Master of Public Health

Master de Santé Publique

Exploring veterinarians' behaviors relating to antimicrobial use in companion animals using the COM—B model of behavior change: A qualitative study

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Acknowledgements

Completing a master in public health has been one of the most challenging experiences of my life so far. Exactly one year ago, it was difficult for me to imagine that I was going to be able to finalize my thesis by now. The path that has brought me here has been full of learning and rewarding moments, but also obstacles and frustrations that are always part of a growing experience. Yet, today, I couldn't be more satisfied with the journey behind me and the final achievement, which would have not been possible without the support of the people around me.

To my supervisors, Ana Luisa Pereira Mateus and Aymery Constant, for their kind support through this journey. This is the first time I work on a thesis, and you were there to guide me step by step, provide me the needed information and help me progress on my research.

To Lucy Hogan, for kindly proofreading my English and making suggestions to improve its clarity.

To my managers and colleagues at the Communication Department of the World Organisation for Animal Health, for their patience and back-up. Studying and working at the same time was demanding, yet I consider myself fortunate that you were there to support my decision, schedule meetings to accommodate to my availability, and cover often for my workload.

To my friends and family, for always believing in me. How important it was for me to receive your encouragement and love over this period.

To my dad, who saw me starting this master, but can't see me finalizing it. I miss you every day but I know that, somewhere, you are celebrating with me.

To all of them, thank you.
A todos ellos, mis gracias infinitas.

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List of acronyms

AMR	Antimicrobial resistance
AMU	Antimicrobial use
BVA	British Veterinary Association
BSAVA	British Small Animals Veterinary Association
CPD	Continuing professional development
DDDVet	Defined daily doses for animals
EC	European Commission
EPRUMA	European Platform for the Responsible Use of Medicines in Animals
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FECAVA	Federation of European Companion Animal Veterinary Associations
FVE	Federation of Veterinarians of Europe
GAP	Global Action Plan
HP-CIAs	Highest-Priority Critically Important Antibiotics
HSE	Health and Safety Executive
IQ	Interview question
IVSA	International Veterinary Students Association
MRS	Methicillin-resistant *Staphylococcus*
MRSA	Methicillin-resistant *Staphylococcus aureus*
MRSP	Methicillin-resistant *Staphylococcus pseudintermedius*
NOAH	National Office of Animal Health
OHHLEP	One Health High-Level Expert Panel
PAW	PDSA [People's Dispensary for Sick Animals] Animal Wellbeing
RCVS	Royal College of Veterinary Surgeons
R&D	Research and development
SAMSoc	Small Animal Medicine Society
TDF	Theoretical Domains Framework
UK	United Kingdom
UTI	Urinary tract infection
VMD	Veterinary Medicines Directorate
WHO	World Health Organization
WOAH	World Organisation for Animal Health (founded as OIE)
WSAVA	World Small Animal Veterinary Association

Abstract

Background: Misuse and overuse of antimicrobials in different sectors, including companion animals, can accelerate the development of antimicrobial resistance (AMR), one of today's most urgent global health challenges. Considering the role of veterinarians in the provision of animal care, it is important to understand the factors that impact on their behaviors when using antimicrobials. Such work can lead to the development of targeted and effective behavior change interventions, which are more likely to promote responsible antimicrobial use (AMU) in companion animals.

Objective: The aim of this study is to analyse the factors which are most likely to influence responsible AMU behaviors in companion animal veterinarians working in the UK.

Methods: A qualitative study was conducted; 13 in-depth one-to-one interviews were performed in early 2023 with companion animal veterinarians working in any kind of practice in the UK. A thematic analysis was undertaken following both a deductive and inductive approach. The identified themes and sub-themes were mapped to the TDF domains and COM-B model, which are theoretical frameworks of human behavior.

Results: This study identifies barriers and enablers influencing responsible AMU of companion animal veterinarians. Barriers identified include: the lack of adequate training, ease of administration of the different formulations, pressure from companion animal owners or employers, fear of the consequences of not prescribing antimicrobials, and the need to educate companion animal owners on AMR and responsible AMU. Factors acting as enablers of responsible AMU include: veterinarians having a good understanding of AMR and its consequences, acknowledging their role in this global health challenge, receiving positive peer support, and having access to information and alternatives to antimicrobials. The type of practices and its policies, as well as the access to laboratory testing and concerns for animal welfare could act either way as a barrier or as a driver depending on the context and specific situation.

Conclusion: Applying the theoretical frameworks to understand behaviors has revealed opportunities for empowering veterinarians' involvement in supporting responsible AMU. The factors and recommendations presented in this research have positive implications as they could be used to identify interventions for promoting responsible AMU in the future.

Keywords: antimicrobial resistance, antimicrobial use, veterinarians, companion animals, One Health, COM-B model, TDF domains, behaviors.

Résumé

Contexte : La mauvaise utilisation et la surutilisation des antimicrobiens dans différents secteurs, y compris les animaux de compagnie, peuvent accélérer le développement de la résistance aux antimicrobiens (RAM), l'un des défis de santé mondiale les plus urgents aujourd'hui. Compte tenu du rôle des vétérinaires de dispenser des soins aux animaux, il est important de comprendre les facteurs qui influencent leur comportement lors de l'utilisation d'antimicrobiens. Ce travail peut conduire à l'élaboration d'interventions ciblées et efficaces en matière de changement de comportement, promouvant une utilisation responsable des antimicrobiens chez les animaux de compagnie.

Objectif de l'étude : L'objectif de cette étude est d'analyser les facteurs les plus susceptibles d'influencer les comportements d'utilisation responsable des antimicrobiens chez les vétérinaires d'animaux de compagnie travaillant au Royaume-Uni.

Méthodes : Une étude qualitative a été menée ; 13 entretiens individuels approfondis ont été réalisés au début de l'année 2023 avec des vétérinaires pour animaux de compagnie travaillant dans tout type de clinique au Royaume-Uni. Une analyse thématique a été entreprise selon une approche à la fois déductive et inductive. Les thèmes et sous-thèmes identifiés ont été mis en correspondance avec les domaines du TDF et le modèle COM-B, qui sont des cadres théoriques du comportement humain.

Résultats : Cette étude identifie les obstacles et les catalyseurs qui influencent l'UAM responsable des vétérinaires d'animaux de compagnie. Les obstacles identifiés comprennent : le manque de formation adéquate, la facilité d'administration des différentes formulations, la pression et la crainte des conséquences de la non-prescription d'antimicrobiens, ainsi que la nécessité d'éduquer les propriétaires d'animaux de compagnie sur le sujet. Les facteurs qui favorisent une UAM responsable sont les suivants : les vétérinaires ont une bonne compréhension de la RAM et de ses conséquences, reconnaissent leur rôle dans ce défi sanitaire mondial, bénéficient d'un soutien positif de la part de leurs pairs et ont accès à des informations et à des solutions de remplacement des antimicrobiens. Le type de cliniques et ses politiques, ainsi que l'accès aux tests de laboratoire et les préoccupations relatives au bien-être des animaux peuvent constituer un obstacle ou un moteur en fonction du contexte et de la situation spécifique.

Conclusion : L'application des cadres théoriques pour comprendre les comportements a révélé des possibilités de renforcer l'engagement des vétérinaires en faveur d'une UAM responsable. Les

facteurs et les recommandations présentés dans cette recherche ont des implications positives car ils pourraient être utilisés pour identifier des interventions visant à promouvoir une UAM responsable à l'avenir.

Mots-clés : résistance aux antimicrobiens, utilisation des antimicrobiens, vétérinaires, animaux de compagnie, Une seule santé, modèle COM-B, domaines TDF, comportements.

Introduction

Antimicrobial resistance (AMR) is one of the greatest global health challenges of our time, which has already become a leading cause of death globally (1). In 2019, approximately 4 million human deaths were linked to AMR (2) – three times more than the total number of deaths associated with diabetes or lung cancer in the same year (3). In the animal health sector, the spread of existing and new resistant strains of bacteria in animals leads inexorably to an increase in animal suffering and loss. Yet, the precise impact of AMR on animal morbidity and mortality remains unknown, and further studies are needed to estimate it (4). The potential consequences that this global health challenge could also have on livelihoods worldwide should not be overlooked, as 1.3 billion people rely on livestock for their living and over 20 million on aquaculture (5). Therefore, AMR is a growing threat to both animal and human health, as well as livelihoods and food security worldwide. In order to secure gains made in health and scientific development over the last 50 years, AMR must be contained (1).

