Cattle farmers' perception of biosecurity measures and the main predictors of behaviour change: the first European-wide pilot study

Short running title: Cattle farmers' perception of biosecurity measures

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ABSTRACT

The importance of biosecurity as a strategy to prevent and control infectious diseases has increased substantially over the last few decades. Several studies have reported a low implementation level of biosecurity measures (BSM), particularly in cattle farms. In addition, a recent study demonstrated that cattle farmers are well aware of the recommended BSM and recognise them as more effective (in terms of time and costs) than treatment for disease. Therefore, other factors must be considered when it comes to understanding the decision-making process followed by a farmer regarding the adoption of BSM. This study analysed the possible influence of five mental constructs described in the Health Belief Model (HBM) on the adoption of BSM and assessed the possible association of these constructs with different demographic and socio-psychological factors. Through an online survey, 988 questionnaires were completed by cattle farmers originating from Belgium, France, Germany, Spain and the Netherlands. The study revealed that the actual implementation of the BSM seems to be significantly influenced by the farmers' perception of the measures' benefits and the perception of health responsibility. Both constructs are influenced by the farmers' personality in terms of risk aversion and biosecurity knowledge. It was also found that organic farmers had a significantly lower perception of the BSM benefits and of their responsibility towards animal, public and environmental health when compared with other types of farmer. Organic farmers in this study seemed less likely to implement biosecurity measures. To increase the adoption of BSM by cattle farmers, it is therefore important to emphasise the actual evidence-based benefits of the measures and to investigate further how to strengthen cattle farmers' sense of responsibility towards animal, public and environmental health.

Keywords: Biosecurity measures; practices; health belief model; behaviour; cattle farmers; risk perception; organic farming; brucellosis; calf diarrhoea; bovine viral diarrhoea.

INTRODUCTION

In animal production systems, the proper implementation of biosecurity measures (BSM) by farmers permits the prevention of infectious diseases and enables better control of transmission within or outside individual production units. The importance of biosecurity as a strategy to prevent and control infectious diseases has increased substantially over the past few decades. Since 2007, biosecurity measures have been part of the European Union Animal Health Strategy (European Comission, 2007).

Several studies have investigated the degree of implementation of BSM in cattle farming. These studies have reported a low level of implementation (Brennan & Christley, 2013; Renault et al., 2018) and highlighted different constraints and barriers such as the efficacy or the cost-effectiveness of measures, the workload required, the BSM feasibility, the lack of motivation and the relevance of the BSM with regard to the actual risks (Brennan et al., 2016; Gunn, Heffernan, Hall, McLeod, & Hovi, 2008; Laanen et al., 2014; Renault et al., 2018). A recent study showed that farmers have knowledge of the recommended BSM and recognise these as more effective (in terms of time and costs) than disease treatment (Renault et al., 2018). Therefore, other factors have to be considered when it comes to understanding the farmers' decision-making processes regarding the adoption of BSM. The complexity of this decision-making process has been described in two recent reviews (Mankad, 2016; Ritter et al., 2017). Based on these reviews, different factors are likely to have an influence: (i) the farmers' psycho-sociological profile (e.g. personality, culture, risk aversion, previous experiences, (ii) the perceived responsibility towards animal, public and environmental health and biosecurity knowledge), (iii) the farming context (e.g. national and international regulations, demands and market prices), (iv) the perception of possible barriers, (v) the risks (disease susceptibility and severity) and (vi) the cost-effectiveness of proposed BSM (benefits).

