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Explaining farmers' adoption of mastitis control practices using psychological constructs from the theory of planned behavior

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HIGHLIGHTS

- Subjective norm, farmers perceived social pressure, influence mastitis control.
- Farmers' perception of being able to control the mastitis situation decides which preventive actions are used.
- Understanding how to affect farmers behavior in their usage of preventive actions can have positive effects on animal health and welfare.

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ABSTRACT

Mastitis control options (MCOs) are management actions that are adopted to prevent mastitis in dairy herds. In this study, the psychological constructs attitude, subjective norms and perceived behavioral control are used to explain farmers' adoption of MCOs. So far, little research has used psychological constructs to explain adoption of MCOs. Based on recommendations by a Swedish dairy association (Växa) aimed at farmers, a total of 15 different management areas, representing MCOs for contagious and environmental bacteria, were used to characterize adoption behaviors. A total of 286 Swedish full-time farmers specializing in dairy production participated in the survey. Four different farmer groups were identified through a cluster analysis of similarities in how farmers adopted MCOs together with data on bulk milk somatic cell count and subjectively evaluated somatic cell counts on the farms. Regression analyses were performed to test whether the psychological constructs could explain differences in adoption across the MCO groups. Results revealed that farmers' decisions about which set of mastitis control options to adopt as preventive actions were explained by the farmers' perceived behavioral control of the situation and by differences in subjective norm. The attitude construct did not contribute to predicting the adoption of mastitis control options. Results suggest that work aimed at implementing MCOs should be complemented by programs specifically designed to improve the ability of farmers to use and/or combine MCOs to both alleviate and prevent mastitis. They also suggest that there is little to gain from programs aimed at fostering attitudes to prevent mastitis. We interpret the findings as indicating a need to strengthen perceived behavioral control as well as subjective norms among Swedish farmers' regarding their preventive work with mastitis. Understanding how to affect farmers' behavior, and thus reducing and controlling mastitis, will have positive effects on animal health and welfare in general.

1. Introduction

Mastitis is one of the most common diseases and a major animal welfare problem in dairy farming (Ruegg, 2017). Apart from causing substantial production losses, and associated income losses for farmers and other supply chain actors, clinical mastitis also impairs animal welfare by being painful for the animal when clinical, causing swelling, and redness of the udder, and increased pain (Siivonen et al., 2011). Reducing incidence of mastitis has been established as a way to improve the economic situation of farmers, the welfare of animals, and the quality of milk in the supply chain, and of reducing public health risks associated with the use of antibiotics in animal production (Hogeveen et al., 2011; Volpe et al., 2016; DeLong et al., 2017).

In the United States, the total aggregated cost for clinical mastitis is

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estimated at $629 million per year, and for mastitis (both clinical and subclinical) the cost is estimated be up to $1 billion per year (Hogeveen et al., 2019). The failure cost of mastitis is estimated to be $US131 per cow per year (Hogeveen et al., 2019). In Sweden, the estimated cost of both sub-clinical mastitis (mastitis without visible symptoms) and clinical mastitis is about 5% of the gross margin in a herd with 150 dairy cows (Nielsen et al., 2010). For this, around 17% of costs are due to expenditures such as treatment and increased labor. In the Nordic countries, such as Sweden and Denmark, the cost is expectedly even higher as treatment cost is much higher than elsewhere.

On dairy farms, both in Sweden and worldwide, mastitis alone is one of the most common reasons for antimicrobial usage (Nobrega et al., 2017; Persson Waller et al., 2016). From a societal perspective, mastitis is problematic because it can increases the use of antibiotics on farms, which may lead to an increased risk of antibiotic resistance when used systematically (Nobrega et al., 2018). This may have consequences not only in dairy cows and other livestock animals but also in humans, as it may spread through direct contact, food or water, and thereby act as a public health risk (Collignon and McEwen, 2019; Dutil et al., 2010; Nobrega et al., 2020; Talebi Bezmin Abadi et al., 2019).

In efforts to prevent mastitis, farmers are advised to adopt various mastitis control practices (mastitis control options, MCOs) (Lam et al., 2013). The MCOs are intended to give farmers structure and guidance to the routine work in order to improve animal health and welfare, given that farm animal welfare is dependent on human care. For dairy veterinary practitioners and extension agents, providing evidence-based advice to farmers is difficult, since they do not know whether their recommendations will be perceived as important by farmers, be implemented within herds, or, ultimately, have any effect (Hall and Wapenaar, 2012; Lam et al., 2013). In a recent study by Svensson et al. (2019) farmers adherence and non-adherence to veterinary advice was suggested to be related to the trust in the veterinarian and perceived feasibility; both related to external (i.e. buildings and regulations) and internal factors (i.e. time and economic considerations), and priorities on the farm (i.e. attachment to the animals and other solutions). This would imply that there is likely a higher possibility that veterinary advice will be implemented on a farm if the veterinarian has a comprehensive understanding of what is possible on that specific farm in combination with shared trust.

Mastitis control programs devised by dairy advisors *commonly* consist of recommendations (MCOs) in order to either control or reduce mastitis prevalence. These programs are tools farmers can implement in their everyday work to reduce the risk and prevalence of mastitis and keep bulk milk somatic cell count (BMSCC) at a low level (Nielsen and Emanuelson, 2013; Swedish Dairy Association, 2011). Previous studies have demonstrated behavioral aspects related to the use of MCOs by dairy farmers. For example, Van den Borne et al. (2014) found that farmers' attitudes and knowledge explained a decrease in the incidence of clinical mastitis on Dutch dairy farms, while Hansson and Lagerkvist (2014a) found that Swedish dairy farmers' evaluations of the benefits and risks of certain MCOs were dependent on the framing of these MCOs. Thus, Hansson and Lagerkvist (2014a) suggested that farmers' assessments of MCOs depend on the individual reference point from which they evaluate their current situation and that assessments are asymmetrical in relation to the framing of the evaluation. They suggested that farmers' management behavior is evaluated differently dependent of the individual referent point, in which farmer's assessment of an MCO is asymmetrically different whether it is evaluated in the risk or benefit domain. Hansson and Lagerkvist (2014a) concluded that farmers behavior is influenced by loss aversion, a cognitive bias that describe why human beings experience losses asymmetrically more severely than equivalent gains. Previous studies also devote considerable attention to farmers' conceptualization of farm animal welfare, of which animal health, and thus mastitis, is one aspect (e.g., Dockès and Kling-Eveillard, 2006; Hansson and Lagerkvist, 2016), and to farmers' attitudes to animal welfare (e.g., Kauppinen et al., 2010; Kielland et al., 2010).