AMR is a phenomenon driven by random mutations and natural selection. Some bacteria are also able to share genetic material with other bacteria, increasing the spread of resistance across bacterial populations. Moreover, this phenomenon can be greatly accelerated by the overuse and misuse of antimicrobials in multiple sectors, as this can exert selective pressure allowing bacteria with resistance traits to survive and thrive (1). Compounding this problem is the fact that transmission of resistant bacteria or their resistance genes is possible between animals and humans via direct or indirect contact, through food/feed and the environment (6–8).

This resistance is a complex problem that requires a united multisectoral approach, globally known as the One Health approach (9). According to the One Health High-Level Expert Panel (OHHLEP), One Health is ‘an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems’. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development (10).

In this context, the World Health Assembly in May 2015 adopted the *Global Action Plan (GAP) on AMR* with the support of the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (WOAH, founded as OIE) (11). The GAP has five objectives:

1) Improve awareness and understanding of AMR through effective communication, education and training;
2) Strengthen the knowledge and evidence base through surveillance and research;
3) Reduce the incidence of infection through effective sanitation, hygiene and infection prevention measures;
4) Optimize the use of antimicrobial medicines in human and animal health;
5) Develop the economic case for sustainable investment that takes account of the needs of all countries and increases investment in new medicines, diagnostic tools, vaccines and other interventions.

One year later, in November 2016, WOAH launched its *Strategy on AMR and the Prudent Use of Antimicrobials* in animals (12). The strategy recognizes the importance of a One Health approach (13), and is aligned with the objectives established in the GAP, through four main goals:
1) Improve awareness and understanding;
2) Strengthen knowledge through surveillance and research;
3) Support good governance and capacity-building;
4) Encourage the implementation of international standards (12).

Both global initiatives seek to increase awareness and understanding among different stakeholders as a way of supporting the development and implementation of tools and policies that could help curb the progress of AMR. Behavior change interventions are critical to achieve this, through the effective practice of clinical medicine and public health (14).

Antimicrobial use in companion animals

The numbers of dogs and cats (hereafter referred to as companion animals) have substantially increased globally in recent years, with a growing emphasis on the welfare of these animals (15). In the UK, the PDSA Animal Wellbeing (PAW) report estimates that there were 11 million dogs as companion animals, as well as 11 million cats, as of March 2023. The same report also states that 53% of adults own a companion animal, representing a slight increase from February 2020, when 51% of adults reported owning one (16). Moreover, the relationship between companion animals and humans has also radically changed through the years, with these animals increasingly being in close contact with humans and with touching, petting and licking happening at high frequency on the basis of animals being perceived as family members. While in the past, dogs were usually maintained outside households, today they are often kept indoors (17).

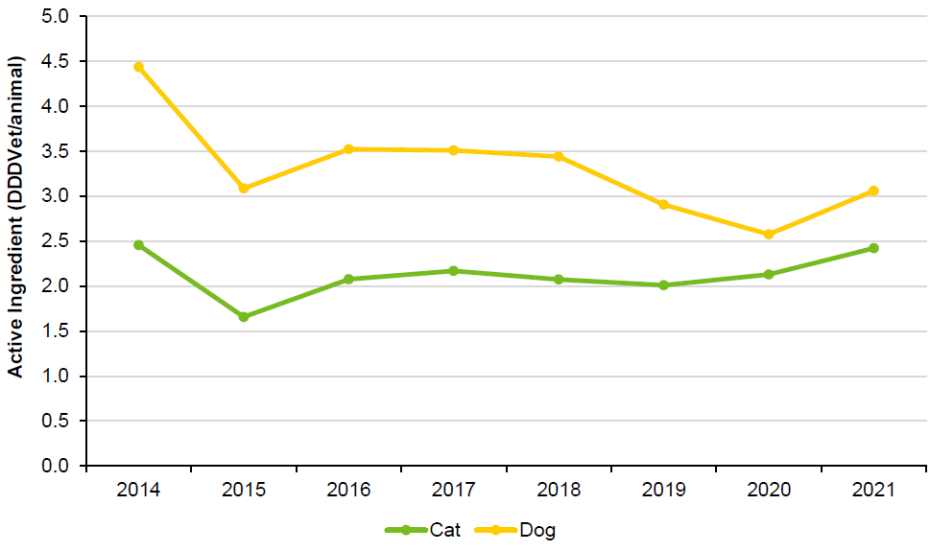
Currently, increased attention is devoted to companion animal health and welfare, resulting in increased expenditure on veterinary care (17). As a consequence, antimicrobials are used frequently

in everyday practice for therapeutic and preventive purposes in companion animals (18), which poses a risk for AMR development and spread in community and veterinary practice settings.

Risk assessment and management need to be based on valid and up-to-date data. As such, it is necessary to understand the patterns and extent of antimicrobial use (AMU) in animals. This has been investigated in several countries, focusing mainly on food-producing animals due to the potential risk of AMR transmission via the food chain. However, AMR can also be transmitted to humans from companion animals through direct close contact and a shared contaminated environment. Antimicrobial consumption data for companion animals are often incomplete, not monitored in several countries and usually refer to drug manufacturer sales rather than to actual use at the animal level (18).

In 2021, AMU in companion animals in the UK has been estimated to be 65.5 mg/kg for dogs and 32.9 mg/kg for cats. In this metric, 'mg' refers to the weight of antibiotic active ingredient sold for use in companion animals. The denominator is the estimated weight of the whole companion animal population at risk. When monitoring trends, however, a different metric – DDDVet/animal (defined daily doses for animals) – is used, which relates to the average number of days that each companion animal in the UK has received an antibiotic per year. This is the preferred metric as it takes into account the length of activity for long-acting products (which are commonly used in companion animals) as well as differences in dose rates used. Sales of antibiotic products were 3.1 DDDVet/animal for dogs in 2021, which represents a 0.5 DDDVet/animal increase from 2020 but a 31% (1.4 DDDVet/animal) decrease since 2014. In comparison, sales of antibiotic products for cats were 2.4 DDDVet/animal in 2021, which represents an increase of 0.3 DDDVet/animal since 2020 but a decrease of 1.4% (0.03 DDDVet/animal) since 2014 (19). A full explanation on how these metrics are calculated can be found in the appendix.

Figure 1. Active ingredient (DDDvet/kg) of antibiotics sold for use in companion animals, 2014–2021

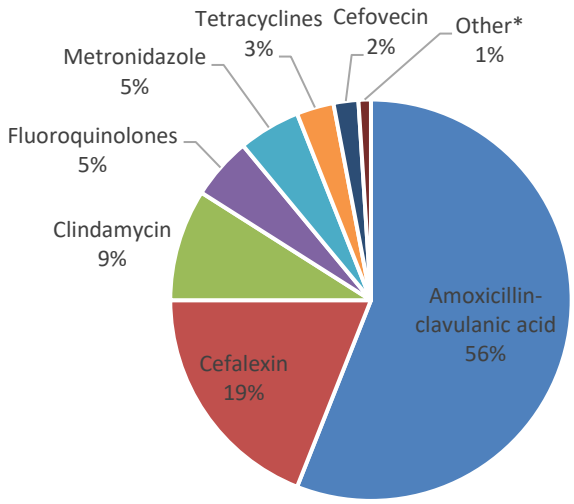


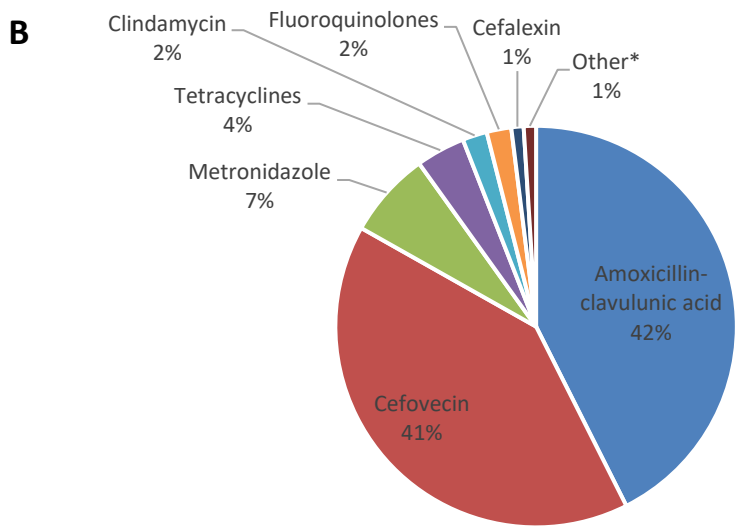
Source: UK Veterinary Antibiotic Resistance and Sales Surveillance Report, UK-VARSS 2021, November 2022 (19).

When it comes to types of antimicrobials, in dogs, amoxicillin-clavulanic acid, a broad-spectrum beta-lactam, was the most sold active ingredient in 2021 in the UK, representing 56% of total sales, followed by cefalexin (a first-generation cephalosporin), which represented 19% of total sales. In cats, amoxicillin-clavulanic acid was also the most commonly sold antimicrobial agent in 2021, representing 43% of total sales, closely followed by cefovecin (a third-generation cephalosporin classified as a highest priority critically important antibiotic (HP-CIA) for humans) (41%) (19).

