Understanding farmers' naturalistic decision making around prophylactic antibiotic use in lambs using a grounded theory and natural language processing approach

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Abstract

The routine use of antibiotics for prevention of disease in neonatal lambs has been highlighted as inappropriate, yet research suggests that many farmers in the UK still carry out this practice.

The aim of the study was to understand farmers' naturalistic decision-making around prophylactic antibiotic use in lambs. Data from 431 posts by 133 different users of an online discussion forum were analysed quantitatively using natural language processing and qualitatively using a grounded theory approach. Results from the qualitative analysis identified five categories that influenced farmers risk perceptions around prophylactic antibiotic use in lambs: anticipated regret, negative emotions and experiential

avoidance; economic considerations; farmer identity; perception of capability; and perception of social judgement. Natural language processing analysis of the posts by the study group were compared to posts on topics unrelated to antibiotic use by control groups from the same forum to understand the underlying style and tone within the text. Analytical thinking and authenticity scores were significantly lower in the study group compared to the control groups ($P<0.01$). Words relating to cognitive processes were significantly higher in the study group compared to the control groups ($P<0.01$). Results of the qualitative and quantitative analysis were integrated to assess the fit of the data and enhance findings from either method alone.

The key findings were the identification of reasons why farmers used antibiotics prophylactically in neonatal lambs. Farmers disassociated the use of oral antibiotics in neonatal lambs from other types of antibiotics within sheep farming. Farmers used the concept of luck and uniqueness to justify their prophylactic antibiotic use. This may explain farmers' low analytical thinking scores as this reflects a more personal style of thinking as farmers express their thoughts on antibiotic use on an individual basis. Farmers' felt that they did not have the capabilities to control neonatal disease without antibiotics during busy periods and this was exacerbated by external economic constraints. For farmers' who used antibiotics for therapeutic use, fear of social judgement was an important factor in their perceptions of risk around antibiotic use. The high frequency of negations and conjunctions suggested feelings of moral duty. As such, antibiotic use has developed into a symbol of their good farming identity which conflicted with the identity held by those who used antibiotics prophylactically. These results can be used to inform knowledge exchange around prophylactic antibiotic use in lambs to improve antibiotic stewardship in the sheep farming sector.

Keywords: antimicrobial use, decision making, natural language processing, grounded theory, farmer behaviour, sheep farmers

Introduction

Antibiotic resistance is a worldwide public health threat. As a result, reducing the amount of antibiotics used in livestock has become a priority within policy (O'Neill, 2016). The sheep industry is the largest livestock sector in the UK in terms of biomass (VMD, 2018), which makes it particularly important that any routine prophylactic use is carefully scrutinised. Prophylactic use of antibiotics refers to antibiotics that are used to prevent diseases. Although relatively little details are known about the precise quantities of antibiotics used on sheep farms, available data suggests low levels of total antibiotics are used in the sheep industry in comparison to in the other livestock sectors (VMD, 2019). On-farm records are challenging to collate as there is no central recording system at present. Veterinary antibiotic sales data can be difficult to interpret as many sheep farms also have a beef enterprise and the antibiotics may have been used in either species.

Antibiotics are used in the sheep sector commonly for the treatment or prevention of diseases of neonatal lambs such as colibacillosis (watery mouth) and septic polyarthritis (joint ill) (RUMA, 2017). Previous reports suggest that as many as 31-68% of UK sheep farms use antibiotics prophylactically in neonatal lambs (Douglas and Sargison, 2018; Lima et al., 2019).

Given the large proportion of farms in the UK using antibiotics prophylactically in neonatal lambs, this area that calls for stewardship and more responsible use of antibiotics. There are many resources available for farmers that focus on why the prophylactic use of antibiotics for neonatal diseases is in many cases unnecessary. For example, the 'Colostrum is Gold' social media campaign and the 'Better Returns' knowledge exchange publications provide information on alternatives to antibiotic use for prevention of neonatal disease (AHDB, 2015; RUMA, 2019a). Current "good practice" for prevention of neonatal disease includes providing sufficient colostrum to new born lambs through appropriate ewe nutrition (RUMA, 2019a). Additionally, farmers should practice good hygiene, which includes regular hand washing and disposable gloves. If lambing

indoors, navels should be treated, pens should be freshly bedded with clean straw and dry disinfectant or lime should be spread before re-bedding pens between ewes (AHDB, 2015). Antibiotics should only be used in the signs of illness. Yet, many farmers continue to administer antibiotics prophylactically to neonatal lambs (Lima et al., 2019). Research is required to understand sheep farmers' decision-making around this behaviour.

Most research on farmers' decision-making around antibiotic use have used observational research techniques such as interviews (Poizat et al., 2017; Golding et al., 2019, Doidge et al., 2020), focus groups (Coyne et al., 2014) or surveys (Brunton et al., 2012; Jones et al., 2015). Antibiotic use in agriculture could be considered a sensitive topic due to the public and media attention it receives, which may make it difficult to study farmers' true opinions on this issue. Farmers may be aware that using antibiotics for prevention is not considered "good practice" and this could result in social-desirability bias when faced with observational research techniques. Additionally, selection bias may be present, where farmers who are interested in antibiotic use are more likely to take part. It may be difficult to contact farmers who carry out undesirable behaviours and they may not be willing to take part in research and talk about their motivations or experiences (Elliott et al., 2005).

In Great Britain, 93% of households had access to the internet and 87% of adults used the internet daily or almost daily in 2019 (Office for National Statistics, 2019). Over two-thirds used social media and 63% used the internet to look up health-related information. This widespread internet use provides a wealth of information on people's opinions, motivations and behaviours; especially through platforms such as Facebook, Twitter, blogs and discussion forums, for example. To reduce issues with bias surrounding sensitive topics, online data from discussion forums has been used to investigate research topics such as male infertility (Hanna and Gough, 2016), drug use (Davey et al., 2012) and depression (Moore et al., 2016). Whilst in human medicine analysis of online discussion forums have been used to understand patients' decisions

around antibiotic use (Santer et al., 2017; Ghouri et al., 2019), there has been no such investigations in veterinary medicine to investigate farmers decisions.

The ethnographic approach of studying online forum communities is often coined "Netnography" (Kozinets, 2015). Online forums allow natural conversations to be observed without the involvement of a researcher. Thus, farmers may be able to express their opinion freely without any perceived judgement. Online discussion forums often form communities where users can share ideas, ask for advice and seek social support (Gill and Whisnant, 2012). This allows researchers to study the deeper motives, attitudes and experiences of a group of farmers who may not normally take part in observational research.

Whilst qualitative analysis can identify the textual meanings of online posts, quantitative analysis can be used to describe the content in a systematic manner by identifying general trends in behaviour, motivations or emotion. Natural language processing is often used to quantify the frequency of word categories within pieces of text (Tausczik and Pennebaker, 2010). Words can be spilt into two main types: function words, such as pronouns, articles and conjunctions; and content words such as adjectives, nouns and regular verbs. Researchers can make inferences from the frequencies of word categories, many of which have been shown to be correlated with different psychological processes. For example, the frequency of first person singular pronouns (e.g. I) was linked with depression (Holtzman, 2017) and the use of causal words (e.g. because) was linked with the emotional process of appraisal (Boals and Klein, 2005). Therefore, natural language processing can unearth the underlying emotions and psychological processes within text.

The combination of two methods of data analysis is called triangulation data analysis. Combining both qualitative and quantitative data analysis enhances the trustworthiness of the results (Renz et al., 2018). Furthermore, data analysis triangulation is useful as researchers can reveal findings that would not be shown using either method alone. Triangulation therefore strengthens the ability to interpret results and provides multiple perspectives of the topic being investigated (Renz et al., 2018).

