are the standardised coefficients of the variables in the structural model. Blue variables denote variables that are exogenous i.e. independent from other variables in the model, with green variables taking either exogenous or endogenous roles i.e. influenced by other variables. The orange variable represents the endogenous behavioural latent variable.

4.1. On farm and industry anthelmintic resistance risk perceptions

One of the main factors in terms of strength of effect is AR risk perception, which has a significant positive effect in all GIN practice models estimated. Knowledge about disease risk and the strategies to mitigate transmission have been highlighted previously by research investigating biosecurity (Toma et al., 2013), Johne's disease (Ritter et al., 2015) and lameness (Bruijnis et al., 2013) as factors influencing good practice uptake. On the flip side those that experienced significant disease issues have been reported as losing confidence in their knowledge (Ritter et al., 2017), or developing a fatalistic attitude or feeling of hopelessness that leads to them learning to live with the disease (Charlton and Robinson, 2020; O'Kane et al., 2017; Crimes and Enticott, 2019). In regard to quarantine practice, the model results demonstrate that increasing respondents perceived risk of introducing AR significantly improved adoption of quarantine behaviours. Furthermore, improving risk perception is also associated with a reduction in negative attitudes towards quarantine advice. The difficulty however, as perhaps indicated by the comparatively low effect between perceived AR quarantine risk and quarantine behaviour, is to attribute a comparable risk towards AR in comparison with other notable ovine biosecurity threats such as sheep scab, Maedi-Visna or *Chlamydia abortus*.

In addition to the perceived risk of acquiring AR, other aspects of risk include the awareness of GIN control problems as well as suspicion or confirmation of AR on a property. The greatest positive determinant of AR testing behaviour was the suspicion of AR ('Suspect AR'). The identification of the factors that prompt farmer's to suspect they have AR on their farms is likely to play an important role for developing targeted interventions, to improve uptake of AR testing behaviours by farmers. The result of which, if AR is confirmed, could provide significant impetus to adopt subsequent SCOPS parasite control practices as previously reported (Jack et al., 2017). The observed relationships between 'AR risk', 'Worm control knowledge', 'Cues to action' and 'Education' highlight some key areas for consideration when planning future knowledge exchange programmes. Respondents' AR risk perceptions in particular show considerable indirect influences, as well as direct influences on AR testing behaviour. The significant influences shown towards AR risk (i.e. 'Education' and 'Occurrence of worm problems') could be comparable with findings from Garforth et al. (2013), suggesting that both an awareness, and previous experience, of a disease agent are integral to forming opinions of disease risk, which is a strong influencer of subsequent behaviour.

4.2. Promotion of anthelmintic resistance testing

The factor 'Cues to action' in this instance reflects the impetus for testing AR based on clinical signs of anthelmintic failure. This factor is shown to have the greatest negative impacts on both 'Suspect AR', as well as directly on the behavioural outcome ('AR test'). This suggests that basing AR testing decisions on visual indicators is negatively impacting on farmers' AR suspicions, which in turn has a detrimental effect on farmers' testing behaviour. This progression cycle highlights the need to encourage farmers' to test for AR in the absence of clinical signs. However, the lack of visual 'cues to action' associated with preclinical AR development has been recognised as a major issue for farmers (Woodgate and Love, 2012). Similarly it has been shown to be difficult to motivate action where diseases may be sub-clinical in nature and therefore their impact on health and/or welfare is less apparent, or where diagnostic tests lack specificity or sensitivity (Wassink et al., 2005; Benjamin et al., 2010; Ritter, 2018). Possible routes for altering the perceptions shown in this model may include raising/addressing social (actions approved by influential individuals), descriptive (perceptions of how others deal with the issue) or injunctive (what is approved by others) norms, perhaps through agricultural media, or alternatively through enhanced interactions with veterinary services, as well as through other education channels.