Figure 2. Proportion of DDDVet/animal of antibiotics by active ingredient/antibiotic class sold for use in (A) dogs and (B) cats, 2021

A





Source: Adapted from UK Veterinary Antibiotic Resistance and Sales Surveillance Report, UK-VARSS 2021, November 2022 (19).

HP-CIAs are antimicrobials classified by the World Health Organization (WHO) as of highest-priority and critically important based on their clinical importance in human medicine and the risk of resistance transfer from non-human sources (20). According to WOAH's list of antimicrobial agents of veterinary importance, the use of HP-CIAs as growth promotors in food-producing animals should be phased out (21), however these guidelines do not include recommendations on their use in companion animals yet. Some guidance is provided by the British Small Animals Veterinary Association (BSAVA), which recommends that antibacterials such as third or fourth generation cephalosporins or fluoroquinolones should only be used in companion animals when culture and sensitivity results indicate efficacy and other agents are inappropriate (22).

In the UK, sales of HP-CIAs accounted for 7% of total antimicrobial sales for use in dogs, which represents a reduction of 41% since 2014. In cats, however, HP-CIAs accounted for 42% of total sales, which represents a reduction of 24% since 2014. Fluoroquinolones represented 70% of HP-CIA use in dogs, whereas in cats, 96% of HP-CIA sales were cefovecin (19).

Additionally, many antimicrobials used in veterinary medicine are also used in human medicine. From a One Health perspective, and due to the close contact between people and their companion animals, the importance of companion animals as potential reservoirs of drug-resistant pathogens for humans has received increasing attention (23). The outcomes resulting from AMU in companion animals are expected to be similar to those observed in human medicine and animal production. The rate at which AMR develops and spreads among the bacteria exposed to these drugs might be determined by the quantities used and usage patterns. The development of AMR in companion

animals could have important implications for public health but also for animal health and welfare (24).

Several studies conducted in Europe have reported an increase in the prevalence of AMR in different bacterial species isolated from companion animals. Ruzauskas *et al.* (2015) isolated a wide range of methicillin-resistant *Staphylococcus* (MRS) strains in companion animals in Lithuania (25). All MRS strains were susceptible to vancomycin, linezolid, daptomycin and quinupristin/dalfopristin (25). Resistance to tetracycline, clindamycin and erythromycin was most commonly observed in diseased companion animals, while resistance to gentamicin, ciprofloxacin, macrolides and tetracycline was most commonly found in kennel dogs (25). In the UK, Beever *et al*. (2015) estimated resistance trends and quantified the occurrence of methicillin-resistant *Staphylococcus pseudintermedius* (MRSP) among 14,555 clinical *Staphylococcus intermedius* group isolates obtained from UK dogs and cats (26). While resistance remained below 10% for cefalexin, amoxicillin-clavulanic acid and the fluoroquinolones, increasing levels of resistance were seen against ampicillin/amoxicillin, cefovecin and enrofloxacin. The authors of the study noted a growing trend of resistance levels to important antimicrobials, including to HP-CIAs over time; moreover, the emergence of multidrug resistance strains, such as MRSP, from clinical cases was confirmed (26).

Transmission of bacteria between humans and companion animals might occur by direct contact (petting, licking, physical injuries, handling of animal waste, etc.) or through the domestic environment (contamination of food, furnishings, etc.). Children are at greater risk than adults because of their closer physical contact with cats and dogs as well as with contaminated household shared environments (floors, carpets, etc.). Horizontal transfer of resistance genes may occur in the opposite direction to bacterial transmission. For example, human bacteria transmitted to companion animals may acquire resistance genes from the commensal flora of companion animals and may be selected by antimicrobial treatment in these animals and vice versa. Furthermore, companion animals can contribute to the propagation of acquired resistant bacteria to other animals, humans and to the wider environment through animal waste (feces and urine) (17).

There is increasing evidence worldwide of the risks associated with the transfer of resistant organisms between companion animals and their owners or veterinary staff. In Brazil, Carvalho *et al.* (2016) found similar resistance patterns for *Escherichia coli* (*E. coli*) strains isolated from dogs, owners and controls. Furthermore, their data demonstrated the possibility that resistant *E. coli* clones were circulating between individuals and animals in the same environment (27). In Canada, Weese *et al.* (2006) suggest that methicillin-resistant *Staphylococcus aureus* (MRSA) can be transmitted between humans and animals many times within a household or veterinary clinic. Owing to the nature of the study, a temporal association can only be made, however the results of this study strongly

suggest interspecies transmission and support previous concerns that pets could become household reservoirs of MRSA (28). Yet the extent to which transmission of resistance through companion animals to humans occurs is still largely unknown (27–30).

Role of veterinarians in antimicrobial use and antimicrobial resistance

Veterinarians have a major influence over AMU in animals due to their prescribing role. All antimicrobials in animals in the UK and across the European Union (EU) must be prescribed by a veterinarian (31). The responsible use of antimicrobials is defined by the British Veterinary Association (BVA) as 'As little as possible, as much as necessary' (32). Additionally, numerous strategies, recommendations and treatment guidelines on responsible AMU have been developed by a variety of UK, European and international bodies, as presented in Table 1.

Table 1. List of guidelines and guidance on the responsible use of antimicrobials in companion animals.

Scope	Organization	Summary of Guidance and Associated Web link	Date
National	BSAVA	BSAVA Scientific Position Statement on Cascade prescribing	2016
National	BSAVA	BSAVA Scientific Position Statement on the responsible use of antibacterials	2022
National	BSAVA/SAMSoc	PROTECT ME Resources and supporting material	2018
National	BSAVA	BSAVA Guide to the Use of Veterinary Medicines	2022
National	BSAVA	Antiparasitic Resistance	May 2022
National	BVA	Responsible use of antimicrobials in veterinary practice 7-point plan	2019
National	BVA	Are you antibiotic aware? A poster for practices	2019
National	HSE	Advice booklet: Veterinary medicines: Safe use of by farmers and other animal handlers	August 2012
National	NOAH	Responsible use of antibiotics	May 2016
National	NOAH	Antibiotics for Animal Health and Welfare: An Overview	May 2016
National	NOAH	Responsible Use of Animal Medicines	May 2016
National	NOAH	Antibiotic Resistance	May 2016

National	RCVS	Guidelines for veterinary medicines – including prescription and supply guidelines, choice of medicinal products, the prescribing cascade and AMR	March 2023
National	VMD	Information and resources on the UK's plans to see antimicrobial resistance contained and controlled by 2040	July 2022
European	EC	Guidelines for the prudent use of antimicrobials in veterinary medicine	September 2015
European	EPRUMA	Approaches for veterinary pharmaceutical waste reduction and correct disposal at the prescriber and user level	2022
European	FECAVA	Posters with recommendations for responsible use of antimicrobials	2022
European	FVE	Guidelines on responsible use of antibiotics	January 2019
International	WOAH	Strategy on Antimicrobial Resistance and the Prudent Use of Antimicrobials	November 2016
International	WOAH	Standards and guidelines in the Terrestrial Animal Health Code (chapters 6.6., 6.7., 6.8., 6.9. and 6.10.) and in the Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. (Guideline 2.1.).	2022
International	WSAVA	Key documents on responsible antimicrobial use and AMR prevention	2021

Source: Adapted from the UK Veterinary Medicines Directorate (last updated: 19 August 2022) (33).

The aim of these strategies is to encourage veterinarians to prescribe responsibly, as well as to reduce AMU (34). For any such strategy to be effective in bridging the gap between prescribing guidelines and clinical usage, it is necessary to understand the factors influencing how veterinary antimicrobials are prescribed.

According to a survey conducted in Europe by the Heads of Medicines Agencies – Veterinary Medicines (HMA-V) and the FVE, the most important factors, overall, that influence the prescribing habits of veterinarians working across different animal species are antimicrobial susceptibility test

results, the veterinarians' work experience, consideration of the risks of AMR and ease of administration (34).