The aim of this study was to use a combination of grounded theory and natural language processing to analyse internet forum posts to understand how farmers make decisions around using, or not using, prophylactic antibiotics in neonatal lambs. We believe this is the first time this combination of methods have been used to analyse farmer decision-making.

Methods

Study sample and data collection

One large UK based forum specifically related to agriculture was selected for this research. The forum is accessible to be read by non-members, but only members can create threads or reply to other users' posts. The forum was searched for the terms "watery mouth", "joint ill" and the name of an oral product that contains spectinomycin. This antibiotic product (active ingredient spectinomycin) was chosen as a search term as it is the most commonly used oral antibiotic for watery mouth. It is authorised for use in lambs and piglets in the UK, though the majority of search results were related to its use in lambs. The search results for other antibiotics commonly used in lambs, such as oxytetracycline, were not used as they are indicated for use in several species and for conditions other than those found in neonatal lambs. Threads identified were reviewed to determine those with relevant discussion of antibiotic use in neonatal lambs. The researcher remained a guest on the forum and did not register as a user, post on the forum or declare presence of a researcher to ensure data collection was unobtrusive.

Posts from threads based on weather and grassland management were also collected from the same forum. The grassland management and weather posts were used as control groups as they were unrelated to antibiotic use. These controls were chosen as they were both topics that sheep farmers have experience in and are likely to engage in. They offer two different types of discourse to compare with the antibiotic use threads. Previous research suggests that weather may have effects on farmers' mental health (Daghagh Yazd et al., 2019); therefore, it was anticipated that discussion of the weather

may have low emotional tone. Whereas, grassland management may require users to think analytically (Gibon, 2005). The control posts were gathered until the number of users were similar to that gathered for the study group.

Ethical considerations

This analysis follows the guidelines set out by the British Psychological Society on internet mediated research (British Psychological Society, 2017). The forums accessed for analysis did not require registration to view forum posts and were therefore located within the public domain. Forum users were instructed not to post any private or confidential information upon registering an account. As the posts were publicly available and did not contain private information, no steps to gain informed consent from those posting were taken. To ensure anonymity of forum users, any identifiable information about participants and forum sites was removed to maintain confidentiality (Tilley and Woodthorpe, 2011). In addition, to preserve anonymity quotes have been paraphrased and researchers took steps in terms of checking all quotes using a search engine to ensure they cannot be traced (Roberts, 2015). The study was approved by the University of Nottingham School of Veterinary Medicine and Science Ethics Committee (no. 3232 200915).

Qualitative data analysis: Grounded theory

A Grounded Theory approach was used for data collection and analysis (Glaser and Strauss, 1967). Forum threads were selected using the purposive theoretical sampling method, where new threads were identified throughout the data collection process. Ten threads were selected for analysis which included multiple threads on watery mouth prevention, joint ill and one thread on general lambing time for 2019. There were 431 posts from 133 different forum users. The forum posts dated from 2015 to 2019 and were accessed October 2019. The relevant threads and posts were copied onto a Microsoft Word document and uploaded into NVivo (NVivo qualitative data analysis Software; QSR International Pty Ltd. Version 12, 2018) to support analysis. Data were coded using the constant comparative method (Maykut and Morehouse, 1994). First,

initial coding was carried out where each discussion thread was read multiple times and relevant posts coded line by line. Then, focussed coding was carried out where clusters of data that were relevant to a particular interpretation were grouped together. Connections were made between codes to produce categories. Categories were reviewed and refined after analysis of each discussion thread until data saturation was achieved. The final categories were defined and related to each other to establish a theoretical concept (Charmaz, 2006). An explanatory theory for farmers' decision making around prophylactic antibiotic use in lambs was produced (Charmaz, 2006).

Quantitative data analysis: natural language processing content analysis

The programme Linguistic Inquiry and Word Count (LIWC) was used for the content analysis of the forum posts (Pennebaker et al., 2015a). LIWC analyses text by reading each target word and classifying it into various categories. The categories include general descriptor categories, linguistic dimensions (e.g. pronoun use) and psychological constructs (e.g. cognitive, social, and affective). The programme quantifies the relative frequency of words that belong to each category. There are also four summary variables that are based on a 0 to 100 scale using percentiles derived from large comparison samples (Pennebaker et al., 2015b). These variables are clout, analytical thinking, authenticity and emotional tone. An explanation of the LIWC variables used in this paper are presented in Table 1.

Table 1: LIWC variables used to address the research question (Adapted from Pennebaker et al. (2015b))

Variable	Explanation
Clout	Scored from 0 to 100 using percentiles. A high score reflects a more confident style, whereas a low score reflects a more tentative style.

Analytical thinking	Scored from 0 to 100 using percentiles. A high score reflects a more formal way of thinking and a low score reflects a personal, narrative style of thinking.
Authenticity	Scored from 0 to 100 using percentiles. A high score indicates an honest, personal style, whereas a low score indicates a guarded, distanced style.
Emotional tone	Scored from 0 to 100 using percentiles. This variable reflects the difference between the use of positive and negative emotion words. A high score indicates a positive tone and low score indicates a negative tone. Scores below 50 are suggestive of negative emotional tone (Cohn, Mehl, & Pennebaker, 2004).
Function words	Count of function words posted by a forum user e.g. it, to, not, very.
Conjunctions	Count of conjunctions posted by a forum user e.g. and, but, whereas.
Negations	Count of negations posted by a forum user e.g. no, not, never.
Cognitive processes	Count of cognitive process words posted by a forum user e.g. cause, know, ought.
Social processes	Count of social process words posted by a forum user e.g. mate, talk, they, child.
Risk words	Count of risk words posted by a forum user e.g. danger, doubt.
Money words	Count of money words posted by a forum user e.g. audit, cash, owe.

LIWC has been validated for numerous psychological domains (Tausczik and Pennebaker, 2010). Many psychological processes can be reflected in the way words are used. Function words (e.g. pronouns, conjunctions) have been shown to be more useful gauges for psychological processes than content words (e.g. verbs, adjectives and adverbs) (Pennebaker and Chung, 2013). For example, an increased use of function words was associated with negative events compared to positive events (Barnard et al., 2020).

The forum posts for each forum user were entered into an Excel spreadsheet where each user was a single row. The spreadsheet was imported into LIWC for analysis of the text. A group of forums posts based on the weather were included as a control group (n users weather=140). A further control group of posts based on grassland management was included (n users grassland=128). Users with <20 words were removed from the analysis (n(study)=22, n(weather)=47, n(grassland)=20). As the data were not normally distributed, the variable distributions for the study group were compared with the weather and grassland group using a Kruskal-Wallis test in Stata 16 (Stata SE/16.1, Stata Corp., College Station, TX, USA). Dunn's Test was used as a *post-hoc* test to identify differences between the three groups and p-value of <=0.05 was considered significant.

Integration of qualitative and quantitative results

For the assessment of the fit of the data, quantitative and qualitative results were presented in a table with the potential outcomes of convergence, complementarity, expansion and divergence. Convergence refers to when the results from the two methods are similar, whereas divergence is when the results from the two methods are different (Morgan, 2019). Complementarity refers to when the results are different and not over-lapping. Expansion is where the results have an overlapping theme but more information is gathered which gives non-overlapping interpretations (Fetters and Molina-Azorin, 2019).