Over the last decade, the importance of socio-psychological studies in the field of veterinary epidemiology has increased significantly, as illustrated by the increased number of publications since 2012 (Wauters & Rojo Gimeno, 2014). Many behaviour change theories have been developed over time to try to predict the implementation of a given behaviour by users, as well as to identify the key factors to be targeted in order to increase the adoption rate of desired practices. In the field of animal production and health, two of the most common models that have been applied are the Theory of Planned Behaviour (Ajzen, 1985) and the Health Belief Model (Janz & Becker, 1984; Irwin M. Rosenstock, 1974) (**Fig. 1**). In both cases, the models assume that the behaviours are mainly depending on mental constructs and analyse the relationship between these mental constructs and the behaviours. These constructs relate to different beliefs and perceptions influenced by different demographic, socio-psychological and contextual variables. The Health Belief Model (HBM) is made up of five mental constructs: (i) the health responsibility (perceived responsibility towards animal, public and environmental health); (ii) the risk susceptibility (likelihood of disease occurrence); (iii) the risk severity (perceived impact of the disease if it occurs); (iv) the barriers (perceived difficulty of performing a BSM and the possible level of control); and (v) the benefits (perceptions of the possible positive outcomes related to the implementation of a BSM) (Janz & Becker, 1984; Irwin M. Rosenstock, 1974). On the other hand, the Theory of Planned Behaviour (TPB) relies on the influence of three main constructs on the intention of performing a behaviour: (i) the attitude towards the behaviour (beliefs and evaluation of the expected behavioural outcomes); (ii) the subjective norms (social factor referring to the social pressure to perform or not perform a behaviour); and (iii) the perceived behavioural control (beliefs about capability and control) (Ajzen, 1991). Different researchers have applied both models with slightly different results from one study to another, based on specificities or new findings (e.g. some HBM models included an additional element called "cue to action" and others considered the disease severity and susceptibility as one sole element) (Carpenter, 2010; Janz & Becker, 1984). When comparing both models, it appears that the elements taken into account are similar but regrouped into different constructs (**Fig. 1**). In comparison to the TPB, the HBM is specific to health behaviours. It is also the most frequently used model in veterinary medicine as illustrated by a search in PubMed with "name of the model" and "veterinary" used as keywords and Boolean operator showing more than 42,818 results for the HBM model and 895 results for the TPB (search effected on June 16th 2020). The HBM also appears more detailed as it includes five constructs compared to three constructs in the TPB.

The aim of this study was to use the outcomes of an online survey to identify the important HBM constructs when assessing the intention to implement or the implementation of different BSM by cattle farmers. The possible associations between different demographic and socio-psychological factors and the different constructs were also investigated.

MATERIAL AND METHODS

Theoretical framework: the Health Belief Model

The current study applied the HBM to explore the different factors influencing cattle farmers' behaviours. **Figure 2** provides an overview of the nine components included in the model. The components included different demographic variables, two psychological variables (risk aversion and biosecurity knowledge) expected to have an influence on the mental constructs, the five mental constructs of the HBM assessed through different questions (3 to 8 questions per construct) and the model outcome formulated as the intention to implement or the actual implementation of the behaviour.

As the perception of susceptibility, severity and any benefits of the BSM are risk-specific, these perceptions were assessed for three different diseases: these were selected as they have a different susceptibility and severity and illustrate different possible transmission pathways of infectious diseases:

- An eradicated disease: brucellosis (BRU)
- An endemic disease: young calf diarrhoea (YCD)
- An endemic disease targeted by national or regional control programmes: bovine viral diarrhoea (BVD)

Perceived benefits were expressed as the perceived effectiveness of the different BSM at preventing and controlling the three diseases. In order to build the HBM model, 17 BSM (**Table 1**) were selected from the BSM listed in a previous study (Renault et al., 2018). The BSM selected were deemed efficient against one, two or three of the selected diseases, showed variability in terms of implementation level, and represented different stress levels (e.g. time-consuming, costly, involving (or not) a specific organisation of work and requesting (or not) specific infrastructures).

Survey development and methodology

The online survey included 66 questions, i.e. 64 closed questions and two open questions **(Appendix S1**). The questions used to assess the different HBM constructs were identified and formulated based on a previously validated questionnaire (Champion, 1984). The survey was developed in an open source software, LimeSurvey, in five languages (English, Dutch, German, French and Spanish). The survey was pre-tested among four farmers in each language before its validation and disseminated by the different authors in six countries (i.e. Belgium, France, the Netherlands, Germany, Spain and the United Kingdom). In Belgium, France and the Netherlands, the invitations to fill-in the survey were sent by the regional animal health associations through their mailing lists. In Germany, invitations were sent by farmers' insurance companies and government veterinary offices. In the UK, invitations were sent through personal contacts of the research team and social media (i.e. professional journals). In Spain, the invitation to participate was disseminated through personal networks with a very low response level due to Spanish farmers' poor access to online technologies. The survey in Spain was thus mainly conducted through face-to-face interviews with farmers randomly selected in livestock meetings (e.g. fairs or exhibitions) or farmers enrolled in a specific research programme (managed by IREC (Instituto de Investigación en Recursos Cinegéticos) and the University of Cordoba) to improve general biosecurity measures against bovine tuberculosis. In Belgium, the Regional Association for Animal Health and Identification (ARSIA for the Walloon Region) added a specific add-on to their "CERISE" application webpage (used by farmers for birth notification and statements of purchases), in addition to the use of its mailing list. This add-on opened a pop-up window inviting individuals to fill in the questionnaire when the farmer connected to the application. It was addressed to all cattle farmers, independently of the herd type and production system. Data were collected from November 2017 to February 2019; several reminders were sent during this period to increase the number of respondents.