Some research has also been done at the national level on factors influencing antimicrobial prescribing behaviors, but this has primarily been undertaken in food-producing animals. A survey sent out to farm animal veterinarians in Flanders and the Netherlands shows some similarities and differences in the attitudes of veterinarians towards AMU and AMR. Cultural differences (level of risk averseness, characteristics of the veterinarian–client relationship) in combination with diverging policies on veterinary AMU in both areas seem to be the basis for these differences, suggesting that regional and national contexts need to be taken into account when assessing veterinary AMU (35, 36). While interviews conducted with veterinarians working in Ireland suggest that their treatment decisions are not just based on clinical factors, such as presumed diagnosis or clinical history, but are also influenced by non-clinical, psychological and contextual factors, such as issues with laboratory testing, pressures from clients and sometimes employers to prescribe antimicrobials against the veterinarian's better judgement, and concern about the perceived negative consequences of not prescribing antimicrobials (31). Existing qualitative research indicates that, even if UK pig veterinarians exhibited a strong sense of social responsibility over the need to ensure responsible AMU, the economic viability of good management practices that could reduce their AMU might influence their decisions (37). There is also evidence suggesting that the risk of AMR is not always prioritized in prescribing decisions. For example, in one study conducted in Italy although AMR awareness among cattle veterinarians was high, over half reported using critically important antimicrobials as a first-line treatment for calf diarrhea (38). When talking about professional responsibility, in a survey conducted by the EU, veterinarians were confident that the use of antimicrobials in farming creates little or no risk to different professional groups and for consumers. While they were aware of the issue of AMR in animals and of potential human health impacts, they also believed that AMU in human medicine creates far more risks than veterinary use (39).

Regarding companion animals, a qualitative study was conducted in the Netherlands to identify factors influencing antimicrobial prescribing in clinics. According to this study, four major categories of influencing factors could be identified: 1) veterinarian-related factors, 2) patient-related factors, 3) treatment-related factors and 4) contextual factors (40). A behavioral lens was also used in the UK to examine drivers and barriers influencing prescribing practices of veterinarian surgeons working in areas ranging from front-line services to secondary referral services in specialist centers. Barriers identified to appropriate prescribing include ensuring business success though client satisfaction, fear of the negative consequences for an animal and for themselves of not treating an infection, diagnostic cost and time, habitual practice and influence of pharmaceutical companies. Identified drivers of responsible AMU included increased AMR awareness of both the public and veterinary

professionals, implementation of good infection prevention measures, improved professional learning, and increased regulation and governmental inputs (although the form these inputs should take is contested) (41). As mentioned before, in response to the threat of AMR a number of national and international guidelines for responsible AMU in companion animals have been developed. The scope and content of these vary and implementation varies from mandatory (e.g. in Sweden) to professional responsibility (e.g. in the UK) or voluntary (42). Available evidence from a qualitative study conducted by Mateus *et al.* (2014) indicates that veterinarians appear to have limited awareness of current recommendations for responsible AMU and antimicrobial choices can be influenced by social norms. Recommendations, if known, were considered to be difficult to implement and of limited use in everyday practice. Among the 21 veterinarians interviewed in this study, only a small number of participants perceived current guidelines as a reminder of best practice (43). A similar situation was observed in other European countries, such as Italy (44) and Belgium (45), where despite the existence of national guidelines, the prescribing behavior of antimicrobials by veterinary practitioners in companion animals is often not in agreement with them. In addition, the authors of the Belgium's study suggested that focus in improvement of this prescribing behavior should be on performing the appropriate diagnostic steps and decreasing the use of HP-CIAs (44,45).

Veterinarian students' self-reported behavior, knowledge, and beliefs related to AMR was assessed in the UK by Golding *et al.* (2022) through a cross-sectional online survey. While knowledge among students was from moderate to good, they also typically believed that veterinarians had less responsibility for causing and preventing AMR than other groups, such as animal owners, human healthcare providers and the general public (46).

To author's knowledge at the time of writing, there is a lack of research applying theoretical models to understand veterinary practices related to AMU in companion animals in the UK.

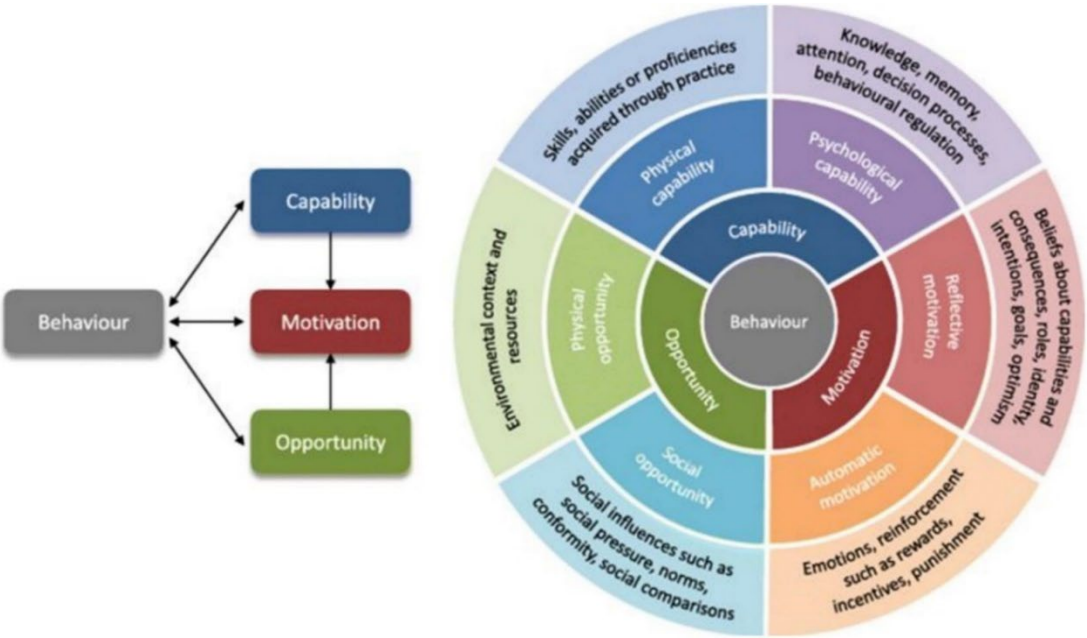
Using the COM-B model to understand veterinarians' behaviors

The use of theoretical frameworks for the identification of barriers to and drivers of antimicrobial prescribing can result in the development of targeted interventions that may be successfully implemented and sustained (47). A number of theoretical models exist that offer explanations of the complexities underlying human behavior and behavioral change.

One such framework used commonly in health contexts is the COM-B model (48). The COM-B model has been developed based on an extensive review of existing behavior change theories, which evolves the study of human behavior from a unidimensional focus on a limited number of individual factors. Instead, the COM-B model treats behavior as a product of many different levels of influence

resulting in a more holistic study. It accounts for cognitive, internal factors as well as the impact of non-cognitive, external factors such as the physical environment and social influences. The COM-B model suggests that for any behavior change to occur there must be a change in one or more of the following behavior components: 1) capability (personal and psychological), 2) opportunity (social and environmental), and 3) motivation (reflective and automatic) (14), as explained in Figure 3.

Figure 3. The COM-B model – a framework for understanding behavior



Source: McDonagh et al. *(2018)* (49).

The Theoretical Domains Framework (TDF) is often used in combination with the COM-B model. The TDF allows for the influences on a person's capability, opportunity, and motivation to be identified and has 14 theoretical domains that interlink with the COM-B components (50–52): 1) capability – skills, knowledge, memory, attention and decision-making processes, and behavioral regulation; 2) opportunity – environmental context and resources and social influences; and 3) motivation – social/professional role and identity, beliefs about capabilities, optimism, belief about consequences, intentions, goals, reinforcement, and emotion (53). These domains are defined in Table 2.

Table 2. Definitions of the domains of the Theoretical Domains Framework

Domain	**Definition**
D1 Knowledge	An awareness of the existence of something
D2 Skills	An ability or proficiency acquired through practice

D3 Social/Professional role and identity	A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting
D4 Beliefs about capabilities	Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use
D5 Optimism	The confidence that things will happen for the best or that desired goals will be attained
D6 Beliefs about consequences	Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation
D7 Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus
D8 Intentions	A conscious decision to perform a behavior or a resolve to act in a certain way
D9 Goals	Mental representations of outcomes or end states that an individual wants to achieve
D10 Memory, attention and decision processes	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives
D11 Environmental context and resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior
D12 Social influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviors
D13 Emotion	A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event
D14 Behavioral regulation	Anything aimed at managing or changing objectively observed or measured actions

Source: As described in Cane et al. *(2012)* (54) *definitions are based on definitions from the American Psychological Association's* Dictionary of Psychology (55)

The use of this COM-B model in the veterinary sector is limited and to the author's knowledge has not yet been applied to the prescription of antimicrobials by veterinarians in companion animals in the UK. Considering the significance of AMU by veterinarians in animals, including companion animals and the potential risk of AMR, it is important to investigate the enablers and barriers that impact on veterinarians' prescription patterns. Such work could lead to the development of behavior

change interventions, which are more likely to influence responsible AMU in companion animals, in line with the guidelines currently available. Therefore, this study seeks to answer the following research question: What are the factors that can influence responsible AMU in companion animal veterinarians working in the UK?