Results

Qualitative analysis

Most threads were started by a farmer asking for advice as they had a problem with neonatal lamb disease, either watery mouth or joint ill. Other farmers were able to relate to the issue, having experienced something similar themselves and would give advice on what they would do in that situation. Often farmers would give opposing views on the matter, which resulted in debate over using antibiotics for prevention. The views for and against the prophylactic use of antibiotics given by the farmers showed that there were two opposing risks that they considered: (1) the risk of only using antibiotics for treatment in lambs and (2) the risk of using prophylactic antibiotics in lambs. The five major categories identified and their corresponding subcategories are presented in Table 2.

Table 2: The categories and sub-categories relating to farmers' decision making around antibiotic use in neonatal lambs identified from the qualitative analysis

Major category	Subcategory
Perception of social judgement	Influence of laws and restrictions
	Influence of consumers and animal rights
Economic considerations	-
Good farming identity	A good farmer doesn't need to rely on antibiotics
	Animal welfare is the priority
Perception of capability	Positive perceptions of capability
	Luck, fate and chance
	External factors restrict farmers' capabilities
Anticipated regret, negative emotions and experiential avoidance	-

Perception of social judgement

Influence of laws and restrictions

Many farmers raised concerns for the future if the prophylactic use of antibiotics carried on. Some farmers were worried that antibiotics would become restricted in the future if they were not seen to act responsibly. Others have stopped using antibiotics prophylactically as they were aware of the risks of not having access to antibiotics in the future. They often gave examples of other countries where antibiotics are more controlled and the vet must administer all treatments, such as Denmark. Farmers were afraid of this happening in the UK as it could result in poor welfare and farms shutting down:

> *"There will come a time when we buy antibiotics that it will have to be for a specific animal and the medicine records will be online with the animal ear tag against the purchase."*

> *"Routine, prophylactic antibiotic use is under pressure from governments and the EU. This will not be imposed by our vets but from above. For example, in the Netherlands vaccines have moved from general use to prescription only and so have to be administered by a vet."*

Farmers also mentioned that their vets were encouraging them to reduce their prophylactic antibiotic use. Those that took their vets advice managed to successfully get through a lambing period without any problems.

> *"My vet has been warning about restrictions to antibiotic for a while."*

> *"I lambed without antibiotics last year mainly because our vets told us to only use it if you get an issue."*

However, there were a group of farmers who did not feel compelled to follow their vets' advice. These farmers were more resistant to the social pressures around using antibiotic responsibly.

"I'll hold my hands up, I use it as a matter of course…My vet who does not agree with routine use of antibiotics allows me this small concession to his standard lecturing."

"My vets don't bother to give me the usual addressing on antibiotic resistance when I ask for it."

Influence of consumers and animal-rights

Some farmers appeared uneasy about others in the forum expressing a reliance on antibiotics for neonatal disease, for fear of what consumers may think. They thought that consumers would not buy lamb meat if they knew prophylactic antibiotic use in lambs was a common practice.

"How do you think that sounds to consumers? Don't forget you need them to buy your product."

"The industry needs to be seen to cut down antibiotic use."

Additionally, they were concerned that animal-rights activists could potentially use this information, which could be damaging to the sheep farming image of grass-fed, extensively reared lamb.

"The thought of eating early born lamb that has only survived its short life with overuse of antibiotics really puts me off lamb. I am sure most consumers think of lamb as being natural born and reared on grass. You are playing right into the animal rights activists' hands."

"I am surprised at the amount of blanket usage, are we potentially sitting on a time bomb regarding the image of lamb?"

As well as the social responsibility for appropriate antibiotic use, there appeared to be a moral responsibility where prophylactic antibiotic use was not seen as "doing the right thing". They believe that only using antibiotics responsibly in the sheep industry would be a good thing to do in the eyes of society

"Used to give everything an antibiotic pill, but stopped that years ago now as it didn't seem right doing it to everything."

"Used to do all lambs born indoors but knew in my head it couldn't be good long term."

"Routine use of antibiotics in lambs or ewes is not something that sits well with me."

In summary, this category highlights the concerns farmers have around the potential restrictions on antibiotic use in the future and how they felt a moral obligation for antibiotic stewardship. Farmers were worried about the impact on their image if consumers or animal rights activists were aware of others using antibiotics as a prophylactic. Farmers who use antibiotics as routine in their lambs appear resistant to the social pressures around antibiotic stewardship and were unwilling to adhere to their vets' advice.

Economic considerations around antibiotic use in lambs

Economic considerations were an important factor in the decision *not* to use prophylactic antibiotics. Some farmers were concerned about the financial consequences of antibiotic resistance in the long term if sheep farmers carried on routine treatment of lambs with antibiotics. A few farmers related this risk to their experiences of anthelmintic resistance, which has become a widespread problem for sheep farmers:

"We should approach antibiotic use at an individual animal level. It has got to be better economically and in slowing down resistance. Look where we are with anthelmintic resistance – ask anyone with triple resistance how hard it is to raise lambs."

"Anyone who has experienced resistant fluke will tell you it is nothing to look forward to."

They also considered the financial implications of antibiotic resistance due to untreatable infections or reliance on expensive antibiotics. They were concerned that other farmers were not thinking about the future:

> *"There has to be a balance, use cheap antibiotics now and make money until you get antibiotic resistance and the antibiotics no longer work. Then pay through the nose for more expensive new drugs or have to do without all together?"*

Economic considerations were often an important factor in the decision to use antibiotics prophylactically. It was seen as cheaper to use antibiotics than to lose a lamb to neonatal disease. Spectinomycin was seen as a particularly cheap antibiotic that was worth giving to all lambs "just in case" they needed it. Indeed, the cost of spectinomycin was considered much cheaper than the cost of other practices that prevent neonatal lamb diseases, such as lime or straw.

> *"If I waited until I lost a lamb to watery mouth I would be down [£X] minimum plus the bottle of antibiotics I would waste because nothing dies uncared for on my farm, versus the [£X] it costs to treat all my lambs."*

> *"I give antibiotics to every lamb without fail. It is cheap and effective."*

> *"I've used [X] bottles of spectinomycin in my early flock at around [£X] a bottle. You can't buy much extra lime or straw for that and I already use a lot of straw. If you were presented figures that show a big saving through using spectinomycin are you saying you would ignore that?"*

Farmers also stated prophylactic antibiotics prevented neonatal diseases which could be detrimental to the value of pedigree flocks. Also, there was indication that farmers had misconceptions about the effectiveness of oral antibiotics against all neonatal diseases as indicated below by using spectinomycin for joint ill.

> *"I use spectinomycin because my pedigree sheep would be left valueless if they got joint ill and cost me a lot of money if they died of watery mouth."*

Occasionally, because farmers could not afford to employ more staff around lambing, there were not enough members of staff to attend to lambs thoroughly, so antibiotics were used to reduce perceived risk. Some believed that if prophylactic antibiotics were not used, shepherding costs would increase so much that farming would not be viable.

> *"When you're on your own lambing sheep because of the financial side of the job, the weather is bad, you're tired and there aren't enough hours in the day it's quite different!"*

Overall, this category identifies that the economics of antibiotic use were considered both in the long-term and in the short-term. In the long-term, farmers were concerned about the increased costs due to antibiotic resistance, whereas in the short-term farmers were concerned about covering lamb losses and keeping their business afloat.

Good farming identity

This category centres on the perception of a conflict between two good farming identities. It highlights the importance of animal welfare in being a good farmer for both identities, but also the relative importance of low antibiotic use. Hence, there are two sub-categories: "A good farmer doesn't need to rely on antibiotics" and "Animal welfare is the priority".