The selection of the different demographic and sociological variables was based on two articles describing the determinants of farmers' behaviours (Mankad, 2016; Ritter et al., 2017). The following demographic variables were considered in the survey: experience (years), education level, gender, herd type, herd size, business stage (starting or expanding, settled or stable, reducing or retiring) and production type (organic / conventional).

Two psychological characteristics were assessed: "risk aversion" was determined indirectly by asking the farmers their degree of agreement with three sentences: (i) I consider myself as a cautious person, (ii) I anticipate risks and take specific measures to mitigate them and (iii) I always bring basic medical products with me for personal use (disinfectant, bandages and pain killers) (**Appendix S2**). The farmers' "Biosecurity knowledge" regarding BSM was determined

by asking them to list three BSM, in order to verify if she/he knew the term “biosecurity” and its associated measures.
The formulation of the questions regarding the different perceptions and beliefs were based on the good practices and practical examples provided in an article describing the construct validation of the HBM (Cummings, Jette, & Rosenstock, 1978). The questions were labelled and grouped in order to assess the five HBM constructs: risk susceptibility, risk severity if it occurs, health responsibility, benefits of BSM and barriers. For each construct, the farmers were asked to rate their degree of agreement with different statements via a visual analogue scale ranging from 0 (fully disagree) to 100 (fully agree).

The intention to implement or the actual implementation of the different BSM were assessed through a 6-level Likert scale with the following levels: ‘0: Not implementing it and I do not intend to’, ‘1: Not implementing it but I might consider it’,’2: Not implementing it but I will do it’, ‘3: Yes, I do implement it but sometimes only’, ‘4: Yes, I do implement it most of the time’ and ‘5: Yes, I always implement it’. An additional category (‘Other’) was proposed to allow additional comments (e.g. not applicable, based on the production system). If the comments provided were not useful (i.e. lack of comment or comment did not permit classification into one of the 6 levels), the country-specific mode was used for unimodal distributions, and a random value-based on the most frequent modes of the country in case of bi-modal distributions.
Data were extracted into a Microsoft Excel spreadsheet and consolidated. The responses given by the participants were coded and the attributes of the different variables defined as explained in **Appendix S2**. The incomplete questionnaires and the questionnaires originating from countries with less than five respondents were excluded.

Scoring methodology for the different constructs

In order to estimate the perception scores for each HBM construct, the scores of questions in which the construct was negatively formulated were reversed to enable uniformity across questions. The farmers’ perception of the different constructs were determined either directly (for the disease susceptibility and BSM benefits constructs) or indirectly by calculating the degree of agreement (agreement score) with the different statements used in the questionnaire (**Appendix S2**). The degree of agreement was assessed through a visual analogue scale providing a score ranging from 0 (fully disagree) to 100 (fully agree), representing the degree of agreement with the proposed statements.

The construct "Susceptibility" was assessed by asking the farmer what the probability of each disease occurrence was in his or her farm in the absence of general or disease-specific preventive measures. The overall susceptibility score represents the average of the disease-specific scores.

The construct "Severity" was determined by asking the farmer her/his degree of agreement with three statements: (i) If this disease was occurring, there would be an important negative effect on my herd productivity (perception), (ii) The economic impact of this disease on my activity over the last 10 years was very high (personal experience) and (iii) Many farmers I know have been affected by this disease over the last 10 years (experience of other farmers). The questions were repeated for each disease. The farmer's overall severity perception was calculated as the average score obtained from the nine questions (three questions for each disease) and reflects the farmer's overall degree of agreement with the statements.