Objectives

The aim of this study is to understand the factors which are most likely to influence responsible AMU in companion animals by veterinarians in the UK by applying the COM-B behavior model.

The objectives of this project are:

1. To assess the level of AMR knowledge among companion animal veterinarians working in the UK
2. To identify the enablers of and barriers to AMU among companion animal veterinarians working in the UK
3. To guide future behavior change interventions targeted to companion animal veterinarians working in the UK

Materials and methods

Study type

A qualitative study was conducted to explore veterinarians' 1) knowledge and awareness of AMR, 2) motivation and professional role in tackling AMR, and (3) perceived barriers to and enablers of optimizing AMU in companion animals. By conducting a qualitative study, an in-depth understanding of veterinarians' behaviors relating to AMU in companion animals can be achieved, as it allows participants to respond more freely and extensively about their thoughts surrounding their decision-making.

Study population

The study was conducted on veterinarians working with companion animals in any type of practice in the UK to ensure that the study group were operating under the same national legal framework that regulates veterinarians' sales and use of veterinary medicinal products containing antimicrobial agents, including off-label use. The selection of the country was based on the national regulatory framework and guidelines, which provided the ideal context for this analysis, as well the convenience of the author for sampling the participants. Participant demographics, including gender, age, years

of practical experience, employment status, country where they undertook their undergraduate studies, area of specialty, and workplace (e.g. first opinion, referral practice), are presented in Table 4. To ensure confidentiality, the participants were assigned unique code numbers. The study's purpose was fully explained to the participants and written consent was obtained before each interview.

Sampling procedure

The sampling strategy aimed to recruit veterinarians working with companion animals in the UK by using convenience and snowballing sampling techniques. Eleven out of 13 participants (84.6%) were identified using the framework of WOAH's partnerships with the International Veterinary Students Association (IVSA) and the World Small Animal Veterinary Association (WSAVA), as well the author's professional networks. This is a non-probability sampling method where the researcher uses opportunities to ask people who are easily accessible and chooses participants whose ideas or experiences will help achieve the aim of the research (56). The remaining two participants were identified using snowballing with suggestions from an initial participant. This is a technique where a previously chosen informant is asked to identify other potential participants with knowledge of a particular area or topic (56). All of the participants were contacted by email.

Data collection

A semi-structured interview guide with open-ended questions, Table 3, was created to gain insights into veterinarians' capabilities, opportunities and motivations to optimize the use of antimicrobials in companion animals. The first two interviews were also considered as a testing phase, and the interview guide was adapted later in order to make it more comprehensive. Participants were invited to take part in one-to-one semi-structured interviews via Microsoft Teams (Microsoft Office) lasting from 23 to 47 minutes. A date and time for the interview was provided to those who agreed to participate. Following completion of the thirteenth interview, it was decided that data saturation had been achieved (i.e. that sufficient data had been collected for the purpose of this study and new data was no longer being generated). Interviews took place between 13 April and 26 June 2023. All interviews were audio and video recorded using Teams. Recordings were transcribed using Team's online transcription service and were then verified multiple times by the author to ensure accuracy. As explained to the participants via the consent form, the audio and video recordings were deleted once the data analysis was finalized.

Table 3. Semi-structured interview guide

Interview question (IQ)

IQ-1	What do you think are the consequences of AMR?
IQ-1a	How do you think AMR impacts your daily practice and the veterinary profession in general?
IQ-1b	How do you think AMR affects society?
IQ-1c	What do you think are the benefits associated with using antimicrobials in companion animals?
IQ-1d	What do you think are the risks associated with not using antimicrobials in companion animals?
IQ-2	How would you describe your use of laboratory testing for diagnosis?
IQ-2a	How easy is it for you to access laboratory testing in your everyday practice and why?
IQ-2b	How often do you test for antimicrobial susceptibility when you are treating an animal suspected of being infected with a bacterial pathogen?
IQ-2c	What kind of laboratory do you have access to (in house/external)?
IQ-3	What kind of peer support do you receive to optimize antimicrobial use?
IQ-4	What do you think your peer's views on antimicrobial use and AMR are?
IQ-5	Whose advice and opinion do you most respect around antimicrobial use and why?
IQ-6	Tell me about your training on antimicrobial use.
IQ-6a	Are you aware of the existence of international/national guidelines [on AMU]?
IQ-6a-i	If yes, how useful are these for you in your everyday practice and what other sources of information do you use to inform your use of antimicrobials in animals if any?
IQ-6a-ii	If not, from where do you get information about antimicrobial treatments?
IQ-7	How do your employers influence your antimicrobial prescribing behavior, if at all?
IQ-7a	What are the policies in your clinic about the use of antimicrobials if any, who set up these policies, and how do they influence your everyday practice?
IQ-7b	What are the policies in your clinic on acquiring antimicrobials (if any), who set up these policies, and how do they influence your everyday practice?
IQ-8	What are your experiences with companion animal owners when selecting antimicrobials?
IQ-8a	How common is it that companion animal owners will request antimicrobials for their animals and in what situations do you see this happening?
IQ-8b	How often do you discuss alternatives to antimicrobials that are equally effective with companion animal owners and in which situations?
IQ-9	What do you think would help improve the relationship between companion animal owners and veterinarians when it comes to optimizing the use of antimicrobials?
IQ-10	What is your understanding of AMR?
IQ-10a	Who do you feel is responsible for AMR?

IQ-10b	What do you think is the role of veterinarians in AMR and why?

Source: Adapted from Farrel et al. *(2023)* (31).

Data analysis

Thematic analysis was used as a method for identifying, analyzing and reporting patterns (themes) within data (57). During the data collection phase, the author looked for patterns of meaning and issues of potential interest in the data. Some initial ideas were noted down when reading and re-reading the transcripts. Once the data collection phase concluded, all the transcripts were imported into Dedoose 9.0.107, a cross-platform app for analyzing data generated through qualitative and mixed methods research studies. All the transcripts were coded by the author in the platform to identify features of the data in a systematic way, giving full and equal attention to each data item. Preliminary categories were merged by bringing several codes together. To enhance the rigor of the analysis and to ensure that the interpretation of the data was not limited to the perspective of the author, the coding was reviewed and discussed with the author's supervisor. The different codes were sorted into potential themes, and all the relevant coded data extracts were collated within the themes. Themes were identified using a mixed approach: an inductive or 'bottom up' approach was used to identify codes that are strongly linked to the data, without trying to fit them into the theoretical framework, or the author's analytic preconceptions, and a theoretical or deductive or 'top down' analysis was implemented driven by the theoretical framework, as well as the previous scoping literature review conducted by the author (57). The identified themes and sub-themes were mapped to the TDF domains and COM-B model. In the final stages, transcripts were read again ensuring that the themes represented the data accurately and appropriate quotations were chosen to illustrate each theme and sub-theme. Throughout the data analysis phase, memos created by the author allowed the coding process and reasoning behind it to be tracked, which helped monitor the rationale adopted during the analysis over time.

Results

Descriptive data

In total, 13 participants were interviewed. All participants were female and most were between 25 and 35 years old (92.4%). While almost 70% of the participants had less than five years of experience, only one was working part-time in a clinic. All were general practitioners and 23.1% of the veterinarians interviewed had studied abroad. Almost 70% of the veterinarians interviewed were working in a first-opinion practice, while the others were working as interns in referral practices. Differences between first-opinion and referral practices in the UK are explained in Box 1.