A good farmer doesn't need to rely on antibiotics

With every post that suggested using antibiotics for the prevention of neonatal disease in lambs, there were farmers that argued against this practice. Being able to maintain good animal welfare whilst using antibiotics only when necessary were seen as traits of a good farmer. By contrast, it appeared those that were relying on prophylactic antibiotic use were seen to be compensating for suboptimal management practices. In response to others saying that methods to control neonatal disease were not practical, some farmers provided their own account of how they manage without antibiotics:

"We used to use spectinomycin but now we now focus on bedding, making sure lambs are dry and not in draughts, and feeding ewes to ensure colostrum is good. We are getting on better so far with better husbandry."

They also challenged other farmers' excuses for their reliance on antibiotics:

"We have straw sheds and lamb early and always have time to clean the pens."

Some farmers suggested changing routine management practices to prevent diseases in the first place. For example, a few users wrote about their experience of stopping tail docking and castration in which it reduced the number of lambs with joint ill. Ceasing this routine practice came as a shock to some of the other farmers suggesting that this would cause other welfare problems. Others began to contemplate whether the tail docking and ring castration they carried out was necessary. This suggested that the set of experience-based rules relating to tail docking in farming practice was gradually shifting.

"We used to get a lot of joint ill in lambs that were a couple weeks old at the time where their tails were dropping off so left a small wound for a few days. We stopped docking a few years ago and only get infrequent cases now."

"When we lamb outside we get no joint ill, especially if you don't ring. Is it something that still needs doing or will the time come when no one does it?"

Animal welfare is the priority

However, low antibiotic use was not the only good farming identity sub-category. Some argued that using antibiotics was better for the welfare of the animal – that prevention was better than cure. Having healthy lambs was important to them and they believed that this was what made them a good farmer:

"It all comes down to the issue of welfare. Is it right not to use spectinomycin and then the lambs get joint ill and have welfare issues, or is it better to prevent these welfare issues?"

"The public would be more disgusted to see images of tapeworms and fluke in offal, images of parasites in meat and images of starving lambs with watery mouth."

There were high emotions when farmers' who were using antibiotic prophylactically were confronted with other farmers suggesting that many cases of watery mouth or joint ill were caused by unhygienic conditions. Farmers would become defensive, as they felt insulted that other farmers were implying that their farm or sheep were dirty. This shows a conflict in good farming identities:

"The dirty comments from some of the [x] are a bit condescending. There are farms sparing on straw but there are many that always have sheds with fresh straw and still get problems."

"Wow, my sheep aren't dirty."

When one user asked how others used antibiotics over the lambing period there appeared to be a separation of spectinomycin – an oral antibiotic commonly used for treatment or prevention of watery mouth – from other types of antibiotics. It seemed as if the prophylactic use of spectinomycin was more acceptable than using other antibiotics that were injectable. Spectinomycin was used more liberally than parenteral (injectable) antibiotics. The use of spectinomycin had become a cultural norm and was part of the rules of the game that define their good farming identity. Thus, spectinomycin use did not harm their good farming identity but use of parenteral antibiotics could.

"Everything that lambs inside gets a dose of spectinomycin but other antibiotics are used rarely."

"Do you mean to take account of spectinomycin? We use spectinomycin in all lambs but other antibiotics are only used when needed."

"We only use spectinomycin regularly but always have [parenteral antibiotic] nearby. Some family members routinely inject lambs."

This category therefore illustrates the presence of two good farming symbols – one of good animal welfare and one of low antibiotic usage. The two symbols can conflict with each other and some farmers do not recognise responsible antibiotic use as a good farming symbol. The routine prophylactic use of spectinomycin appears to have become a cultural norm in sheep farming.

Perception of capability

Positive perceptions of capability

Farmers agreed that good hygiene and colostrum intake by lambs was the best way to prevent neonatal disease in lambs.

"A clean environment and plenty of good colostrum is the basic first defence."

"Plenty of colostrum trumps all. How many single lambs do you see go down with watery mouth? Not many."

"Get more soya included in the ration as it will improve the quality and quantity of colostrum. As long as the lambs get a belly full of colostrum soon after lambing they won't succumb to disease."

Farmers who did not use antibiotics prophylactically wrote about the practices that they implemented to prevent neonatal disease. They believed that farmers did not need to rely on antibiotics to prevent disease and urged other farmers to change their practices if they did so.

"I've not had a case this year. The only difference is nutrition, I'm feeding the most expensive ewe rolls and everything is great."

"We haven't used it for many years. Vaccinate ewes for clostridial diseases and feed them well for milk production before and after lambing. Make sure the lambs suck well early. Have ewe breeds that have a good maternal instinct, good lambers and produce lambs that want to suck."

"You need to change your system. We manage to clean out every [X] hours or between every other ewe... For an area of [X] ewes, I like to use a round bale of straw every other day. It might be excessive but our joint ill and scouring is under [X]%."

Farmers occasionally wrote about how they weaned themselves off using prophylactic antibiotics. These were farmers who had previously used antibiotics in all lambs and over the years reduced the numbers of lambs treated with antibiotics. Over time they have realised that they did not need to use antibiotics routinely and they are capable of preventing neonatal lamb disease without a reliance on antibiotics.

"I lamb indoors and used to use antibiotics on multiples starting part way through lambing. This year I have only dosed the triplets and only because I had some left in the fridge. Next year I will not use it unless there is a problem."

"We used to give antibiotics to all the multiples as we used to see a lot of watery mouth in our old barns and the practice continued when we got new barns. I decided to only use spectinomycin on weak lambs. It was effective as we did not get any cases and we did not use antibiotics routinely."

Luck, fate and chance

In some cases, farmers were frustrated as they felt they were following best practice and still ended up with ill lambs. They did not know how other farms could manage without having to use antibiotics around lambing time. In the cases where farmers seemed to be following good practice, getting incidents of neonatal lamb disease appeared to be attributed to chance. Often, farmers said that some farms can "get away" with not using

antibiotics, suggesting these farmers do not experience the disease because they have been lucky.

It is useful at this point to distinguish between luck, fate and chance (Ferguson and Cox, 1996). Fate refers to a sense that an event is predetermined, whereas chance is the probability of an event happening and is linked to uncertainty. Luck is somewhat more complex and relates to something that may be seen as a property of the person (an internal factor) or the context (it was luck that x happened), but luck can be balanced: I am a lucky/unlucky person, others are more or less lucky/unlucky compared to me or that was a lucky/unlucky event.

The quote below relates to some farmers being luckier than others. Success is determined by who you are.

> *"Some farmers may need antibiotics more than others, whereas others would get away with it. Sufficient colostrum has more to do with it than clean pens; you can be cleaning pens out after every ewe and still get it."*

Some farmers indicated than even with good management practices lambs can become ill and so use of antibiotics becomes the only option and is linked to the idea of chance and fate.

> *"Whatever system we use, whether we lamb outside, dip their navels, use antibiotics; I don't think we can ever be freed of this threat."*

> *"I hear other farms will get disease no matter what they do if they don't treat all lambs with antibiotics, and it's not down to them being dirty. The ewe carries it and it's in the shed from years of use."*

> *"I agree about trying to keep sheds dry and clean, but this disease will cause problems in flocks with good hygiene too."*

There was often the view that farms are not all the same and a practice that works for one farm may not work for another. There was a perception of 'uniqueness' on every

farm and farms could not be compared. Farmers needed to consider the area of their farm and season of lambing when controlling neonatal lamb diseases; again reflecting uncontrollable factors linked to fate or chance.

> *"You don't have to do anything wrong. One of my vets told me it depended what area you were in to a degree. With having sheep in different locations I could agree."*

> *"There is a lot of difference in the day lengths and dampness between December and March so you are not comparing like for like."*

Whilst most farmers appeared to be aware of the risks of antibiotic resistance through using antibiotics for prevention, many argued that the control measures such as cleaning out pens and putting down lime were not practical to implement. Again, this relates to uncontrollable events like the weather and again chance.