The construct "Health responsibility" was assessed indirectly. The farmers were asked their level of agreement with eight statements illustrating their responsibility towards animal, public and environmental health (Table 2). The average score was then calculated accordingly.

The construct "Benefits" was calculated for each BSM (N = 17), as well as for the overall benefits (across the 17 BSM). For each BSM, the farmers were requested to provide their perception of BSM benefits regarding the prevention or control of each of the three diseases; the average score was then computed to obtain the BSM specific-benefit score. The benefits of a BSM were defined as "the measure of efficiency (in terms of cost and time effectiveness) and its capacity to prevent disease and/or reduce losses".

The construct "Barrier" assessed the farmer's perception regarding her/his level of disease control. The farmer was asked her/his degree of agreement with two sentences: "I am able to prevent the disease by implementing appropriate measures" and the opposite statement, "The prevention of the disease relies mainly on measures to be implemented by the authorities, there is not much I can do". The two questions were asked for the three diseases and the average score calculated in order to determine the "Barrier" score.

Negative binomial regression models

Effects of demographic and psychological variables (explanatory variables) versus psychological variables and Health Belief Model constructs (dependent variables)

A backwards stepwise regression model was applied in Stata SE/14 (StataCorp LP, College Station, TX, USA) to assess the influence of different explanatory variables on the five HBM constructs (**Fig. 2**). The possible influence of demographic variables on risk aversion and biosecurity knowledge were also considered. A negative binomial regression was used as the variables did not seem normally distributed (based on a Shapiro test) and the goodness of fit of the Poisson models were insufficient.

Firstly, a univariable analysis was performed using a negative binomial regression to assess the level of influence of the different explanatory variables on each dependent variable. Secondly, for each construct, a multivariable analysis including all the explanatory variables with a *p*-value below 0.1 (in order to be conservative) was conducted. The model was progressively simplified by removing the least significant variable with a $p>0.05$. The model was considered complete, either when all variables had a significant *p*-value (<0.05), or when it could not be further simplified without having a significant difference between the most complex and the simpler model (likelihood ratio test with a p-value < 0.05).

As the model presented in **Fig. 2** assumes a possible influence of the demographic variables on both the psychological variables and the perceptions, a test was performed in order to identify possible high associations between variables which could interfere with the multivariable regression models. If both a psychological and associated demographic variable (based on the Kruskal-Wallis test) were to be included in the multivariable regression model, the psychological variable was the only one included as it is assumed to have a higher direct influence on the HBM constructs.

Association between the Health Belief Model constructs (explanatory variables) and the intention to implement or the actual implementation of BSM

A backwards stepwise regression model was applied in Stata SE/14 (StataCorp LP, College Station, TX, USA) to assess the influence of the different HBM constructs on BSM implementation (or intention to implement). This was performed for each BSM (N = 17) as well as for the overall BSM using the average scores of each BSM as an overall benefits score and BSM implementation score. As variables were not normally distributed based on a Shapiro test, a negative binomial regression was used (larger variance compared to the Poisson model assumption).

RESULTS

Respondents' profile

A total of 996 complete answers were received from nine countries with an average completion time of 24 minutes (range: 4.7 to 3945.85 minutes; quartile 1: 16.2, median: 20.7 and quartile 3: 28.4 minutes). The four questionnaires received from the UK and three questionnaires from unsolicited countries were not considered in the analysis due to the very small number of answers (less than five). One Belgian questionnaire was deleted as the farmer mentioned "Not Applicable" to all the BSM when asked about his or her intention or action regarding measure implementation. Therefore, 988 respondents originating from five countries were considered in the data analysis (**Table 3**): Belgium (701 farmers), Germany (128 farmers), France (68 farmers), Spain (64 farmers) and the Netherlands (27 farmers). Among the respondents, 12% were organic farmers (or in conversion to organic farming) and the farm types identified were 49% beef farms, 33% dairy farms, 14% mixed farms and 4% other farm types (e.g. fighting bulls). The herd size ranged from 0 to 1900 head of cattle. The farmers mentioning having zero head of cattle were kept in the survey based on the assumption that they represent farmers having cattle but not willing to provide the size of their herds as this is often a sensitive question.