Table 4. General characteristics of the participants

	N	%
Total population	**13**	**100**
Gender		
Male	0	0%
Female	13	100%
Age		
20-25 years old	1	7.6%
25-30 years old	6	46.2%
30-35 years old	6	46.2%
Years of experience in practice		
<5 years	9	69.2%
5-10 years	3	23.1%
>10 years	1	7.7%
Employment status		
Part time	1	7.7%
Full time	12	92.3%
Country of studies		
UK	10	76.9%
Abroad	3	23.1%
Specialty		
General practitioner	13	100%
Other	0	0%
Workplace		
First-opinion practice	9	69.2%
Referral practice	4	30.8%

Box 1. First-opinion versus referral practices in the UK

First-opinion practice

It is a local primary care veterinary practice that provides basic services for companion animals. Preventive medicine is one of the most common aspects of veterinary medicine discussed during the

Referral practice

A referral takes place when the normal veterinarian decides that they cannot provide the level of expertise or facilities required to treat a companion animal in the best way possible. Alternatively, the

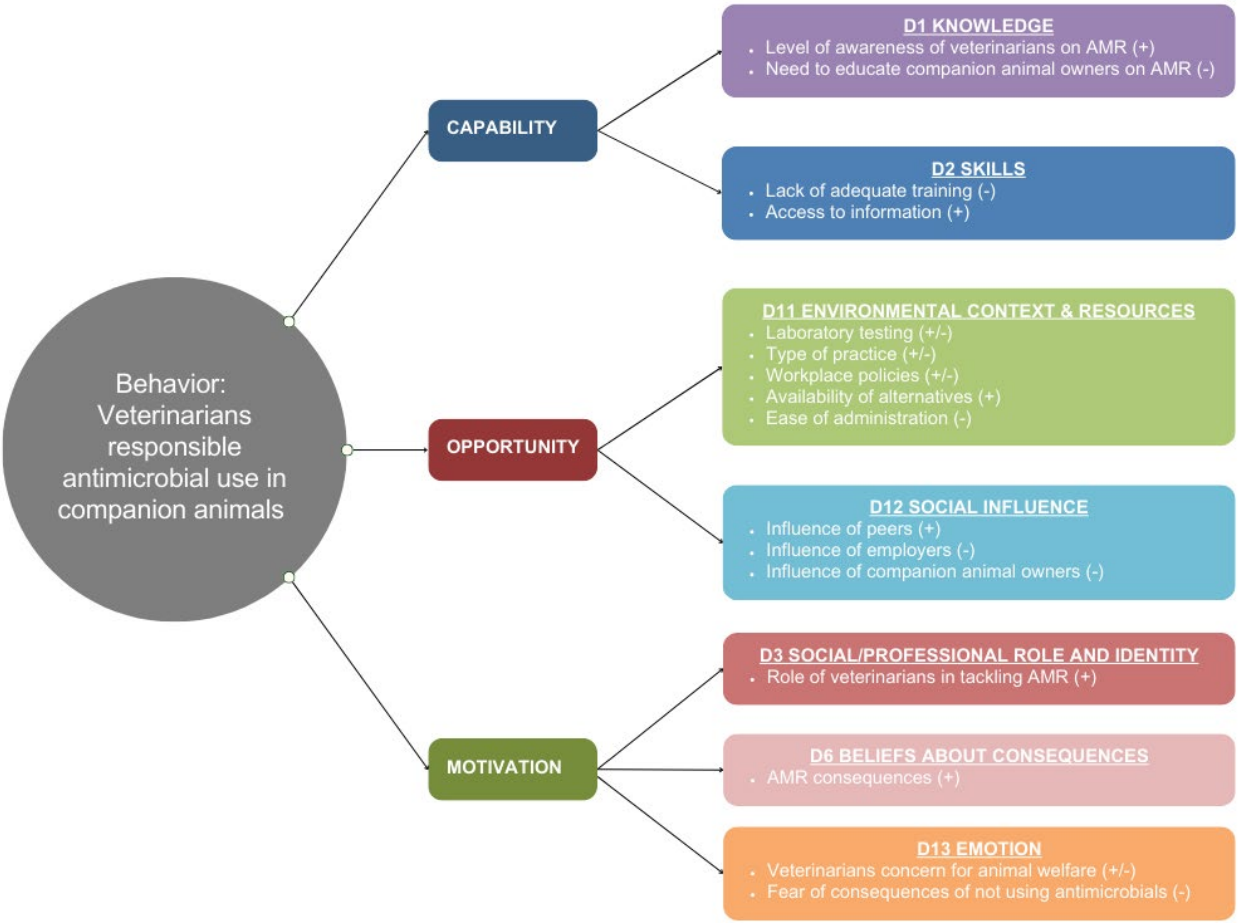
first-opinion small-animal consultation. Veterinarians should recognize when a case or a treatment option is outside their area of competence and be prepared to refer it to a colleague, organization or institution, whom they are satisfied is competent to carry out the investigations or treatment involved.	referral process can be started at the request of an owner who wishes to have treatment performed by a veterinarian with more experience in a particular field.

Source: Adapted from the Royal College of Veterinary Surgeons (RCVS) Code of Professional Conduct for Veterinary Surgeons *(last updated 27 July 2022)* (58).

Qualitative data

This study provides insights into factors influencing veterinarians' responsible antimicrobial prescription behaviors when dealing with companion animals, as shown in Figure 4. Seven of the 14 TDF domains (knowledge; skills; social/professional role and identity; beliefs about consequences; environmental context and resources; social influences; emotion) were identified and mapped to the COM-B elements.

Figure 4. Thematic 'map' illustrating barriers (−) and enablers (+) that influence responsible AMU



Capability

Veterinarians' psychological and physical capabilities influenced their antimicrobial prescription behaviors. Psychological capability is defined within the COM-B model as the capacity to engage in the necessary thought processes, such as comprehension and reasoning, while physical capability is mainly the skills to implement the desired behavior that could be acquired through practice (14).

D1 Knowledge

Level of awareness of veterinarians on AMR

All participating veterinarians were able to explain what AMR is, addressing the mechanisms for its development and, therefore, demonstrating a good knowledge of this issue. Additionally, regardless of their years of experience in practice, there was an understanding among participants of the risks associated with AMR, as well as the benefits of using antimicrobials.

> 'The benefits are astronomical from the point of view that if you've got a bacterial infection and you have an antibiotic that can treat it, you can treat an animal, help an

> illness, but also again potentially save its life depending on what infection you're dealing with. So, they're very useful things to have.'
>
> Interviewee 11, first opinion, over 10 years of experience

Need to educate companion animal owners on antimicrobial resistance

Participants also believed that the education of companion animal owners on the risks associated with AMR is fundamental to improve the relationship with them when it comes to optimizing AMU. Veterinarians felt that it is important for companion animal owners to understand the negative consequences of misuse and overuse of antimicrobials in companion animals, as well as the alternative options that they could implement as a way of motivating and encouraging them to follow the advice of the veterinarian.

> 'I would say education. I think if you can kind of boil it down to their individual animal and say, look, if I give you this now in two months' time, we might be in a very different situation where I can't fix it and you kind of relate it to that individual animal. I think people are very open to that conversation and willing to put the effort in to do other things cause cleaning, like for example, cleaning an ear, is much harder work than giving them antibiotics. It is. And so, you do have to do a little bit of getting them on side to put that effort in and have faith that this alone is better in the long term. So, I think the education that this is actually helping, me not giving you something is helping is quite an important to stick, [be]cause they just think well you're not helping me because you're not giving me anything like that kind of mindset. But like I say people are open to it, but the education definitely has to be there.'
>
> Interviewee 4, first opinion, less than five years of experience

<u>D2 Skills</u>

Lack of adequate training

While all the participants acknowledged having received some education on AMU during veterinary school, most of them agreed that it was very basic training and insufficient to adequately prepare them for real-world scenarios. Therefore, they learned how to use antimicrobials through their everyday work.

> 'Fairly minimal at university, it gave us the principles, so they drilled in the concept of antimicrobial resistance and why it's important to be careful of it, why it's important to consider your antibiotic choice and the risks of antimicrobial resistance. So as a concept that was university. In terms of applying that to actual day-to-day life and the antibiotics you will come across in practice, I don't think we did a lot of that at university and that you've sort of learned on the ground.'

Interviewee 10, first opinion, less than five years of experience

Regarding postgraduate education, some of the participants mentioned the existence of the continuing professional development (CPD) program in the UK. CPD encourages looking forward and identifying opportunities to learn something new, refreshing existing knowledge, improving skills, or simply keeping up to date with the latest developments within a particular profession or industry. In practice, CPD can mean everything from taking a training course or attending an educational event, to studying for new qualifications or learning new aspects of a job (59). According to the RCVS, CPD is a professional responsibility and requirement for all veterinary surgeons, who are supposed to allocate at least 35 hours per year to this program (60). However, participants emphasized their preference for prioritizing practical skills such as surgery over acquiring additional knowledge on AMU. The fact that CPD on this topic is not compulsory does not encourage them to enroll in such training.

> 'About CPD, it could be basically on anything you want it to be on, so we pick it. And so, if you wanted to be a surgeon, you would pick all of your subjects to be surgery based. So, unless you have an interest in AMR, there's no requirement for you to learn about it, you could just ignore it completely. And so even myself, who I guess has an interest in the subject, I haven't done any specific CPD on it. But it is available, it's an option. CPD can be literally anything. And so, for example, having a conversation with your colleague about a case that counts as CPD, and so you can classify kind of any personal development. So, there are definitely some cases, AMR information, that you could count, but it's not published as CPD I suppose.'

Interviewee 4, first opinion, less than five years of experience

It was also highlighted by one participant that veterinarians should be better educated on alternative ways to treat infections that do not require AMU.