Despite the contributions made by previous studies, little attention has been given to the impact of underlying psychological constructs (attitudes, motivation etc.) on farmers' adoption of MCOs, and thereby gaining increased understanding in how to influence farmers in such a way that animal welfare can improve. Psychological constructs, have been investigated in relation to farmers' perception of farm animal welfare in general (Hansson and Lagerkvist, 2014b; van den Borne et al., 2014), but could also be of relevance for understanding farmers' adoption of MCOs. By identifying the most important psychological constructs that should be strengthened in order to stimulate further adoption of MCOs, such research could be helpful in attempts to formulate advice that are more effective for farmers on adoption of MCOs and thus improve animal welfare and health. The aim of the present study is, therefore, to explore how adoption of various MCOs in relation to the farms' BMSCC and farmers' evaluation of the SCC on the farm can be explained using psychological constructs. For the present study, we are using constructs well recognized as affecting human behavior and behavioral intent, namely perceived behavioral controls, subjective norms and attitudes. These three constructs are commonly part of the theory of planned behavior (Ajzen, 1991).

2. Material and methods

2.1. Selection of farmers and data collection

All Swedish full-time farmers specializing in dairy production were eligible for inclusion in the study. Names, phone number, and addresses of a random sample of 1200 specialized dairy farmers were obtained from a register of all Swedish farmers administered by Statistics Sweden (Örebro, Sweden). The randomization were performed by Statistics Sweden for which they provided us with contact details to a randomly selected sample of all active dairy farmers registered at the end of 2015 ($N = 4039$). Statistics Sweden is the authority in Sweden responsible for official statistics and other government statistics. All randomly selected farmers were invited to participate in our study. The selected farmers were asked to complete an online questionnaire between April and June 2016. To ensure the farmers' anonymity, the survey was conducted by a third party specializing in survey data collection (IPSOS Sweden, Stockholm) on behalf of the research group, and the research group obtained unidentified data from the completed questionnaires. Power estimations was performed prior to the study and based on the total population of active Swedish dairy farmers in 2015 with a confidence interval of 95% and a margin of error of 5%. According to our estimation, a total sample of at least 351 participants was needed to be able to draw any statistical conclusions from the questionnaire. To ensure that the sample was big enough, IPSOS Sweden reminded farmers about the questionnaire until that requirement was fulfilled.

An invitation letter containing the aims and objectives of the project was sent by post to potential respondents, together with a link to the online questionnaire. In total, 1200 farmers were invited to participate. When contacted by the survey company, the farmers were also given the option of completing the questionnaire as a hard copy instead of online. This enabled farmers with limited access to computers to participate. During the data collection process 40 respondents no longer matched the target group (they had retired or sold their dairy cattle) leaving us with a total sample of 1160 farmers. Additionally three declined to participate due to illness, and 62 farmers could not be contacted for a reminder due to phone numbers being incorrect or unavailable, 143 farmers declined to participate due to time constraints, 42 declined to participate for other reasons. A total of 356 (30.7% of the total sample with active dairy farmers matching our target group) farmers participated in the study (42 used the hard copy version).

The questionnaire took 30–40 min to complete and each participating farmer was sent two lottery tickets as a token of appreciation on completing the questionnaire. The questionnaire was ethically approved by the local ethics vetting board (Ref. 2016/075) and the study was part of a larger multidisciplinary project. The questionnaire instruments were developed by researchers with expert knowledge of mastitis in dairy cows, working together with researchers with expert knowledge of psychometric testing. The instruments were not pre-tested in the conventional sense, but significant experience on how to set questions for the target group was derived from previous work by members of the research group (e.g., Hansson et al., 2012).

After the initial data collection, additional data on herd size and average calculated BMSCC for 2014–2016 (the years closest to those in which the questions in the questionnaire applied) was obtained from the Swedish Official Milk Recording Scheme (SOMRS), in which around 80% of all Swedish dairy farms are included,. The BMSCC obtained is based on individual cow test-day information on milk yield and SCC, rather than on milk delivered (Nielsen and Emanuelson, 2013). For this data, a coded data key on participating farmers with contact information was sent by IPSOS to Växa that are managing the SOMRS, which created a dataset with matching information. This procedure meant that all farmers in both databases were anonymous to the research group and the data provided by Växa was anonymous to IPSOS. After matching the two databases, a sample of 305 farms was obtained, as only associated dairy farms could be matched with BMSCC. From the 305 farms, 19 were excluded for the present study as they did not have a BMSCC mean for all three years. In total 286 farmers were included in the final analysis (see Table 1).

Table 1
Descriptive statistics on participants, here presented according to mastitis control option (MCO) groups 1–4 and all participating farmers. In total 286 farmers were included in the analyses.