> *"I hear what he says but argue that practicality beats best practice when your livelihood is on the line."*

> *"In reality, when the weather is bad so you can't turn the ewes out and it's in the early hours of the morning and you're tired no one is going to be cleaning out pens."*

This argument for using prophylactic antibiotics over implementing control measures was particularly prevalent later in the lambing seasons, once fatigue had begun to set in:

> *"We didn't use iodine on all the lambs as fatigue and time were problems."*

> *"At this time of year we get more cases because E. coli is building up in the sheep and fatigue is taking its toll. We are not as observant in seeing triplets suck properly. From now on all triplets will get a shot of spectinomycin."*

External factors restrict farmers capabilities

There were times where farmers wanted to use best practice but were restricted by external factors. Farmers suggested that starting the lambing season later (around April

or May) provides a better environment for reducing disease burden due to more favourable weather. However, for a few farmers, the market demand meant that they have shifted their lambing time to "higher risk" periods of December and January when the weather is generally colder and wetter. This means ewes and lambs were more likely to be housed indoors, making it easier to transmit disease.

> *"The drive from the meat buyers to lamb from early autumn is increasing every year and they are putting forward good contracts to anyone who is prepared to do so."*

> *"We lamb early because our contract tell us when lambs are required for the supermarket. We are producing for public demand rather than for the sake of it."*

The low profit margins for sheep meant that farmers were rearing larger flocks without an increase in employment which puts strain on their capability to manage hygiene with sheds at busy periods.

> *"I can see why those lambing a lot of sheep see spectinomycin as sensible insurance."*

For those that were still farming on a small scale, every lamb loss had a massive impact on productivity.

> *"I would ask whether [X] ewes would ever be worth the energy"*

> *"I only have a handful of lambs born compared to many farms, so one ill lamb is too much."*

Market demand also meant that some management practices that could potentially reduce disease were not taken up. For example, one farmer stated that although castrating lambs may result in more joint ill cases, they need to castrate ram lambs otherwise their abattoir would not take them.

> *"The testicles – many abattoirs don't want to see them unless we nip them at weaning which leads to extra stress on the animals."*

Additionally, some farmers with joint ill problems were aware of a vaccine for a particular causative agent, *Erysipelothrix rhusiopathiae,* which was available for pigs. However, because it is not licenced for use in sheep in the UK, they were refused prescription by their vet. *Erysipelothrix rhusiopathiae* is not the most common cause of joint ill in lambs in the UK, but is most commonly associated in older lambs, with outbreak situations and after tail docking or castration (Lloyd et al., 2016; Opriessnig et al., 2020).

> *"I've begged for the Erysipelothrix but the vet won't let me have it."*

> *"What are the legalities of the Erysipelothrix vaccine? My vet won't let me have it but he lets me have other drugs off label. Why is the vaccine different?"*

Overall, this category highlights that there are many farmers who believe they are capable of preventing neonatal disease through maintaining hygiene and optimal colostrum quality without routine prophylactic use of antibiotics. It also highlights that there are many barriers towards perceiving this capability. Farmers believed that neonatal disease is partly down to luck, fate or chance that they had no control over the disease, and that at the peak of lambing they were too tired or did not have enough time to carry out the desired management practices. External factors such as market demand and vet restrictions exacerbated this perception of lack of capability which influences the routine use of antibiotics in neonatal lambs.

Anticipated regret, negative emotions and experiential avoidance

This final category centres on the negative emotions experienced at lambing time. These emotions are linked to the concept of anticipated regret, that the farmer knows they will regret it in the future if they do not act now. That is people are regret averse and thus work to avoid actions that will induce regret (Loomes and Sugden, 1982).

The emotional strain of having animals die from diseases that are seen as preventable affected farmers decision to treat lambs with antibiotics. Sometimes they have tried to avoid routinely using antibiotics prophylactically at lambing time in the past but due to

bad experiences have resorted back to this use. The use of routine prophylactic antibiotics was an act of experiential avoidance - an attempt to avoid uncomfortable thoughts, feelings, experiences or memories (Hayes et al., 1996). They learn to cope with the bad experience by controlling or avoiding it through routine prophylactic antibiotic use.

> *"The allow your flock to evolve [without antibiotics] argument almost broke me – both financially and mentally – when it killed [x] percent of my lambs in 48 hours a few years back. Best practice is an aspiration but surviving is a necessity."*

There was even a case when an outbreak not related to bacterial diseases, nematode infection, spurred the use of blanket prophylactic antibiotic use in lambs. The farmer wanted to ensure lambs were not dying from preventable disease because of the negative emotions they had previously felt.

> *"We had something similar with nematodirus a few years ago, never again do I want to feel like that so we do the same [give spectinomycin to all lambs]."*

Occasionally, farmers said that they used antibiotics in all of their lambs because if they did not use antibiotics then the lambs would die. Consequently, the use of antibiotics was a matter of life or death. To them, lambs becoming ill was inevitable if they did not routinely use antibiotics prophylactically. They were confident that prophylactic antibiotics played an important role in their disease prevention and anticipated that they would get neonatal disease if they did not use antibiotics.

> *"If early lambing flocks can't use spectinomycin then it will mean increased use of other drugs to treat lambs once they become infected."*

Thus, antibiotics were used in an attempt to minimise contact with unpleasant experiences and provide instantaneous relief. Often, the immediate effects of experiential avoidance are positive (Hayes et al., 1996). Indeed, the lack of lamb deaths or cases of neonatal disease after the routine use of prophylactic antibiotics provided a

612 short-term positive effect and reinforcement for the behaviour, even though doing so
613 may create harm in the long run (Hayes et al., 1996).

614 *"I have used spectinomycin for the first time and I haven't any cases of joint ill*
615 *for the first time in years. It provides comfort."*

616 The routine use of prophylactic antibiotics to avoid neonatal disease - and the negative
617 emotions attached to it - prevent farmers from having experiences which challenge their
618 perceptions of how these diseases can be controlled. That is, the underlying problem
619 around neonatal disease control does not get resolved which exacerbates a long-term
620 reliance on antibiotics.

621 *"I have used oral antibiotics for years and it's great if you do it shortly after*
622 *lambing…if I skip a lamb they usually get watery mouth."*

623 *"I never looked back after using oral antibiotics."*

624 In some cases, farmers started using antibiotics prophylactically with their vet's
625 recommendations due to an outbreak on the farm. After this, farmers continued
626 prophylactic use in subsequent years, suggesting a new reliance on antibiotics. The use
627 of antibiotics was initially used as a useful short-term strategy to avoid the problem of
628 neonatal disease but then became a generalised and inflexible pattern of behaviour.

629 *"We usually only had a handful of cases each year which was manageable. A few*
630 *years ago, half way through lambing many lambs went down with joint ill. A third*
631 *had to be put down, as there was no improvement. That year and ever since, we*
632 *have given Betamox at 24 hours old and we haven't had a case since."*

633 This final category therefore illustrates that farmers often anticipate negative
634 consequences if they do not routinely use antibiotics in their lambs. This is sometimes
635 spurred by previous experiences and the negative emotions surrounding this. Farmers
636 use antibiotics to avoid feelings of regret and minimise distress.