> 'Probably more vets being educated on alternatives to antibiotics, or alternative ways to treat certain infections. I don't believe that it's always going to be like learning about antibiotic resistance is the best, you know, like learning about of consequences of that would be the best way to, like scaring people into doing it. Because I think that actually if you don't know any better, you don't know, right? So, like, if they actually had seen and been taught other alternatives to do before doing the antibiotics, that would be a better, better alternative.'

Interviewee 3, first opinion, from 5 to 10 years of experience

Access to information

When it comes to access to information and resources on antimicrobial prescription, most of the participants confirmed that they rely on the guidelines or posters available at the clinic where they

work. Among these guidelines, they mentioned the materials from BSAVA (Protect Me poster, manual), RUMA, WSAVA, the UK's Veterinary Medicines Directorate (prescribing cascade), GRAM, and the miniVET guide. Only three participants were aware of the existence of international guidelines, mostly from WHO. None of them mentioned following the recommendations from WOAH. Additionally, the majority of the participants use other sources of information to look for scientific and peer-reviewed studies, such as the internet, books, scientific journals or professional magazines. Yet, they tend to make use of these resources only when dealing with challenging cases rather than on a regular basis.

Opportunity

Barriers and enablers within the social and physical clinic environment shaped the opportunities for veterinarians responsible prescription of antimicrobials. Physical opportunity is afforded by the environment (i.e., time location, resources). Social opportunity refers to the social factors that influence the way that we think about things (i.e. cultural norms, social cues) (14).

D11 Environmental context and resources

Laboratory testing

The majority of veterinarians admitted that they do not conduct as many tests as they felt they should do. The main obstacle to performing a culture before starting treatment appears to be the cost, as companion animal owners do not want to pay for it. Sometimes they would also insist on immediate treatment without waiting for the results, therefore not perceiving the added value of testing to guide treatment.

> 'In terms of the cost, it's a mixture. Most people, they want to avoid it, they don't want to pay extra to be honest, and also sometimes if a treatment just works then why not, and people will just be like, "Let's do it. Let's start with antibiotic A and, if it works, then we're going to continue with antibiotic A if it doesn't let's switch". But have that much more like experimental approach rather than pay for the test, which would be definitely more beneficial. But I can also see why people not spending money on that as we've had some pretty strong price hikes in the previous years, previous months, not just in the vet care world, but also just in general the cost of living has skyrocketed. So, if you can spare yourself £10-20, people will do that.'
>
> Interviewee 7, first opinion, less than five years of experience

Additionally, the time delay for getting the results was mentioned as another drawback associated with antimicrobial susceptibility testing. Although it does not fully discourage veterinarians from using these tests, often antimicrobials are prescribed anyway before the results are back.

> ‘It's really easy. We just take swab and then send it off, so it is really easy for us, actually in both places that I've worked. And the result can take a little bit of time so often, sometimes in my experience, but often I see it a lot where people are starting the animal on a broad-spectrum antibiotic and then would change the antibiotic based on the result. Because they're worried that if you leave at five days waiting for a culture result that it's going to worsen.’
>
> Interviewee 8, referral practice, less than five years of experience

Other barriers to testing that were mentioned were the concern of not seeing the animal again due to lack of follow up by the companion animal owners and the potential negative impact of the testing procedure on the animal welfare when it requires anesthesia.

On the other hand, the access to an external laboratory was considered to be easy by all the veterinarians. Six of the participants had also the resources needed to perform in-house swabs for cytology to get a first diagnosis approach, in particular for ears or skin cases. Additionally, several participants mentioned using the support provided by the laboratory technicians to interpret the results of the test and decide on the best therapy option.

> ‘Very easy because it is available in every practice, the lab provides transport for the samples, the results are provided electronically, and the prices overall are relatively approachable. The owner is the limiting factor because they can’t afford unfortunately to do that. There is consultant on the other side of the phone so if there is some question or anything, I can always discuss results with them and choose the most appropriate treatment for the animal.’
>
> Interviewee 1, first opinion, less than five years of experience

Veterinarians prioritized testing when dealing with recurrent cases, as these were perceived to have some history of AMR. A participant also mentioned that profit-driven policies in place could act as enablers for performing susceptibility tests, even for conditions that are not deemed relevant by veterinarians:

> ‘When I was working for a corporate practice, they brought in the requirement that any ear dog, any dog presented with a swollen ear, the ear was to be swabbed so that directly impacted that more of them were getting swab. But actually, what happened was that everybody kind of set up a kind of well why? Because I know what this is and it's such a random one for them to choose because, regardless, they only had one thing on the shelf for us to give most of the dogs anyway, so it didn't really matter. And actually, what it was, it felt more like we're just trying to take more money. It came down from the top of the business, we weren't told to make the decision, so I would assume it was business. The only one I got told about at the time was that we needed to swab bad ears. I don't know if they were maybe going to bring in more like for example, I kind of figured if

> they're going to do that, they're going to say any UTI [urinary tract infection] case, you need to take a sample, any skin disease, you're going to have to swab, it felt like that's maybe where that was going. But then they got a lot of backlash, I think, from the ear thing. And so, whether or not they brought that in, I don't know.'
>
> Interviewee 3, first opinion, from five to 10 years of experience

More rapid testing methods which can be used in clinics are perceived as potential drivers to make more effective use of susceptibility and diagnostic testing and ensure the correct antimicrobial is given to animals as soon as possible. It was also mentioned that diagnostics should be cheaper or part of a package of subscription-based services within the context of new payment models.

> 'How much are moving towards a subscription-based services? And I think that will be very helpful because that means that the owner won't be put off of running diagnostics which will help guide the use of antimicrobials in more appropriate and responsible ways and their current path by the diagnostic. The costs with that. And so, I think the kind of revising of the pay and payment structure model will really be very helpful.'
>
> Interviewee 6, first opinion, less than five years of experience

Type of practice

Some participants noticed a difference in terms of AMU when working in a first-opinion setting compared to a referral practice. Participants currently working in referral practices acknowledged that companion animal owners would support their decisions more and follow their advice regarding AMU. One participant even pointed out that much less antimicrobials are used to treat cases in referral practices.

> 'I think definitely that there might be cases, for example, that I saw when I was in first-opinion practices that were managed with antibiotics, in a referral setting that amount is really reduced, so we see a lot less antibiotic use now, where I work right now, but there's still a lot of cases that, you know, things like septic peritonitis or infectious cases that we wouldn't be able to manage without antibiotics.'
>
> Interviewee 8, referral practice, less than 5 years of experience

Additionally, two participants who worked in charity veterinary practices acknowledged some differences with business-oriented practices that could impact on their prescription behaviors. Yet they provided examples of barriers and enablers of responsible AMU. While one of these examples highlighted the pragmatic approach that veterinarians are supposed to take that might lead to a more rationale AMU, the other addressed the facilities limitation that might result in the misuse or overuse of antimicrobials.

> ‘So, I work for a charity vet outlet and so we are quite limited with [the] antimicrobials we have on the shelf, and mainly because of price, but also, we are very pragmatic in the way that we approach cases. So we're quite lucky in that we don't have to be influenced by what the client wants quite as often as we do in private practice, whereas potentially when you're in private practice and someone wants you to do something for their animal kind of just to show that you're trying, (…) And so I think we're quite good at that. For example, ear infections and you see that if you start plugging every antibiotic down, you start breeding resistance and even in that one case. So, we don't prescribe antibiotics at all and, to be honest, that was a new thing for me, maybe a couple of years ago and I realized that 99% of my cases didn't need antibiotics anyway. That is not something that I was taught as a protocol in private practice, which is where I started. I think it does influence my practice significantly, but I think where I work has a big impact on that, I would say and rather than I think obviously personal opinion comes into it, but I think the environment you're working on has a huge impact on what the individual vet does.’

Interviewee 4, first opinion, less than five years of experience

> ‘So again, for example, from our point of view as a charity, that one thing that I am quite uncomfortable with is we are very tight for space on things like dental procedures. […] And that means that in the meantime before they get that bad or hopefully just prevent them getting that bad quite often we’re treating dental disease with antibiotics and pain relief, but realistically, everyone knows that without removing that tooth, you’re not going to get rid of the source of infection and all you’re doing is kind of dumbing it down. But at that time, that tooth is infected, and you feel like you need to do something about it, even if you can’t remove it. And removing it at that time is not an option because we don’t have the physical space to do it.’

Interviewee 4, first opinion, less than five years of experience

Workplace policies

Additionally, the access to antimicrobials could vary according to the clinic and its policies. For half of the participants only certain drugs were kept on stock, which might influence their antimicrobial selection. To use other options, they would mostly be required to justify their decision with an antimicrobial susceptibility test on a case-by-case basis. Reasons for this can vary from cost, stock availability or supply issues, but profit from the sale of antimicrobials was not suggested as a motive on an individual level to prescribe drugs by veterinarians participating in this study.