	MCO group I $n = 115$	MCO group II $n = 54$	MCO group III $n = 83$	MCO group IV $n = 34$	All participants $N = 286$
Age in years, average (mean ±SD)[a]	64.5 ± 12.9	62.9 ± 9.9	64.4 ± 10.7	62.6 ± 10.2	64.0 ± 11.4
Male (%)	78.3	81.5	68.7	75.8	75.5
Number of dairy cows, average (mean±SD)[b]	129.9 ± 115.2	76.9 ± 69.0	95.9 ± 86.7	156.5 ± 325.6	112.8 ± 144.7
Agricultural education, y/n,%	58.3	55.6	50.6	48.5	54.2
Married/partner, y/n,%	88.7	87.0	92.8	90.9	89.9
Family herd, y/n,%	80.0	81.5	79.5	69.7	78.7
Planned (generational) change					
Yes	25.2	25.9	33.7	15.2	26.6
No	7.8	13.0	7.2	6.1	8.4
Don't know/too early to say	67.0	61.1	59.0	78.8	65.0
At least 75% of income from milk production, y/n, %	47.0	37.0	65.1	58.8	51.7
Somatic cell count[c]					
Very high	2.6	–	–	–	1.0
High	15.7	13.0	–	18.2	10.8
Medium	76.5	35.2	1.2	42.4	42.7
Low	5.2	38.9	79.5	36.4	37.1
Very low	–	13.0	19.3	3.0	8.4
BMSCC, arithmetic mean (mean ±SD)[d]	267.5 ± 63.4	235.6 ± 92.1	199.4 ± 52.3	246.8 ± 84.5	238.9 ± 74.8
BMSCC, geometric mean	260.0	218.3	192.2	232.4	227.5

[a] In 2015, the median age of Swedish farmers was 55–59 years (Jordbruksverket, 2015).
[b] In 2015, the average Swedish dairy herd was 74 cows, although more than 50% of herds had more than 100 dairy cows (Swedish Board of Agriculture, 2023).
[c] Farmers subjectively evaluated levels of somatic cell count.
[d] BMSCC = bulk milk somatic cell count; provided by Växa Sverige.

2.2. Theoretical assumptions of the psychological constructs

For the present study, psychological constructs commonly used to explain behavioral intent according to theory of planned behavior were used. Theory of planned behavior is a psychological theory used to explain human behavior (Ajzen, 1991). The main tenet of theory of planned behavior is that an individual's behavior is predicted by their behavioral intentions. These intentions are determined by the individual's perceived behavioral control (perceived ease or difficulty and confidence in ability to perform a particular behavior), the subjective norm (perceived social pressure or approval for a particular behavior), and attitude (positive or negative evaluation of a particular behavior) (Ajzen, 1991). Thus, in relation to adoption of MCOs, the theory of planned behavior would posit that the individual farmer's intention to adopt MCOs depends on their evaluation of mastitis prevention, on their perception that there is support from others in their social network to work with mastitis prevention, and on their perception that they have the capability to work to prevent against mastitis.

The psychological constructs used as determinants of behavioral intent in theory of planned behavior are generally considered to be non-observable, latent constructs and must therefore be assessed from observable responses (Ajzen, 2010). Following recommendation from Ajzen (2010), each of the three constructs (perceived behavioral control, subjective norm, attitude) in the present study were measured by multiple items developed especially to capture the constructs and fit the research question. According to the theory, behavior is explained as a result of a person's behavioral intent. In the present study, farmers' actual behavior in the form of adopting MCOs was used to represent behavior. Controlling for mastitis is not a question of performing a single, occasional action, but is rather a continuous effort that most dairy farmers must pursue. Due to this, farmers' intentions (commonly used in theory of planned behavior) to control mastitis were not explored in the present study, but rather what they are actually doing (behavior) and how that could be explained by the psychological constructs from theory of planned behavior. This means that behavioral intent cannot be meaningfully represented on its own; it exists simultaneously with the observed, ongoing behavior. Through this reasoning, we assumed that farmers' intentions to control mastitis are already set when they decide which MCOs to use. Therefore, we use the psychological constructs from theory of planned behavior to directly explain farmers' adoption of MCOs (behavior) rather than intention, which is a more common application of theory of planned behavior.

2.3. Questionnaire measures

Three items were used to capture perceived behavioral control (Table 2). For example, "I think it is easy to find the information I need to work preventively against mastitis in my herd" (1) *Completely disagree* – (5) *Completely agree*).

Five items comprised the **subjective norm** measure (e.g. "I believe that other farmers think I take care of my animals in a good way and prevent mastitis effectively": (1) *Completely disagree* – (5) *Completely agree*).

Five items assessed **attitude** to mastitis prevention (e.g. "I actively seek new ways and measures to prevent mastitis from occurring": (1) *Completely disagree* – (5) *Completely agree*). All items are presented in Table 2.

Mastitis Control Options. To assess farmers' adoption of MCOs, recommendations on strategies to control contagious and environmental bacteria provided by Växa were used (see Fig. 1). The set of recommendations consist of 15 different management areas related to aspects such as hygiene, milking order, breeding etc. Växa recommends starting from the bottom and working up to the top of the hierarchy, since the most influential and fundamental MCOs are located at the bottom and

Table 2
Items representing the three subscales of the theory of planned behavior. Each item is rated on a scale from (1) *Completely disagree* – (5) *Completely agree.* Chronbach alpha is given for each subscale. In total 286 farmers were included in the analyses.

	Mean (SD)	α
Perceived behavioral control		0.81
I think it's easy to find the information I need for preventive measures/actions towards mastitis in my dairy herd.	3.61 (0.98)	
When I implement new measures/actions in my herd, I think it is easy to find information on how it can be done.	3.38 (0.96)	
If there are any problems I need to solve, I almost always know where to turn for help.	4.03 (0.94)	
Subjective norms		0.85
I believe other farmers think that I take care of my cows and prevent mastitis in a good way.	3.62 (0.86)	
I know that others think I am doing well with my action against mastitis in my dairy herd.	3.45 (0.84)	
I feel that my relatives, family, and friends appreciate how I work to prevent mastitis.	3.59 (0.89)	
I want to make a good impression on others with my preventive measures/actions against mastitis.	3.27 (1.07)	
I think others see me as a pioneer.	2.87 (0.96)	
Attitudes		0.81
I like to take on and learn new ways and measures/actions to prevent mastitis.	3.76 (0.92)	
I am always actively looking for new ways and measures/ actions to prevent mastitis.	3.42 (0.99)	
I would consider making changes in my current mastitis prevention work if I had any recommendation that seems better.	4.12 (0.83)	
Working to improve my dairy cows' health is economically viable.	4.63 (0.65)	
As a dairy farmer, I am obliged to take good care of my herd.	4.60 (0.70)	