A Theoretical Framework for farmers' decision making around prophylactic antibiotic use in lambs

Through consideration of the results, a theoretical framework was produced to depict the constructs that act upon sheep farmers' perception of risk around the prophylactic use of antibiotics in their lambs (Figure 1). Their perceptions of risk consequently influences the farmers' behaviour to either routinely use antibiotics prophylactically or use antibiotics only for treatment. Economic considerations, good farming identity, and perception of capability influence both the perception of risk around treating lambs with prophylactic antibiotics and the risk around *not* treating lambs with prophylactic antibiotics. Anticipated regret, negative emotions and experiential avoidance influences the perception of risk around not treating lambs with prophylactic antibiotics. Whereas perception of social judgement influences the perception of risk around treating lambs with prophylactic antibiotics. Economic considerations and perceived capability influence each other as the external perceptions of capability are caused by market demand.

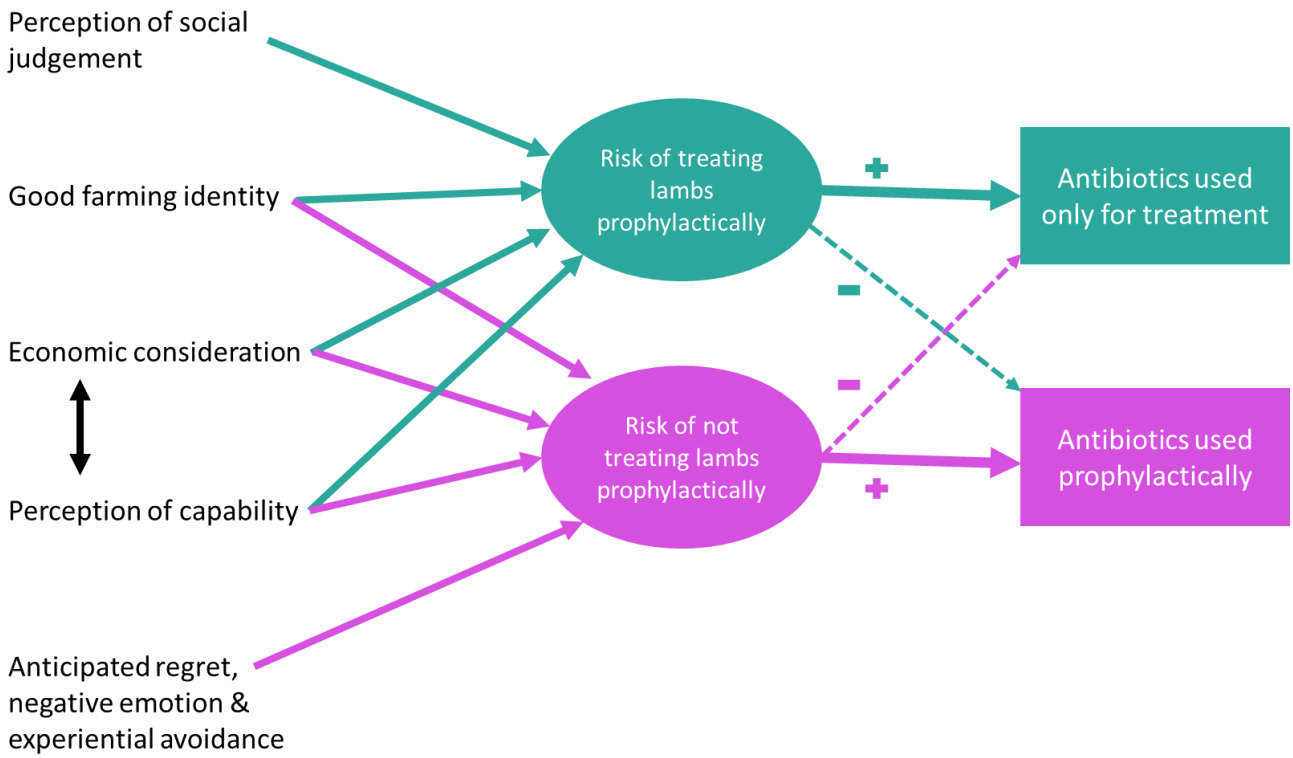

Figure 1: ***(Intended to be reproduced in colour on the Web (free of charge) and in black-and-white in print).*** *Theoretical framework based on grounded theory analysis for the prophylactic use of antibiotics in neonatal lambs. The pink (**light grey in print version**) arrows refer to factors relating to the perception of risk around not treating lambs prophylactically. The blue-green (**dark grey in print version**) arrows refer to factors relating to the perception of risk around treating lambs prophylactically. Plus signs indicate a positive influence on the outcome and minus signs indicate a negative influence on the outcome.*

Quantitative analysis: Natural language processing content analysis

The scores for analytical thinking and authenticity were significantly lower in the study group compared to the control groups ($P<0.01$) (Table 3). Although there was no significant difference between groups for emotional tone, the score of emotional tone was below 50 suggesting greater negative emotional tone in the study group.

Table 3: Mean and median scores for the four summary language variables in the study group and the control groups, and the results from the Kruskal Wallis test and post-hoc Dunn's test

	Neonatal disease (N=111)		Grassland (N=108)		Weather (N=93)		P	Dunns test
	Mean	Median (IQR)	Mean	Median (IQR)	Mean	Median (IQR)		
Analytical thinking	61.87	65.26 (48.92-79.61)	68.40	70.61 (56.34-83.57)	73.30	82.37 (61.17-93.26)	<0.01	EP
Clout	48.77	49.17 (33.19-66.17)	48.88	50.00 (30.55-66.19)	47.27	46.55 (32.99-60.66)	0.81	-
Authenticity	47.46	48.27 (26.45-65.58)	61.77	65.74 (39.44-88.90)	73.94	85.21 (64.56-93.70)	<0.01	EP
Emotional tone	42.85	37.41 (25.77-66.06)	51.55	47.90 (25.77-79.34)	51.71	51.03 (25.77-80.64)	0.07	-

EP= probabilities were different within each pair of forums groups

The relative frequencies of word categories for the study group (neonatal disease) and the two control groups (grassland and weather) along with the results for the Kruskal Wallis test with the post-hoc Dunn's test are presented in Table 4.

673 **Table 4: Median and median relative frequencies of words used in the study group and**

674 **control groups, and the results on the Kruskal Wallis test with post-hoc Dunn's test**

	Neonatal disease (N=111)		**Grassland (N=108)**		**Weather (N=93)**		**P**	**Dunns test**
	Mean	**Median (IQR)**	**Mean**	**Median (IQR)**	**Mean**	**Median (IQR)**		
Function words (e.g. it, to)	51.30	51.63 (48.48-54.63)	51.17	50.88 (47.48-55.06)	46.37	45.95 (42.86-50.80)	<0.01	W-G W-N
Conjunctions (e.g. and, but)	6.95	6.90 (5.56-8.24)	5.99	6.07 (4.52-7.55)	5.43	5.17 (3.77-6.98)	<0.01	W-N G-N
Negations (e.g. no, not)	2.15	2.11 (0.96-2.92)	1.72	1.58 (0.00-2.76)	1.21	0.93 (0.00-2.17)	<0.01	EP
Cognitive processes (e.g. cause, know)	14.55	13.38 (11.30-17.95)	11.72	11.18 (9.05-14.00)	8.09	8.57 (4.88-10.19)	<0.01	EP
Social processes (e.g. mate, talk)	5.90	5.59 (3.57-8.16)	5.67	4.79 (3.03-7.81)	3.20	2.78 (0.00-4.61)	<0.01	W-G W-N
Risk words (e.g. danger, doubt)	1.21	0.81 (0.00-1.82)	0.47	0.00 (0.00-0.49)	0.52	0.00 (0.00-0.51)	<0.01	W-N G-N

Money words (e.g. cash, owe)	0.65	0.00 (0.00-0.91)	0.56	0.00 (0.00-0.85)	0.30	0.00 (0.00-0.00)	<0.01	W-G W-N

W-N= probabilities were different within the weather group and the neonatal lamb group, G-N= probabilities were different within the grassland group and the neonatal lamb group, W-G= probabilities were different within the weather group and the grassland lamb group, EP= probabilities were different within each pair of forums groups

Integration of the quantitative and qualitative analysis

To integrate and report the results of the qualitative and quantitative analysis, a cross tabulation of results is presented in Table 5. The possible outcomes of convergent, complementarity, expansion and divergent results were assessed (Fetters and Molina-Azorin, 2019; Morgan, 2019). These are considered in detail in the discussion section.