The greatest positive influencing factor towards the adoption of FEC monitoring behaviour is the confirmation of AR. This would suggest that the importance of detecting resistance may not only be limited to informing anthelmintic treatment efficacy, but also towards encouraging further use of parasite diagnostic testing for mitigating further AR development. Respondents AR risk perceptions demonstrate a strong influence on 'AR confirmation' which has a direct effect on FEC monitoring behaviour. This result differs to findings from cattle producers that demonstrated a non-significant influence of risk perceptions towards farmers' diagnostic behavioural intentions (Vande Velde et al., 2015; 2018). This may suggest a greater AR risk perception among sheep producers when compared with cattle producers, where the prevalence of, and impacts associated with, AR are less frequently reported (Bartley et al., 2021a).

4.3. Perceived implementation challenges

Attitudinal factors which influence practice adoption concern the practicality of implementation (represented by 'FEC cons' and 'quarantine resources') as well as perceived complexity and consistency of advice (represented by 'quarantine advice'). The former factors represents the perceived practicality issues relating to the faecal sampling process required for FEC testing and resource requirements for quarantining of incoming animals. The importance of time and efficiency to farmers adoption behaviours is well established in the literature (Kahn and Woodgate, 2012; Woodgate and Love, 2012; Garforth et al., 2013) and presents a major constraint, especially on the adoption of measures requiring routine operation such as for monitoring of FECs. The sampling procedure can vary widely depending on the farming system and characteristics of the farm. For example to obtain samples that are representative of a flock or group ideally requires that a randomised proportional number of samples are taken. Current guidance suggests that that the target group be loosely gathered into a corner for a short period of time and a minimum of 10 fresh faecal samples collected and processed (individually or poled; Stubbings et al., 2020). This approach may also prove more difficult on more extensive farms with large acreages as well as on farms with limited labour availability. The large effect that this factor has on FEC testing behaviour suggests that either advice needs to be adapted to address the range of circumstances which may discourage farmers adopting this method routinely. Or alternatively, where the efficiency of sampling may not be improved, the justification of time and resources needs to be met with clear benefits such as those represented by 'FEC pro'. Although it appears that the perceived practical drawbacks of conducting FEC may offset the perceived benefits in terms of improving treatment timings and animal productivity. The perceived practical requirements concerning farm biosecurity measures have demonstrated a negative influence on quarantine practice adoption, which has also been acknowledged by others to have a strong influence on farmers' willingness to control disease (Toma et al., 2015). Furthermore, a study by the University of Reading and Scottish Agricultural College (2003) also found resource requirements, such as cost and time, were perceived by auxiliary industry representatives to be a major constraint on farmers' biosecurity implementation. With regard to quarantine advice, this study also recognised the perceived complexity of biosecurity measures associated with large variation between farms characteristics and farming systems (University of Reading and SAC, 2003). Therefore a single guideline approach to biosecurity is likely to be inadequate to suit the wide range of farming conditions and production systems recognised within the UK.

4.4. Impact of social pressures

The influence of external social pressures (i.e. Social norm beliefs) has demonstrated a prominent effect, both directly and indirectly, on all GIN practice models presented. In relation to FEC monitoring behaviour, social norm perceptions positively influenced FEC monitoring attitudes, which indicates a shared view among respondents regarding the benefits of using diagnostic testing. Additionally, social norm perceptions demonstrated a negative influence toward indicators of reactive 'cues to action' regarding the impetus to test for AR, which in turn negatively influenced AR testing behaviour. This would indicate that respondents that are more conscious of external expectations to test anthelmintic treatments are more likely to believe in a proactive response to testing treatment efficacy. The influence of social norms has also been acknowledged as a strong determining factor towards to use of parasite diagnostics by cattle farmers' (Vande Velde et al., 2015; 2018). Regarding quarantine/biosecurity practices, social norms also exhibited a positive influence towards adoption. Other studies have proposed that the perceptions of 'good' and 'bad' farmers as those who can or can't manage endemic disease threats may reflect a cultural impact of collective beliefs as an important motivation for implementing farm biosecurity measures (Heffernan et al., 2008; Brennan and Christley, 2013).