the least influential at the top. The ultimate goal is to reach having a BMSCC less than 150,000 cells/mL, which indicates a low prevalence of subclinical mastitis (see Fig. 1 for allocation of all MCOs). For each individual MCO, see Appendix 1 for a complete list, farmers were asked if they adopted the measure ((1) *Yes* – (0) *No)*. The MCOs located on level 1 (bottom) deal with milking routines and biosecurity during calving, those on level 2 with hygiene-related MCOs during milking and the physical environment, those on level 3 with vitamins and minerals and stress in animals, and those on level 4 (top) with animal breeding. As farmers do not seem to follow the recommendations given by their veterinarian of starting with the most influential MCOs located on the bottom of the pyramid and working their way up, a decision was made to categorize the MCOs into subgroups related to five areas. In order to cluster the farmers into groups based on usage of the MCOs, each MCO was categorized into subtypes representing strategies related to the environment, biosecurity, milking, feed and breeding, using a similar procedure to Lind et al. (2019).

2.4. Statistical analyses

Two Step Cluster Analysis. A two-step clustering approach (Chiu et al., 2001) was used to identify groups of farmers with the most pronounced similarities in use of MCOs together with their subjective evaluation of SCC at the farm and measured BMSCC. The subjective evaluation of SCC was measured using a single item question "How would you describe the prevalence of clinical mastitis in your dairy herd during 2015?" with response alternatives from very low (1) to very high (5). This method was chosen as it provides an auto-clustering mechanism and can handle large datasets efficiently (Gelbard et al., 2007) and be applied to both continuous and categorical variables. The clustering itself is based on probability rather than a deterministic algorithm for creating clusters. The procedure has been used successfully with self-reported behavioral data (Rundle-Thiele et al., 2015) and in studies on decision-making (Delaney et al., 2015).

The cluster analysis included farmer's subjective evaluation of SCC and measured BMSCC on the farm. These measures are believed to function as reference points for farmers when deciding which MCOs to adopt. The BMSCC used in the present study equals the yearly mean for the SCC that farmers use, together with their farm advisor or veterinarian, when discussing farm health and possible strategies for improving the SCC. This implies that farms with high BMSCC and who consider the SCC high may have implemented an MCO bundle that is similar to a bundle chosen by farms with low BMSCC and where the farmers consider the SCC acceptable or low as a means to reduce the BMSCC. This implies that the MCOs used may function as reactive measures in order to directly reduce the SCC or as proactive measures to keep the situation under control. Using the individual MCOs as reactive or proactive strategies may therefore, from a behavioral perspective, differ, whereas the decision itself may be perceived as being the same. In regards to this, if the BMSCC and subjective evaluation of SCC are not

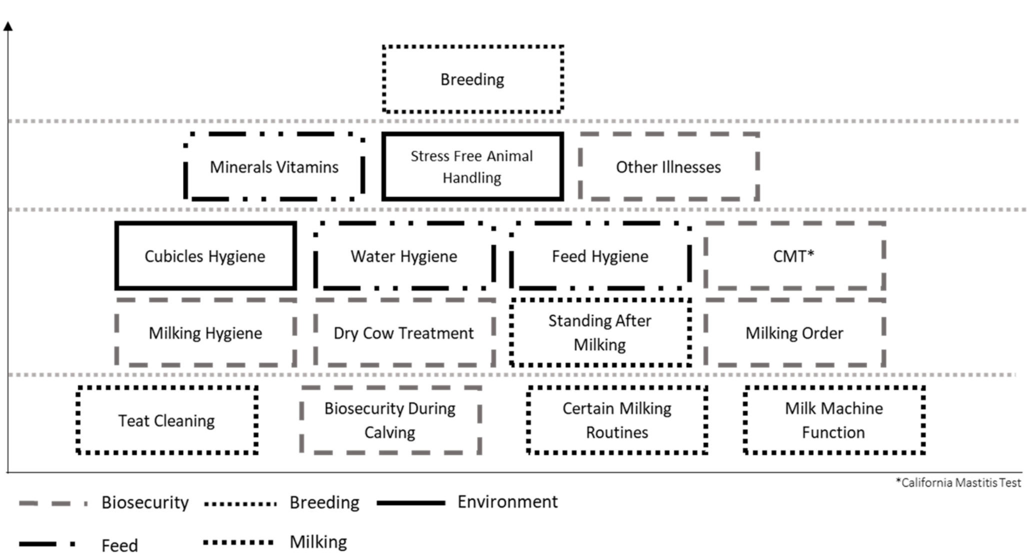

Fig. 1. Hierarchical pyramid of recommended mastitis control options (MCOs) to prevent cow-bound or infectious bacteria causing mastitis in dairy herds. The strategies are allocated to four levels based on their impact on cell count with the ultimate goal of having a BMSCC of less than 150,000 cells/mL Subtypes of MCOs used for the analyses are marked in figure, see legend for group membership.

included in the factor analysis, those farms would end up in the same cluster group despite being different in important aspects. To avoid this potential bias in our cluster solution, we opted for including BMSCC and subjective evaluations of SCC as indicators of farmers' reference points in the cluster analysis of their adopted MCOs.

The cluster analysis provides the ability to sort the farmers into groups based on multiple MCOs without preconceived ideas regarding relationships among the selected variables and their association with management practices.