685 **Table 5: Assessment and integration of qualitative and quantitative results to**

686 **understand farmers' decision making around routine prophylactic antibiotic use in lambs**

	Qualitative results	Quantitative results
Convergent results	The decision making is based on the consideration of two opposing types of risk: (1) the risk of not treating lambs prophylactically with antibiotics and (2) the risk of treating lambs prophylactically with antibiotics.	Frequency of risk words (e.g. danger, doubt) was significantly higher in the study group compared to both control groups.
	Economic pressures were considered for both types of risk.	Frequency of money words was significantly higher in the study group compared to the weather control group.
	Feelings of regret around not treating neonatal lambs prophylactically with antibiotics puts emotional strain on the farmer.	Frequency of cognitive processes words was higher in the study group compared with the control group. Frequency of negations was higher in the study group compared with the control group. Emotional tone score was below 50 in the study group.

	Farmers who used antibiotics only for therapeutic treatment in lambs felt a social and moral responsibility for appropriate antibiotic use.	Frequency of conjunctions and negations were higher in the study group compared with the control group.
Expansion results	A farmers' perceived capability can influence their perception of risk relating to antibiotics.	Frequencies of cognitive processes words, conjunctions and negations were significantly higher in the study group compared to control groups.
	Farmers who used antibiotics only for therapeutic use in their lambs were influenced by social judgements.	Scores for authenticity were significantly lower in the study group compared to the control group.
	Farmers justified their prophylactic antibiotic use through concepts of luck and uniqueness.	Analytical thinking scores were significantly lower in the study group compared to the control groups.
	There were conflicting perceptions of the good farming identity.	Frequencies of cognitive processes words, conjunctions and negations were significantly higher in the study group compared to control groups.

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Discussion

To the authors' knowledge, this is the first paper to use natural language processing (NLP) content analysis to understand farmers' opinions around antibiotic use. Additionally, it is the first study in the veterinary field to integrate quantitative NLP data with qualitative data. The benefits of data analysis triangulation were of increased validity and completeness of the results and further insights into farmers' decision making process. For example, perception of risk was identified in the qualitative analysis as an important factor influencing antibiotic use behaviour. Analysis via NLP analysis showed convergent findings with an increased frequency of risk focus words when farmers were writing about antibiotic use for neonatal disease compared to the control groups.

The use of data triangulation allowed the generation of more meaning from the data and therefore enhance the inferences made from the data. Whilst the qualitative analysis presented what was being said by the farmers, the quantitative analysis uncovered the underlying style and tone of the text. For example, social judgement was identified as an influence of risk perceptions in the qualitative analysis and the NLP analysis expanded this interpretation by identifying a guarded and distanced tone within the text. Furthermore, data triangulation meant that more findings were identified than would be possible using either method alone. The conflicting good farming identities requires an in-depth understanding of the farmers values and experiences that can be achieved through qualitative analysis. The good farmer identities would unlikely to have been established in this research if NLP analysis was used alone.

This analysis showed that farmers were undertaking two types of risk assessment: (1) the risk of using antibiotics only for treatment and (2) the risk of routine use of prophylactic antibiotics in lambs. Key findings of this study include the disassociation of oral antibiotics from other types of antibiotics within the sheep farming field and the role

of luck and uniqueness on farmers' perceptions of capability. These findings are discussed within the categories below.

Good farmer identity

How the farmer perceives their identity plays a key role in whether they routinely use prophylactic antibiotics in all lambs or not. In both situations, farmers are trying to 'do a good job' (Zinn, 2017). There were a high frequency of cognitive process words, conjunctions and negations in the study group compared with the control groups which reflect high cognitive complexity (Tausczik and Pennebaker, 2010). Cognitive complexity is a marker of debate such as recognising conflicting goals or alternative viewpoints (Brundidge et al., 2014; Wyss et al., 2015). Therefore, the high cognitive complexity may be due to the debates around the conflicting good farmer ideals surrounding antibiotic use.

'Good farming' draws on Bourdieu's concepts of cultural capital, habitus and field (Bourdieu, 1984; Bourdieu and Richardson, 1986). The cultural capital refers to the symbols of social status. Embodied in cultural capital is habitus, which is the skills, habits and dispositions engrained through experience. The field refers to the particular sector in the social world that have their own set of rules to achieve cultural capital; sheep farming could be seen as its own 'field'. Good animal welfare is a recognised and accepted symbol of 'good farming' by farmers (Bellet, 2018), but responsible antibiotic use may be a relatively new symbol that not every farmer has recognised yet.

The concepts of habitus and field may play a role in normalisation of routine prophylactic antibiotic use in neonatal lambs. Farmers disassociated the use of oral antibiotics for prevention from other types of antibiotic use such as parenteral antibiotics, where oral antibiotic use was seen as more acceptable. This shows that using oral antibiotics was considered a normal part of lambing time, and developed into a cultural norm. However, the rules of the game within the field of sheep farming are still developing and some farmers have started to question this practice. The cultural capital achieved through not routinely using antibiotics prophylactically was a particular influence for those that see

responsible antibiotic use as a good farming symbol. These farmers have accumulated capital through perceived approval from people other than farmers, such as their veterinarian, consumers and policy makers. In other words, they have observed the injunctive norms surrounding antibiotic use. This has allowed them to develop a new good farming symbol that incorporates both good animal welfare and responsible antibiotic use.

The study also highlights how the rules of the game can change and how new good farming symbols can be established. It also shows how habits can be broken, and that use of prophylactic oral antibiotics around lambing time can become 'de-normalised'. Some farmers talked about gradually reducing the use of prophylactic antibiotics over time and realising that this did not have any negative consequences. Through learning and routinizing the practice of not using prophylactic antibiotics, their concept of what is considered risky shifted. As they gradually reduced their prophylactic use, they learnt that this risk of not using prophylactic antibiotics in their lambs is not as high as expected. Through this gradual exposure, they were re-learning that there was a one to one link between not using antibiotics prophylactically and good outcomes.

Economic constraints and the impact on perceived capability

The economics of prophylactic antibiotic use was considered on both sides of the risk argument. Words related to money were used more frequently in the study group compared to the weather control group. The qualitative analysis revealed that in the short term the use of antibiotics for prevention of disease was thought to reduce production losses. However, in the long term, a reliance on cheap antibiotics may cause antibiotic resistance and therefore a need for more expensive antibiotics or even lamb deaths. As antibiotic resistance is perceived as an issue which will be encountered long into the future, some farmers consider this to be less important than the challenges they face in the present (temporal discounting). Farmers may value the present certainty of healthy lambs more than the uncertain future positive effect of preventing antibiotic resistance.

There were also external economic constraints impacting on the way in which farmers carried out management practices, which in turn could affect the levels of disease in the flock. Sheep farms typically have a much lower business income than other types of farming in the UK such as dairy, poultry and arable (DEFRA, 2019). Much like in lower income countries, sheep farmers are restricted by economic and biological margins which may result in reliance of antibiotics (Hinchliffe et al., 2018).