In conjunction with social norm beliefs, the strong influence of positive veterinary service attitudes as demonstrated, supports the widely-held view of veterinarians as a highly-trusted resource for farmers concerning animal health (Garforth et al., 2013; Jack, 2018). However in regards to biosecurity practice, this may be largely conflicting with many veterinarians own views of their knowledge or general interest to advice on biosecurity matters (University of Reading and SAC, 2003). This may reflect some reticence amongst veterinarians regarding their own abilities to adapt to their shifting role towards providers of flock/herd health advice (Ruston et al., 2016), as well as being viewed as a primary source for biosecurity information (Gunn et al., 2008). In order to capitalise on this relationship veterinarians need to understand this role as 'pro-active' advisor (Jansen and Lam, 2012; Hall and Wapenaar, 2012), identify appropriate styles (Derks et al., 2013) and formats (Bartley et al., 2021b) to facilitate effective communicate lines and to tailor the advice accordingly. Previous work has highlighted disparities between the views and importance's place on activities between farmers and veterinarians (Hall and Wapenaar, 2012; Melville et al., 2021) so it is essential that both sides communicate what they want to achieve and what resources are available.

4.5. Demographic influences

The final theme to be discussed relates to the demographic backgrounds of respondents including: level of experience, education background and GIN control knowledge, as well as specific farm characteristics, namely farm topography. The latter physical farming characteristic associated with farm topography demonstrated a significant indirect influence on the uptake of the assessed quarantine behaviours. The greatest influence of topography was towards quarantine resource attitudes, which indicates that respondents located at higher topographies are less associated with negative attitudes towards quarantine resource requirements. This finding would also support survey findings from the University of Reading and SAC (2003) which found that the majority of surveyed upland farmers expressed a relative ease to implement quarantine procedures including a 28-day quarantine period and entry screening when compared with lowland farmers.

The demographic characteristic of age or experience demonstrated an inverse relationship with best practice GIN control adoption with more experienced respondents less likely to adopt recommended behaviours as presented. This characteristic has also been acknowledged as a social influence on the adoption behaviours of other agricultural innovations such as artificial insemination (Howley et al., 2012), as well as animal health and welfare technologies (Toma et al., 2014) with younger farmers more associated with adopting new technologies and practices compared to older farmers. This occurrence has also been associated with younger farmers who are thought of as more likely to better educated and therefore be more aware, and adaptable, to new approaches in modern agriculture (National Research Council, 2002; Howley et al., 2012). The positive influence of an agricultural college education ('Education') has also been associated as an important characteristic of more progressive farmers (Van den Ban, 1957). The aversion of older farmers to adopting such innovations may give an indication of scepticism or caution towards implementing unfamiliar methodologies. Innovations, like those recommended by SCOPS, could also conflict with the self-identity of many farmers' who hold a more productivist i.e. production driven mind-set, in contrast with more contemporary post-productivist ideals orientated towards environmental issues and sustainability (Burton and Wilson, 2006). Additionally the perceived value of experience by farmers' is likely to also shape farmers' self-identities, which would support the view of more experienced sheep farmers as the 'experts' of their farming system, and therefore less likely to seek external guidance (Kaler and Green, 2013).

5. Conclusions

The wide range of socio-psychological factors presented reflect the complex nature of behavioural change and, the requirement for further work to be conducted to better understand farmers' parasite control decision making processes. The SCOPS recommendations cover many facets of parasite disease control management, of which three areas were of focus in this paper. Such practices will aid in preventing the introduction, and spread, of resistance between farms as well as facilitate the use of decision making tools to inform effective parasite management. The importance of AR to the long-term viability of commercial sheep farming necessitates that changes are made to address the key concerns and issues from farmers, who ultimately should be the main beneficiaries of such recommendations. As previously discussed such changes to the format and content of the current SCOPS recommendations need to appeal to the wider farming community. Future recommendations should demonstrate transparent benefits and practical applications in order to sustain long-term positive behavioural change. The importance of veterinarians as a highly-trusted information resource validates the need to improve engagement of veterinarians concerning sustainable parasite control approaches to facilitate collaboration with farmers. The need for interaction between farmers and their advisors is key to resolving the issues raised to enable the necessary explanation, justification and execution of recommended practices to suit farmer's needs and farming conditions. Finally, by involving primary stakeholders in the recommendation development process as proposed by modern extension approaches, this is likely to engender a collaborative and concerted effort which is critical to development within the agricultural industry.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2022.105594.

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