Farmers' perceptions

The farmers' perception of the occurrence probability of BVD, BRU and YCD (susceptibility) ranged from 0 to 100 with a median of 50%, 28% and 73% respectively (**Fig. 3 [A]**). Regarding the diseases' severity, the median of the degree of agreement was of 44%, 34% and 58% for BVD, BRU and YCD, respectively (**Fig. 3 [B]**). The diseases' severity and their economic impact are therefore perceived as "not really important" by the farmers.

The farmers' perceptions regarding their responsibility towards animal, public and environmental health (health responsibility) was overall high (quartile 1: 63%, median: 72%, quartile 3: 81% and range: 0 to 100%). The majority of farmers agreed with the proposed statements on: the importance of risks, the need for proper health monitoring and the need for actions to preserve animal, environment and public health.

The farmers' perception regarding the level of control required to prevent infectious diseases on their farm was used as an indirect measure of the perceived barriers. Overall, most farmers disagreed with statements relating to having little control or depending on others (e.g. the government) to prevent or control infectious diseases (median of the degree of agreement below 40%) (**Fig. 3 [C]**).

The possible benefits of the 17 BSM proposed can be described for each disease (mean score of the BSM benefits for a given disease) or overall (mean score of all the benefits related to that BSM). The majority of the farmers (more than 50%) perceived the efficiency of the different BSMs as greater than 50% (**Fig. 4**), at the exception of having double fences for YCD for which the average farmers perception of the measure efficiency was below 50%.

The level of intention to implement the BSM was also assessed in the survey (**Fig. 5**). Seven measures were nominated as being implemented by more than 60% of the farmers (control programmes, closed herds, test at purchase, proper carcass disposal, feeding-dedicated equipment, regular screening of animal health status and litter and barns' hygiene) and four measures revealed a low level of implementation (<40%): all-in all-out system, isolation of sick animals, visitors' hygiene and clothing and double fences in pasture.

Negative binomial regression models

Effects of demographic and psychological variables (explanatory variables) versus psychological variables and farmers' perceptions (dependent variables)

The stepwise backward regression analysis highlighted an association between several demographic and psychological variables and the farmers' perceptions, as well as between some demographic and psychological variables (**Fig. 6 [A]**). The different regression models are provided in **Appendices S3 [A and B]**. The Kruskal-Wallis analysis confirmed a high association between country and risk aversion (p-value<0.0001), and country and biosecurity knowledge (p-value<0.008). Additionally, there were high associations seen between education level and the biosecurity knowledge (p-value=0.0001), and between gender and risk aversion (p-value<0.0002). Therefore, if two associated variables were to be included in the multivariable model (p-value<0.1 in the univariable model), the psychological variable was the one included.

Regarding the association between demographic and psychological variables, risk aversion was significantly lower for males, and for farmers in two specific countries (i.e.: Germany and the Netherlands) when compared to Belgium. Biosecurity knowledge was significantly higher for farmers in Spain, those who were experienced and those with a higher education level.

The farmers' sense of responsibility towards animal, public and environmental health was significantly higher for individuals with higher biosecurity knowledge and risk aversion as well as for non-organic farms. It was also significantly higher for farmers in Spain, and significantly lower for farmers in Germany, compared to farmers in Belgium. The overall perception of the different disease susceptibility and severity was significantly higher for non-organic farmers, farmers with a better biosecurity knowledge, and those with a larger herds size. The perceived barrier were significantly lower for farmers with a higher biosecurity knowledge. The perception of BSM benefits was significantly lower in organic farms and higher for farmers owning a larger herd and having a higher risk aversion.