These external economic constraints of sheep farming were shown to impact farmers' perceptions of being able to control neonatal disease. Although all farmers recognised that good hygiene practices may prevent neonatal disease, these were often seen as not practical to always implement. Thus, at the height of lambing season, farmers may lose the psychological or physical capacity or capability to engage in good hygiene practices; turning to prophylactic antibiotics to regain control over the situation. Capability is one of three necessary conditions for a volitional behaviour to occur (Michie et al., 2011). In the quantitative analysis, a significantly higher amount of cognitive words, conjunctions and negations highlight that farmers' cognitive load is higher which may impact their psychological capacity (Tausczik and Pennebaker, 2010).

However, there were cases where not all of the credit for preventing neonatal disease was attributed to the farmers' ability. Some farmers expressed that having healthy lambs without using antibiotics was not solely credited to the farmers' skill but also to luck. We show that farmers clearly distinguish between fate, chance and luck. Some farmers were seen as just unlucky and this indicates that for them, interventions are less likely to be perceived as effective as they attribute negative outcomes to their bad luck. Likewise, if farmers believe that diseases are due to chance – and thus uncontrollable – then it is much harder to convince them that change in behaviour or policy will make a difference.

There was also another related concept of a farms 'uniqueness' that emerged. Farmers may be equally skilled but the uniqueness of their farm might mean they are not as capable to prevent neonatal disease. The perception of uniqueness on sheep farms has

already been reported by Kaler and Green (2013). They suggest that a lack of records and on-farm data collection adds to this perception of uniqueness, as farmers are not able to compare each other. Indeed, this might also be the case for sheep farmers' comparisons of antibiotic use as there is currently a lack of data around antibiotic use in the sheep sector (RUMA, 2019b; Doidge et al., 2020). This perception of uniqueness of every farm could possibly explain why the scores for analytical thinking were lower in the study group compared with the control groups (Pennebaker et al., 2014).

Anticipated regret, negative emotions and experiential avoidance

There was a largely emotional element to motivation for the prophylactic use of antibiotics identified in the current study, a construct not widely researched or reported in farmer decision making. Previous experiences, where lambs have died as a result of potentially preventable diseases such as watery mouth and joint ill were leading to such emotional motivation. This is an example of volition in risky behaviour (Nordgren et al., 2007). The choice to use or not use antibiotics prophylactically in lambs is a voluntary risk. Therefore, if a negative outcome occurs because the farmer has chosen not to use antibiotics prophylactically, the farmer will feel personally responsible for the deaths and this leads to regret. Farmers can anticipate the threat of regret, which leads to reduced tendency for risky behaviour. The risky behaviour in this case is not using antibiotics for prevention of disease in lambs.

Farmers attempted to avoid the negative experiences and feelings associated with preventable neonatal disease through the use of prophylactic antibiotic use, which could be an example of experiential avoidance (Hayes et al., 1996). Experiential avoidance has been linked to certain behaviours such as poor physical activity, as well as various forms of psychopathology, for which interventions such as exposure therapy may overcome (Kashdan et al., 2006; Newman and Llera, 2011). In exposure therapy, patients are exposed to the feared emotional stimuli in a graduated manner. The exposure could be to an object, situation, or activity. For farmers with experiential avoidance, the exposure would be to the distressing situation of not using antibiotics prophylactically in their

lambs. We are not suggesting there is a direct linkage in our study population with this construct, but it raises the possibility of its role and especially techniques such as exposure therapy that could to be used for changing behaviour of routine prophylactic use. In our study, we saw accounts of farmers gradually reducing their antibiotic use over their lamb crop to successfully discontinue their habitual prophylactic use of antibiotics without causing excessive distress to the farmers. This has similarities with exposure therapy as farmers were progressively exposed to the fears and worry of not using antibiotics prophylactically. This may be an effective strategy for behaviour change that could be investigated in the future.

There was also a lower emotional tone score for the study group compared with control groups which suggests a negative emotional state. Other word categories within the LIWC dictionary may be additional identifiers of a negative emotional state. For example, use of negations was negatively correlated with indicators for positivity (Hancock et al., 2007; Pang et al., 2020). The high frequency of negation words used by contributors in the neonatal lamb threads may be indicative of their low mood due to anticipated regret.

Perception of social judgement

Farmers who did not use antibiotics for prevention in their lambs were aware of the social implications around the risk of antibiotic overuse. For these farmers, the motivation for limiting antibiotic use was their perceived judgement from society. The farmers also felt a moral responsibility to ensure they were using antibiotics appropriately. When people describe pursuing a duty or something they ought to do, they use more exclusive words such as negations and conjunctions (Vaughn, 2018). Therefore, the high frequency of conjunctions and negations in the neonatal lamb posts could be explained by farmers' feelings of social or moral duty around their antibiotic use.

The farmers appeared aware that the forum was publicly available and were concerned that members of the public could see other farmers expressing a reliance on antibiotics. This may be one of the reasons why the scores for authenticity were lower for the study

group compared to the control groups. The lower score suggests a more guarded discourse, perhaps because of the farmers' fear of social judgement.

Farmers who used prophylactic antibiotics in their lambs were perhaps less susceptible to the social pressures around reducing their antibiotic use. They avoided or dismissed conversations around antibiotic use with their vets. Previous studies have shown that promoting disease prevention to farmers can be difficult for farm vets (Ruston et al., 2016). For farmers who are not susceptible to social pressures, it may be useful to target the other constructs identified in this study, such as experiential avoidance and perceived capability, to improve their antibiotic stewardship.

The use of data from online forum posts means that the study findings were restricted to farmers with internet access who were aware of the farming-based discussion forum. The demographics of farmers in this study were unable to be obtained. The naturalistic, unobtrusive approach to data collection meant there was an inability to ask for elaboration or clarification of points made by forum posters. However, this approach was likely to result in less social desirability bias than interview or survey data collection methods.

Conclusions, Research and Industry Implications

This study used method triangulation of discussion forum posts to understand farmers' decision making around prophylactic antibiotic use in lambs. Farmers must consider two opposing risks in the decision to use antibiotics in neonatal lambs: (1) the risk of only using antibiotics in neonatal lambs for the treatment of disease and (2) the risk of routinely treating lambs with prophylactic antibiotics. These risks were influenced by their economic considerations; perception of social judgement; perceived capability; anticipated regret, negative emotions and experiential avoidance; and their good farming identity.

In terms of research implications, the study presented reasons why farmers perceived risks of not treating lambs with antibiotics as high, which included some previously identified constructs such as lack of psychological or physical capacity or capability to control neonatal disease, and economic constraints. Constructs relating to concepts of luck and uniqueness mean that farmers may not adhere to best practices for the prevention of neonatal disease. This suggests that farmers need personal advice on their antibiotic use rather than relying on the sector-wide information sources that are currently available.

On the other hand, the research also provides evidence of how farmers have successfully stopped their prophylactic use habits. Gradual exposure to more responsible antibiotic use during lambing time may help to counteract farmers' experiential avoidance. Additionally, the research shows that judgement from consumers and authorities was an important factor in these farmers perception of risk around using antibiotics prophylactically. Appropriate or responsible antibiotic use was an important part of their identity as a good farmer. Prophylactic antibiotic use could be reduced through developing an increased recognition of appropriate antibiotic use as a symbol of good farming. For successful behaviour change, it is particularly important to de-normalise the use of prophylactic antibiotics around lambing time as there is a currently a disassociation of oral antibiotics from other types of antibiotics within the sheep farming field. These results can be used to inform knowledge exchange and intervention strategies around prophylactic antibiotic use in lambs to improve antibiotic stewardship in the sheep farming sector.

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Declaration of interest

Declarations of interest: none

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