In comparison to the study by Lind et al. (2019), the present study is based on the most recent recommendations of MCOs towards contagious and environmental bacteria provided by Växa. Coding for the groups of MCOs was adopted and non-adopted. For each MCO group the following coding was used: "(0) – no MCOs adopted", and "(1) – MCO group adopted" if at least one of the measures within the group had been adopted, indicating that the farmers used strategies related to that area. In total four clusters of groups could be identified based on Schwarz Bayesian Information Criterion, hereafter referred to MCO groups. For the Silhouette measure of cohesion and separation our MCO groups were found to have an average silhouette of 0.5 (range 0–1) which is considered as good. Why a higher average silhouette was not reached may be explained by the farms having high similarities in their implemented MCOs. For the clustering of MCO groups, the variables for Breeding (predictor importance = 1.0) and Environmental MCOs (predictor importance = 0.92) followed by the subjective evaluation of the SCC (predictor importance = 0.81) was identified as the three most important predictors defining the MCO groups. For the remaining variables BMSCC (0.35), Biosecurity (0.32), Feed (0.28) and Milking (0.08) lower predictability were identified, explained by the small difference in usage of these MCOs between all famers. These four MCO cluster groups then defined the dependent variable for the subsequent analyses, which assessed the association between the psychological constructs and the adoption of MCOs (See Table 3 for a description of the four MCO cluster groups).

Principal Factor Axis. Principal factor axis analysis (PFA) was used as a reliability test for the three subscales of theory of planned behavior to ensure that the items loaded on the correct subscale. This is a common procedure in validating theory of planned behavior constructs (e.g. Kautonen et al., 2015). The adequacy of the data set was examined by assessing the overall Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) as well as Bartlett's test of sphericity (Field, 2009a). Due to the correlation between the theory of planned behavior subscales (see Table 4) oblique rotation (PROMAX) was used, as it allows for cross correlation between the variables. To investigate internal consistency, inter-item correlations, Cronbach's alpha and corrected item-total correlations were calculated for the scales for the total sample. Based on the results, Cronbach alpha is presented together with descriptive statistics (mean and SD) for the factors and all individual items and presented in Table 2.

Regression Analyses. A multivariable multinomial logistic regression analysis was used due to the high correlation between the theory of planned behavior constructs (Table 4, see Appendix 2 for the correlation of the constructs within the MCO groups), i.e. evaluating the change to model fit introduced by the addition of a variable. For the analyses, the MCO groups identified in the cluster analysis were used as the dependent variable. For the regression analyses, MCO group I were used as the reference to which the other three MCO groups were compared.

The multinomial logistic regression allow estimations of the relationship between a categorical dependent variables with multiple levels (here MCO groups) and independent variables (here theory of planned behavior constructs) (Kwak and Clayton-Matthews, 2002; Field, 2009b). By using this approach, we were able to evaluate whether the model could be significantly improved by adding one construct over another in separate steps. This way of performing the analysis, instead of adding all subscales at once, allowed us to determine the individual effects shown by each construct. All possible combinations (here referring to order of variables inserted) were analyzed, resulting in a total of six (6) multinomial regressions each containing four (4) levels. The change was compared using Count R^2 and Adjusted Count R^2. The Adjusted Count R^2 is a modified version of Count R^2 that is adjusted for the number of predictors in the model. The Adjusted Count R^2 increases only if the new term improves the model more than would be expected by chance. We performed likelihood ratio tests to test whether the addition to the model was nested in the previous model. If the result was found to be statistically significant ($p < 0.05$), it meant that the model was improved by the addition.

Based on comparisons of the background variables related to herd characteristics (self-reported data), herd size (number of dairy cows) and total household income from the dairy production were found to differ statistically significant between the MCO groups. The base model (Model 1 in Table 5) therefore includes herd size and income and was added to all subsequent models, as they are believed to affect which MCOs are in use. Next, to test the individual impact of the theory of planned behavior psychological constructs (see Table 5), these were entered one by one in separate steps.

Statistical analyses (i.e. descriptive statistics, cluster analysis, correlation analysis, factor analysis, and multinomial regression) were executed using the Statistical Package for the Social Sciences (SPSS, IBM Corp., IBM SPSS Statistics for Windows, Version 24.0, Armonk, NY, USA). Stata Statistical Software (Release 15. College Station, TX: StataCorp LP, 2017) was used to perform multivariable multinomial logistic regression to control for nested models.

Table 3
Description of groups from the cluster analysis. In total 286 farmers were included in the analyses.

Performed preventive measures/actions	Group membership MCO[a] group I	MCO group II	MCO group III	MCO group IV
Breeding	■	□	■	–
Environmental	■	–	■	■
Biosecurity	■	□	■	■
Feed	■	□	■	■
Milking	■	□	■	■

[a] MCO = mastitis control option.
■ MCO type adopted, □ MCO type partly adopted, - No MCOs adopted.

Table 4
Correlation between the theory of planned behavior subscales perceived behavioral control, subjective norm, and attitude. In total 286 farmers were included in the analyses.

	Perceived behavioral control	Subjective norm	Attitude
Perceived behavioral control	1		
Subjective norms	0.448***	1	
Attitudes	0.455***	0.567***	1

*P < 0.05, **P < 0.01, ***P < 0.001.

3. Result

3.1. Descriptive statistics and cluster analysis

The participating farmers completing the questionnaire, and having complete BMSCC data, (N = *286*) were predominantly male (75.5%) aged from 29 to 91 years old (M = 64.0 years; standard deviation (SD) = 11.4 years). A total of 51.7% of all participating farmers reported that they received at least 75% of their household's total disposable income from milk production (biggest group represented in MCO group III). Overall, the participants evaluated the SCC in their herd to be low to medium during 2015 (see Table 1 for descriptive statistics). We identified statistically significant differences between the MCO groups in

Table 5
Summary of hierarchical multinomial regression analysis testing whether the psychological constructs could explain differences in adoption across the mastitis control option (MCO) groups[a]. Hierarchical multinomial regression was used to evaluate the change to model fit introduced by the addition of construct and control variables. All regressions are performed using MCO group I as reference (*please note that not all hierarchical models are shown*) in comparison to the other MCO groups. Model 1 is used as the base model for all analyses. Results are presented as the unstandardized beta (B), the standard error for the unstandardized beta (SE B), the odds ratio (EXP (B)). In total 286 farmers were included in the analyses.