The influence of the different explanatory variables on the perceived benefits of the BSM were also assessed individually for each BSM (N = 17) (**Fig. 6 [B]**). No significant explanatory variable was identified in the final model for the measure M2 (closed herd), M3 (all-in all-out system), M6 (control of vehicle access), M10 (feeding-dedicated equipment) and M17 (double fences). The benefits of a proper work order when attending animals (attending animals from the youngest to the oldest and from healthy to sick) were perceived as significantly lower for farmers in Spain compared to farmers in Belgium. The benefits of isolated maternity boxes or pens were perceived as significantly lower by organic farmers compared to conventional farmers. The remaining 10 BSM varied significantly, based on two to three explanatory variables. Among these variables, risk aversion and biosecurity knowledge were the most frequent and were positively associated with 6 and 4 BSM respectively. Farmers with a higher risk adverse profile were more likely to have a higher perception of the benefits of animal testing at purchase, a proper quarantine, isolation of sick animals, regular screening of animal health status, visitor s' hygiene and clothing, as well as providing dry, clean litter and suitable barns. The perception of farmers with a higher biosecurity knowledge was also higher for the benefits of isolating sick animals, regularly screening the animals' health status, keeping the calves in individual boxes and controlling visitors' hygiene and clothing.

Association between the Health Belief Model constructs (explanatory variables) and the level of intention to implement the BSM

The five HBM constructs were used as explanatory variables in 18 multivariable models; one model was tested for each BSM, and an additional model tested the overall implementation of BSM (**Appendix S 3 [C]**). The final models (**Fig. 6 [C]**) showed that the perception of disease susceptibility and severity did not make any significant difference in terms of BSM implementation with the exception of keeping the calves in individual boxes. This BSM seemed more likely to be implemented when the farmers had a higher perception of the disease severity and BSM benefits. The level of intention or implementation of a given BSM was significantly higher when the perception of its benefits was higher and when the sense of responsibility towards health was higher. When analysing the influence of HBM constructs on the implementation of individual BSMs, health responsibility was associated with a significantly higher level of implementation for nine measures, and perception of BSM benefits was associated with a higher level of implementation for all 17 measures. Three BSM appeared to be significantly less likely to be implemented when the perceived barriers were higher: controlling vehicle access, the use of feeding-dedicated equipment and controlling the visitors' hygiene and clothing.

DISCUSSION

The influence of psycho-socio-demographic factors on farmers' behaviour is now largely recognised and taken into account in the different communication and awareness raising strategies related to BSM or prevention of infectious diseases (Mankad, 2016; Ritter et al., 2017). As mentioned in a previous study, the theories of behaviour change (mainly HBM and Theory of Planned Behaviour) have been increasingly tested or applied to behaviours related to animal health (Brennan et al., 2016). Most of these studies used the HBM to assess the implementation of a specific BSM or risk (e.g. the application of nematode control programmes (Vande Velde, Charlier, Hudders, Cauberghe, & Claerebout, 2018; Vande Velde et al., 2015a)). Nevertheless, to our knowledge, only one study has applied multiple behaviour change models to actually identify the determinants of BSM implementation in general and assess their level of influence on the actual behaviour (Richens et al., 2018). Being able to identify the most important beliefs and perceptions to address and change in order to facilitate the adoption and long-term implementation of BSM is a key element of any communication strategy.

This study showed that, among the five HBM constructs, three significantly influenced the level of BSM implementation. The perception of the benefits of using BSM and the farmers' perception of their responsibility towards animal, public and environmental health influenced significantly and positively the use of 17 and 9 BSM, respectively, as well as the overall level of BSM implementation. The perception of the barriers to using BSM influenced significantly and negatively the implementation of 3 BSM. As the model assumes that the HBM constructs are influenced by different demographic and socio-psychological variables, it is therefore important to analyse which of these variables appear to influence these three HBM constructs.

One potential limitation of the study relates to questionnaire development and its lack of validation. The questionnaire's capacity to properly capture the HBM constructs has not been properly validated. However, the questions were developed along similar lines as in previous studies (Brennan et al., 2016; Mankad, 2016; Ritter et al., 2017; Vande Velde et al., 2015a; Vande Velde, Charlier, Hudders, Cauberghe, & Claerebout, 2018), and guidelines described by Champion (1984) were consulted.