	Model 1			Model 2			Model 3			Model 4		
Variables	B	SE B	*EXP (B)*	B	SE B	*EXP (B)*	B	SE B	*EXP (B)*	B	SE B	*EXP (B)*
MCO group II												
Number of cows	−0.007	0.003	0.993*	−0.007	0.003	0.993*	−0.007	0.003	0.993*	−0.007	0.003	0.993*
Income from the dairy production	−0.043	0.150	0.956 ns	−0.029	0.152	0.971 ns	−0.037	0.153	0.964 ns	−0.040	0.154	0.961 ns
Perceived behavioral control				−0.133	0.074	0.875†	−0.171	0.079	0.843*	−0.171	0.083	0.843*
Subjective norm							0.323	0.274	1.381 ns	0.323	0.298	1.381 ns
Attitude										0.005	0.357	1.005 ns
MCO group III												
Number of cows	−0.003	0.002	0.997 ns	−0.003	0.002	0.997 ns	−0.003	0.002	0.997†	−0.003	0.002	0.997†
Income from the dairy production	0.429	0.141	1.536**	0.417	0.140	1.517**	0.417	0.141	1.518**	.0434	0.142	1.543**
Perceived behavioral control				0.045	0.060	1.046 ns	−0.011	0.069	0.989 ns	0.020	0.073	1.021 ns
Subjective norm							0.381	0.224	1.464†	0.547	0.255	1.728*
Attitude										−0.420	0.310	0.657 ns
MCO group IV												
Number of cows	0.001	0.001	1.001ns	0.001	0.001	1.001 ns	0.001	0.001	1.001 ns	.001	0.001	1.001 ns
Income from the dairy production	0.439	0.196	1.552*	0.469	0.200	1.599*	0.468	0.200	1.597*	0.455	0.500	1.576*
Perceived behavioral control				−0.145	0.086	0.864†	−0.171	0.92	0.843†	−0.175	0.094	0.839†
Subjective norm							0.179	0.330	1.195 ns	0.133	0.357	1.142 ns
Attitude										0.155	0.409	1.168 ns
R^2		0.037			0.049			0.053			0.057	
Count R^2 (adjusted count R^2)		0.402 (0.000)			0.402 (0.000)			0.416 (0.023)			0.416 (0.023)	
Chi^2		28.56***			37.05***			40.45***			43.12***	

[a] MCO groups used as the dependent variable:
MCO group I, used as reference group, adopted preventive actions related to breeding, environmental, biosecurity, feed and milking measures.
MCO group II partly adopted preventive actions related to breeding, biosecurity, feed and milking measures.
MCO group III adopted preventive actions related to breeding, environmental, biosecurity, feed and milking measures.
MCO group IV adopted preventive actions related to environmental, biosecurity, feed and milking measures.
† $P < 0.10$.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

regard to total household income from dairy production, size of herd, subjective evaluation of the somatic cell count and measured BMSCC.

Based on the adopted MCOs, combined with the farmer's subjective evaluation of the herd SCC and measured BMSCC, we identified four groups. We interpret the grouping as follows: Group I consisted of farmers performing all types of MCOs and having the highest BMSCC. We interpreted this group as representing farmers working with mastitis on all levels but not succeeding, as their level of BMSCC is the highest (arithmetic/geometric mean = 267.7/260.0) among all farmers. Forty-seven percent of the farmers in this group reported that dairy production represents at least 75% of their total household income. Group II consisted of farmers performing parts of the MCO types related to breeding, biosecurity, feed, milking and environmental strategies, with a relatively high BMSCC (arithmetic/geometric mean = 235.6/218.3). We interpret this group to be selective of MCOs that work on their own farm but with low control of the BMSCC. For this group, only 37% reported that dairy production is responsible for at least 75% of their total household income, which is the lowest reported dependency. Group III consisted of farmers performing all types of MCOs and having the lowest BMSCC (arithmetic/geometric mean=199.4/192.2). We interpreted this group as farmers with high interest in mastitis control. For this group, 65.1% of all farmers reported that dairy production is responsible for at least 75% of their total household income, making it the most dependent on dairy production. Group IV were farmers performing four out of five MCO types fully, except for breeding, with a BMSCC similar to MCO group II (arithmetic/geometric mean = 246.8/232.4). We interpret this group, in a similar way as Group II, as selective of MCOs that work on the own farm but with low control of the BMSCC suggested by the measured somatic cell count. Group IV stands out in regard to the other three groups as these farmers do not use breeding as a strategy to prevent mastitis. This group is the second most dependent group on income from dairy production with 58.8% of all farmers reporting that dairy production is responsible for at least 75% of their total household income. See Table 1 for descriptions and characteristics of the groups and Table 3 for a schematic overview of the MCO groups and their adopted measures.

3.2. Principal factor axis analysis

We used the PFA to validate the dimensionality of the psychological constructs perceived behavioral control, subjective norms and attitudes. The KMO had a value of 0.843, suggesting that the sample is adequate for PFA (Hutcheson and Sofroniou, 1999; Field 2009a). Bartlett's test of sphericity revealed statistical significance ($\chi2 = 1816.76$). Our interpretation of the PFA results was guided by examining factor loadings. Variables which had a loading of >0.4 on only one factor were interpreted as indicative of that factor based on the total sample size (Field, 2009a; Hair et al., 2006). Following this, we set the number of factors as three based on the theoretical assumptions of the theory of planned behavior. Two of the items which theoretically belonged to perceived behavioral control loaded on the scale for attitude (0.441 and 0.584) were therefore excluded from further analyses. This meant that from the initial 15 items, the remaining 13 items was used to represent theory of planned behavior in the further analyses, see Table 2 for all items. As all theory of planned behavior variables are correlated with each other (Table 4) and believed to explain behavior, all were included in the analyses and added to the initial model. For the included 13 variables used to measure the theory of planned behavior constructs, the identified factors explained 54.6% of the total variance (perceived behavioral control 39.5%, subjective norm 8.5%, and attitude 6.6%). The average for each of these items formed reliable subscales for perceived behavioral control (Cronbach's $\alpha = 0.81$) subjective norm ($\alpha = 0.85$) and attitude ($\alpha = 0.81$).

In order to test the internal consistency of the three theory of planned behavior subscales (here referring to the constructs: perceived behavioral control, subjective norm and attitude), the corrected item-total correlations of the total sample ranged from 0.52 to 0.74 for perceived behavioral control, from 0.59 to 0.73 for subjective norm and from 0.48 to 0.70 for attitude. Item-total correlations did not indicate any improvement for the model when removing one of the items for the scales. Communalities ranged from 0.46 to 0.91. All values are well within what is acceptable for a factor analysis (Field, 2009a).

3.3. Regression analyses

Adding perceived behavioral control to each of the regression models resulted in statistical significance ($p < 0.05$) for Group II in comparison to the reference group. For Group IV a tendency ($p < 0.1$) was identified when adding perceived behavioral control in comparison to the reference group when controlling for at least one of the other two theory of planned behavior measures, see Table 5 (data not shown for all models, results from all analyses are available upon request from the corresponding author). For subjective norms, when adding the subscale to the regression base model, no association was found ($p < 0.657$) for MCO groups II and IV but a tendency was identified for MCO group III ($p = 0.063$) when using MCO group I as a reference. Similar results were identified when controlling for the other two theory of planned behavior constructs for MCO group III using MCO group I as a reference ($p < 0.05$). No statistical significance was identified for subjective norms for the other groups, meaning that no improvement was identified for any of the models. For attitudes, when adding the subscale to the regression model, no association was found for any of the models (p-value ranging from 0.174 to 0.989).

4. Discussion

Our findings suggest that, when controlling for measured BMSCC for each farm over a period of 3 years and farmers' own evaluation of the situation on the farm, perceived behavioral control and/or subjective norms are the most influential determinant of farmers' actual adoption of MCOs. The findings also suggest that attitudes do not impact farmers' actual adoption of preventive strategies. We interpret these results as indicating that of the three theory of planned behavior constructs, perceived behavioral control and subjective norms are the most important to address in further strengthening farmers' actions to improve mastitis prevention.

Adding perceived behavioral control strengthened each of the regression models, although only to a small extent. This was not found to the same extent for either subjective norms or attitudes. For subjective norm statistical significance was only identified for MCO group III in comparison to MCO group I. This means that we found statistical support for parts of our assumption about the impact of psychological constructs on adoption of MCOs in farmers' own herd. The results yielded partial support for the hypothesis that farmers are affected by subjective norms in some cases, but, interestingly, no support for them being affected by their own attitudes concerning mastitis prevention (see Table 5). This is believed to be a result based on other differences between the MCO groups.

The group of farmers belonging to Group I and III, which both report using all subtypes of MCOs (representing strategies related to the environment, biosecurity, milking, feed and breeding), have the highest and lowest BMSCC out of all four groups. The difference between these two groups are mainly explained by the income from the milk production, number of cows and perceived subjective norms, as no difference could be identified for perceived behavioral control or attitude (see Table 5). One of the major differences between these two groups is their dependence on income from dairy production for the household. Group III, which has the lowest BMSCC, is the group that reported the highest dependence on income from dairy production in comparison to group I, which reported the second lowest dependence. Group IV, in comparison to Group I (used as reference), showed no difference for perceived behavioral control. Whereas a difference was found for Group II in comparison to Group I, where those in Group I report to have higher perceived behavioral control. The control variable, herd size, used as the base model in all analyses, only showed statistically significant associations between Group I and II (Table 2). The differences between these groups can also be explained by the difference in the dependence of total household income from dairy production.

A comparison was made of the descriptive statistics between the participating farmers and the average Swedish dairy farmer in 2015. Based on background variables, such as age and herd size (shown in Table 1), the comparison was made to evaluate whether the sample was representative of the whole population of Swedish dairy farmers. Data for this comparison was obtained from the Swedish Agriculture Statistical Yearbook (Statistics Sweden, 2015). It seems from this that farmers participating in the study were slightly older than the national average and had more dairy cows than average. Results need to be interpreted in light of this.

Overall, our results suggest that Swedish dairy farmers, irrespective of which MCO subtypes are used in the herd, are similar in their attitudes when it comes to mastitis as a production disease. This is not to say that this psychological construct is not important for mastitis control but, based on the variation observed, it cannot function to explain differences in farmers' adoption of MCOs. Regarding the models' possibility to explain the variation identified, the adjusted Count R^2 only increased for model 3 and 4 suggesting that the addition of two or more of the theory of planned behavior constructs improved the model's more than would be expected by chance.

Rather, our results imply that the dependence on the dairy production is one of the major explanatory variables. This may be contrasted with previous findings by Jansen et al. (2009) suggesting that farmers' attitudes towards mastitis are a better predictor of incidence between farms than farmers' self-reported behavior. This may be explained by differences between countries with regard to herd sizes and regulations as it may affect how individual farms are affected when diseases occur on the farm. Other probable explanations to this difference may be explained by the difference in the methods and study design used, where Jansen et al. concludes that measuring farmers' attitudes is better at predicting differences in mastitis incidence than farmers' self-reported behavior (in our case use of MCOs).

Compared with previous research on behavioral aspects related to dairy farmers' mastitis management, our study makes a novel contribution by investigating the impact of several underlying psychological constructs on farmers' adoption of commonly recommended MCOs. In our approach, we related the psychological constructs, in the form of subtypes, commonly used in theory of planned behavior, directly to farmers' behavior and their actual adoption of MCOs. This approach may be desirable from a farm advisory perspective, as behavioral intent may only partly correspond to actual behavior (Webb and Sheeran, 2006). This may be contrasted with previous studies, which have suggested that dairy farmers' adoption intent in mastitis control is strongly associated with mastitis incidence and that the intent itself is driven by whether the farmer has a positive perception of the effectiveness of proposed measures to control mastitis (Jansen et al., 2010).