The total number of complete questionnaires achieved (N = 988) was substantial. Nevertheless, the over-representation of Belgium is likely to be a bias as well as the different methods used in each country to contact farmers. For example, these disparities might explain the result relating to the higher biosecurity knowledge in Spain compared to Belgium as the majority of Spanish farmers who participated in the survey were involved in a biosecurity research programme. The country specific context regarding mandatory BSM and/or disease control programmes as well as the country specific disease status' might also have influenced the farmers' perceptions. As an example, the perception of the disease susceptibility related to a given disease is more likely to be lower in a disease free country compared to a country where the given disease is endemic. The perception of a disease severity is also more likely to be higher if the country has an eradication program targeting this disease, which could lead to additional economic losses in case of outbreaks. The farmer differences between countries should therefore be considered with caution. Nevertheless, the identified country bias should only influence the correlation between the demographic variables and the HBM constructs themselves and, based on the HBM model assumptions, should not affect the results of the multivariable analysis performed to determine the influence of the mental constructs on the behaviour. The use of a pop-up on the web page of the farmer associations' website (generating the opening window inviting them to fill in the questionnaire) appeared to increase the number of responses and should be considered for similar future studies.

The two psychological variables, risk aversion and biosecurity knowledge, were significantly associated with a higher health responsibility and a higher perception of the benefits of the BSM (for six and four BSM, respectively). The farmers with a higher biosecurity knowledge and a higher education level also had a significantly lower perception of the barriers. This would likely lead to a higher implementation of these BSM negatively influenced by barriers: controlling vehicle access, using feeding-dedicated equipment and ensuring proper hygiene and clothing for visitors.

Some demographic variables such as organic farms and herd size did not significantly influence the psychological variables but seemed to influence the three most prominent HBM constructs: the health responsibility, the benefits and the barriers. Organic farmers (N=119) showed a significantly lower responsibility towards health and a lower perception of the benefits of four BSM: existence of a disease control programme, preventing animal access to surface water, existence of isolated maternity pens, and individual housing for calves. Therefore, their implementation level was likely to be lower compared to non-organic farmers. As the number of treatments per year and per animal is limited under organic farming systems, it would be expected that effective BSM would be considered essential to reduce the occurrence of infectious diseases on these farms. These finding are therefore somewhat surprising.

In the univariable model, country seemed to influence several perceptions significantly. Nevertheless, due to high associations with the psychological variables, country was not considered in the multivariable analysis whenever the psychological variables were included. The possible direct influence of country on the intention to implement or implementation of BSM was therefore not systematically assessed. In addition due to a possible country bias due to the different ways of diffusion of the survey invitations, no conclusions can be taken as to the eventual causal link between the country and the perceptions.

This study, performed across a number of EU Member States, is one of the first to analyse the influence of different perceptions on the overall implementation of BSM with the exception of work performed in Great Britain (Richens et al., 2018). Other previous studies have focused on a specific behaviour. To our knowledge, the current study is also the first study to include the "health responsibility" construct and some psychological factors as possible explanatory variables.

This study confirms the findings of previous studies on behaviour change regarding the importance of farmers' perception of the efficacy or effectiveness of a BSM (Jansen, van Schaik, Renes, & Lam, 2010; Moya et al., 2019; Richens et al., 2018; Vande Velde et al., 2015b) and the communication strategies focusing on the BSM effectiveness to promote behaviour change (Jansen & Lam, 2012).

The influence of farmers' perceptions of their responsibility towards animal, public and environmental health on whether BSM are implemented is an interesting finding in this study, which is worth investigating further. The role of "the beliefs regarding the existence of a problem" was previously identified as an important element in terms of behaviour change (Jansen & Lam, 2012). The possible influence of the motivation behind the cattle farmers' behaviours is also considered by some policy makers such as the Department for Environmental, Food and Rural Affairs in the UK (DEFRA, 2008): they defined five categories of farmers, influenced by different communication strategies, in order to better promote behaviour changes. These five categories were: "custodians" (strongly influenced by their commitment to protect the countryside; they see themselves as guardians of a farming heritage), "lifestyle choice" (eager to achieve a high-standard of farming with their main source of income being non-farming activities); "pragmatists" (they love farming and want to make enough money to achieve a satisfactory standard of living), "modern family businesses" (focused on profit and running an efficient business) and "challenged enterprises" (facing major challenges and anxious about farm survival). It might be interesting to further explore how the farmers' sense of responsibility towards animal, public and environment health could be used as a trigger for behaviour change in a similar way to DEFRA.

A commonly held belief is that behaviour might be highly influenced by risk perception in terms of disease susceptibility and severity and many communication strategies therefore rely on the fear of a given disease. Nevertheless, this mental construct did not seem to influence our results, as the risk perception, either in terms of susceptibility or severity, did not significantly influence the implementation of BSM, with the exception of housing calves individually.