Based on these results, it cannot be concluded that the differences identified in usage of MCOs between the four clusters of farmers are associated with differences in BMSCC at herd-level. Decisions about which strategies are implemented may in fact be a result of farmers' perception of the situation on the farm and usage of the MCOs as either reactive or proactive measures to handle the situation. This means that using different combinations of MCOs (i.e., MCO cluster) does not lead to differences in BMSCC between farms alone, rather our results show that using the same MCOs might lead to large differences in BMSCC. This may be explained by other factors in the herd than purely which preventive measures are in place. Having a higher financial dependence (self-reported) on dairy production may affect preventive work, as having sick animals may affect farms differently in regard to how much risk the farmer is willing to take.

We interpret the lack of support for effects of attitudes on the adoption of MCOs we found in the present study as an indication that there is already good group cohesion among Swedish dairy farmers. This would suggest that there is a cohesive view of mastitis as a production disease. Previous studies have suggested that farmers' adoption of management practices on the farm are motivated by a reputation about being a "good farmer", which includes having clean barns, healthy animals, and good husbandry (Leach et al., 2010; Nielsen, 2011). This could be one possible explanation for the lack of differences detected between our MCO groups, as farmers may be driven by a desire to live up to the standards set by their social milieu. It is noteworthy that a study by Swinkels et al. (2015) found that farmers are sensitive to other farmers' subjective norms, as indicated by farmers extending mastitis treatment past the period recommended by veterinarians just to live up to an ideal. On the other hand, studies have shown that others' perceptions of dairy product quality and image, as well as recognition of a job well done, are the least important motivators for farmers in improving mastitis management (Valeeva et al., 2007).

The findings have clear implications for agricultural extension services aimed at strengthening farmers' adoption of MCO. In particular, our findings indicate that extension services should be complemented with programs specifically aimed at strengthening farmers' perception of the control they have over implementing MCOs on their farm. This is further supported by our previous findings exploring the effect of advisors using motivational interviewing to improve farmers adherence to advice. In line with the present findings, Svensson et al. (2019) showed that when farmers perceive advice as feasible to implement, taking into consideration both external (i.e. buildings and regulations) and internal (i.e. time and economic considerations) limitations and possibilities on the farm, they are more likely to adopt the advice on the farm. The findings point to the importance of having an understanding of the factors on the farm which may function as barriers and hinder (i.e. farm facilities, farmer characteristics, labor force and economic situation) as there is a lot to gain. Furthermore, considering that perceived behavioral control is related to self-efficacy (Ajzen, 2002; i.e., in the individual's belief in their ability to carry out actions or avoid adverse outcome) our findings indicate that work on implementing MCOs should be complemented with programs that include specific elements which help develop the ability of farmers to use and or combine MCOs to alleviate and prevent mastitis. The programs should be designed to strengthen farmers' beliefs in their own ability to affect the mastitis situation. It should also be noted that, based on the cross-sectional data we had available for farmers' adoption of MCOs, we were unable to establish a causal association between farmer's actual implementation of MCOs, as represented by farmer MCO groups, and measured BMSCC. This is because we lacked prior information about the time sequence and how long the MCOs had been in place. Our results suggest that the BMSCC level in the herd is not mainly affected by farmers' decisions about what MCOs to adopt, which corroborates previous results (Emanuelson and Nielsen, 2017). Those authors identified two MCOs as being associated with lower BMSCC, while we found that one of the MCO groups investigated (Group III) had herds with significantly lower levels of BMSCC than all other MCO groups.

There are some limitations of the present study. First, it should be emphasized that when asking questions about animal wellbeing and health, there is a risk related to social desirability bias in the replies (e.g., Lusk and Norwood 2010) and the findings need to be interpreted in light of this risk. Farmers that replied may represent a certain group that are more interested in udder health, in comparison to the general population of Swedish dairy farmers, which may result in a biased representation of what measures are used in Swedish dairy production. Second, it should be acknowledged that our sample differed to some extent from the national average, with larger herds compared with the average dairy farm in Sweden in 2015. Our initial sample consisted of 356 farms but after merging the two datasets our sample was reduced to 286 farmers due to not all farm being associated with Växa Sverige with all data available. Therefore, our conclusions might not be representative of the average dairy farmer in practice in Sweden today. At the same time, ongoing structural changes mean that farms are becoming progressively larger, implying that our findings are arguably valid for the type of farms that will remain active in the near future. Important to note is that since the data collection in 2016, the dairy sector has been under big changes. This can have affected some of the output presented here, as it may not displaying the current situation. Although, the pyramid of MCOs is still in practice in advising farmers on how to approach and work preventively with mastitis on the dairy farm in Sweden. Farmers invited to participate in the questionnaire was based on a representative sample of all farmers working with dairy production in Sweden during 2015, where each farmer had an equal chance of being invited to participate. For the present study, we have not controlled for any self-selection bias, which may have occurred due to the reasons mentioned above.

5. Conclusions

With insights from this study, understanding farmers behavior and adoption of MCOs, animal health and welfare improvements, with regard to mastitis, can be achieved by tailored advice. The farmers' decisions on adoption of MCOs were significantly explained by farmers' perceived behavioral control over the situation and subjective norms, but not by farmers' attitudes. Considering the findings from a farm extension perspective, our results imply that animal welfare improvement can be achieved by focusing on programs aimed at strengthening farmers' perceived behavioral control as well as sharing experiences by concentrating on their ability to use or combine MCOs and strengthening their beliefs about their own abilities. We suggest that there is little to gain in terms of adoption of MCOs from programs that seek to strengthen attitudes in relation to mastitis control.

CRediT authorship contribution statement

Nina Lind: Conceptualization, Methodology, Data curation, Writing – original draft, Funding acquisition. **Helena Hansson:** Methodology, Writing – review & editing. **Ulf Emanuelson:** Methodology, Writing – review & editing. **Carl-Johan Lagerkvist:** Methodology, Writing – review & editing.

Declaration of Competing Interest

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