The results found in the current study confirms a number of previous findings in the veterinary literature, demonstrating no influence of the risk perception (perceived susceptibility and severity) on the level of intention to implement a specific BSM (Vande Velde et al., 2015b). Nevertheless, it contradicts other studies (Garforth, 2015; Moya et al., 2019) in which any public health problems or disease outbreaks on the farm or neighbouring farms were reported as triggers to behaviour change. The possible influence of such events was taken into account in the present study. Indeed, questions relating to individual experience of disease outbreaks on the farm or neighbouring farms were included, in order to assess the perception of risk severity. Nevertheless, this construct did not significantly influence the level of intention to apply BSM. Based on these contradictory findings, future investigations into the influence of these personal experiences as a unique construct with direct effect on BSM implementation should be considered. This element has been included in some HBM and referred to as "Cues to action" (I M Rosenstock, Strecher, & Becker, 1988).

CONCLUSION

It is now widely recognised that communication strategies should address different mental constructs in order to improve the adoption of BSM by farmers. Nevertheless, the relative importance of these constructs on actual behaviour change has not been properly investigated in veterinary medicine so far. This study confirms previous findings, which highlight the importance of basing communication strategies on evidence-based benefits whilst acknowledging the low influence of risk perception in the decision-making process. It also highlights a new psychological element, as health responsibility and attitude seem to highly influence the perception of the BSM benefits. Future studies should focus on determining the efficiency of the different communication strategies that have been targeted using the findings from this current study.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL APPROVAL

Due to the nature of the study and the low risk exposure of the participants, formal approval from an Ethics Committee was not a requirement at the time of the study.

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Figure captions

Figure 1. Comparison of the Theory of Planned Behaviour and the Health Belief Model

Figure 2. Health Belief Model applied in the study

Legend: * Calculated score: variable measured by a composite score in the multivariable regression model (see Appendix S1).

Figure 3. Farmers' perception of disease susceptibility and severity and of the possible barriers to their control

Legend: Boxplot showing the different quartiles representing the three different diseases (three shades of grey) and an overall score (black), with the horizontal line representing the median "Overall": Perceived susceptibility of the three diseases (average of the three disease specific susceptibility scores)

Figure 4. Perceived benefits of the different biosecurity measures on the prevention and control of: [A] Bovine viral diarrhoea, [B] Brucellosis, [C] Young calf diarrhoea, [D] the 3 diseases

Legend: M1- Control programmes, M2 - Closed herd; M3 - All-in all-out system; M4- Test at purchase; M5- Proper quarantine; M6- Control of vehicle access; M7- Isolation of sick animals; M8- No access to surface water; M9- Cemented area and cover for carcasses; M10- Feeding-dedicated equipment; M11- Proper working order (from young to old and from healthy to sick animals); M12- Isolated maternity boxes or pen; M13- Regular screening of animal health status; M14- Individual boxes for calves; M15- Control of visitors' hygiene and clothing; M16- Litter and barn hygiene; M17- Double fences in pastures.

Figure 5. Intention to implement or implementation of biosecurity measures by the farmers

Figure 6. Significant associations identified from the different final models obtained by the backward stepwise regression analysis

Legend:

[A] Significant associations between the demographic and psychological variables and the Health Belief model constructs: [a] Significant association compared to Belgium; [b] Significant association compared to Beef herds.

[B] Significant associations between the demographic and psychological variables and the benefits of the biosecurity measures: [a] Significant association compared to Belgium; [b] Significant association compared to Beef herds. The gender variable as well as the biosecurity measures without any association were removed from the figure (M2, M3, M6, M10 and M17).

[C] Significant associations between the Health Belief model constructs and the intention to implement or the implementation of biosecurity measures

Table captions

Table 1. List and typology of the biosecurity measures addressed in the questionnaire

Legend: * Number of infectious diseases which can be partially controlled by this BSM among the three diseases proposed.

Table 2. List of statements used to assess the perceived responsibility towards animal, public and environmental health

Table 3. Farmers and farms profile of the respondents

Legend: [a] Higher education refers to short or long term tertiary study; [b] Examples of "other" categories: veal calves and fighting bulls.