> ‘I would say the only thing that they do is certain antibiotics they will not routinely keep in stock, so you would only be able to order them in, if you had done culture and sensitivity and it showed that obviously there were sensitivity to that antimicrobial, then they would allow you to order it in, but otherwise you wouldn't be able to prescribe it.’

Interviewee 13, first opinion, less than 5 years of experience

Availability of alternatives to antimicrobials

Most participants stated that they would try to propose alternatives to antimicrobials to their clients when they are equally effective, in particular for dermatological, otological and gastrointestinal (i.e. diarrhea) cases. While some veterinarians noted that there are more alternatives available in the market, others believed that there is more evidence to support their use.

> 'I think it's probably about the same as when I graduated, but I've found that since I've graduated, it's more in that condition you don't have to use antimicrobials anymore and rather than this is an alternative treatment. I definitely think there's more understanding of that, even from referring vets that email us. We've referral places emailing us and saying, "If I understand the current thought process is that we don't actually need to use antimicrobials in these conditions anymore, is that correct?". And we would say "Yes".'

Interviewee 12, referral practice, from five to 10 years of experience

Ease of administration of formulations

The antimicrobial formulation and its ease of administration would be another factor that some participants confirmed to consider before prescribing. When it is difficult for the companion animal owner to ensure the administration of an antimicrobial, due to its formulation, some veterinarians might end up using a second line antimicrobial that is long acting injectable. According to guidelines, this kind of antimicrobial may only be prescribed when initial first-line options were ineffective (61).

> 'Some vets used to inject a second line antimicrobial often to cats that they couldn't eat tablet because it's a long-lasting antibiotic injection. But even though it was a second line antibiotic, it shouldn't have been used, but they would prefer not to use tablets so they would give them injections.'

Interviewee 6, first opinion, less than 5 years of experience

<u>D12 Social influence</u>

Influence of peers

Only three out of the 13 participants mentioned that they do not receive any kind of support from their peers when it comes to optimizing their use of antimicrobials. For the ones who feel positively supported by their peers, the kind of support they receive can take various forms: from discussing cases or guidelines with peers, having access to advice from specialists, referral centers, external laboratories or managers, to using social media professional groups to share and seek advice on complex cases.

> ‘I would say probably my more experienced/trusted colleagues are probably who I listened to the most. So, if I have an animal that I'm not sure which way to go, they normally give me recommendations and probably my manager who is a veterinarian and things like that, but not necessarily, but that's just my current manager.’
>
> Interviewee 4, first opinion, less than five years of experience

Many factors were also mentioned as potential influencers of their peers’ views on AMR and AMU, including their age, training, specialty, personal interest, habits, ease of administration, client pressure, country regulations and working environments.

> ‘(…) but I would say people who have come up and had the same sort of learning as me so within my age range I would probably take their advice first, because I think they've probably had a more up-to-date understanding of what AMR is and how important it is versus some of the older colleagues.’
>
> Interviewee 4, first opinion, less than five years of experience

Influence of employers

While some participants did not feel their decisions were influenced by their employers, others explained how employers could impact on their prescription practices by settling AMU policies and protocols in the clinic. Ultimately, for some cases, these policies and protocols are driven by business reasons.

> ‘I think they definitely do because they write the protocols that we pretty much have to follow and I don't necessarily mean they say “Yes, you have to use this antimicrobial if this happens” but they control the wider picture.’
>
> Interviewee 4, first opinion, less than five years of experience

Influence of companion animal owners

Over half of the veterinarians reported to have had experiences with companion animal owners requesting antimicrobials for their animals, mostly for urinary tract infections (UTIs), but also for conditions that were not infectious. Companion animal owners believe they know what their animals need based on previous experience. Therefore, there is a need to educate them in order to be more open to changing their practices.

> ‘I would say most cases, even cases that like antimicrobials haven't even crossed your mind, and they'll be asking for it. Or for example, I had someone that wasn't actually my client, but someone who took their pet into the vet requesting antibiotics for a hypocalcemia and they were convinced that antimicrobials were going to fix this, and we were like, there's nothing to do with that, it's not an infection at all, it needs a shot of calcium, like that sort of thing. And I don't even know if people know what antibiotics are

> or what they do. In some cases, they just see an injection going in and assume that that's what it is. And even when it might not be at all. Like so, this calcium injection, it's not an antibiotic at all, but that's what they saw, they saw an injection, they saw antibiotics fixed their animal. And the next time they walk in, and they want the same thing, so they request it again.'
>
> Interviewee 4, first opinion, less than five years of experience

This client pressure to prescribe antimicrobials can influence some veterinarians as they feel the responsibility to keep clients or managers happy.

> 'And I've definitely worked in places previously where it's about trying to keep the client happy and so I've definitely been in places where if you haven't given antibiotics cause you don't think it's warranted, the clients come back a day later with a complaint because the animal didn't get better. It sees another vet, or your boss or something. And they say, "Well, why didn't you give it antibiotics? Here, have this". It gets better within two days and then you're in trouble for not, I guess, treating appropriately. Or from your boss, mainly just for not keeping the client happy.'
>
> Interviewee 4, first opinion, less than five years of experience

Yet, overall, companion animal owners are likely to trust or accept the advice from the veterinarians on AMU. Explaining to companion animal owners the consequences of overuse and misuse of antimicrobials is key to making them understand that not every case requires these drugs.

> 'The ones that push for it, once you've explained that you feel it's not needed, is a much lower percentage, I think. I'd probably say there's only maybe 10 or 20% that try to debate with you about whether or not you're right, most of them will go "Ok, fair enough". They often jump straight to antibiotics because they almost assume they're a cure, they don't really get the concept between, well, this is a viral infection, so antibiotics probably aren't that helpful. And so, I'd say it's probably about 60-70% suggest it, 10 or 20% would be willing to debate with you about it.'
>
> Interviewee 10, first opinion, less than five years of experience

Motivation

Several barriers and enablers tapped into veterinarians' motivations, which are defined as the brain processes which direct our decisions and behaviors. The COM-B model differentiates between automatic motivation (i.e. emotions and impulses) and reflective motivation (i.e. evaluations and plans) (14).

D3 Social/professional role and identity

Role of veterinarians in tackling AMR

In this study, all veterinarians acknowledged their responsibility in taking action to mitigate AMR. They recognize that this responsibility is a shared one, and instead of accusing a particular individual or stakeholder, they are aware that everyone involved in the development, prescription, or use of antimicrobials in both human and animal medicine bears responsibility.

> 'I think everyone really because the people that are prescribing the antibiotics play their part in things, the people that are taking the antibiotics also so not finishing a course of antibiotics and things like that also doesn't help the situation. So, I'd say everyone, I'd say medical professionals and the general public, maybe without knowing, but yes.'
>
> Interviewee 13, first opinion, less than five years of experience

Yet, some participants believe that the small animal sector was using antimicrobials in a more responsible way than the large animal sector. They attributed the misuse or overuse of antimicrobials in the latter mostly to farmers.

> 'I think on veterinary medicine in the small animal side we're pretty good, but then I think the farm animal side you often have farmers just using them whenever they want and literally prescribing them themselves like and just injecting an unknown amount into an animal just to see if it helps a bit.'
>
> Interviewee 8, referral practice, less than five years of experience

<u>D6 Belief about consequences</u>

AMR consequences

There is a good understanding among participants of the potential consequences of AMR. Among them, the impact of AMR on animal production, animal welfare, human livelihoods, and public health were mentioned, underscoring veterinarians' One Health approach to this issue. Participants also recognized that the development of AMR can lead to treatment failures or longer treatment periods down the line. Moreover, a few participants mentioned that they were already experiencing the consequences of AMR in their daily practice.

> 'I've had a few kinds of cases on a smaller level, so things like ear infections for example, where the same patient has come in and they've been given antibiotics after antibiotics like topical antibiotics, and eventually it gets to a point where the patient is resistant to a lot of the mainstream ones that we would use.'
>
> Interviewee 13, first opinion, less than five years of experience

> 'I think it could be really bad and we have just diagnosed two cases of MRSP in our hospital recently on orthopedic procedures, and luckily, they are responding to flushing

> and some sort of topical treatments, but you know it potentially would have been like amputation for those animals. So, it's the potential of being able to sort of have treatment options and not.'
>
> Interviewee 11, first opinion, more than 10 years of experience

It was also pointed out by one participant how veterinarians delaying the use of antimicrobials can impact trust in the veterinary profession.

> 'I think I worry that people are not well versed enough in when to seek professional help or they're unkeen to come back again because say, they've spent the money on the first appointment and then if it was getting worse then they are unkeen to come back to re spend the money. Also losing faith in vets because say something gets worse, then they might say "If you just give them in the first place…".'
>
> Interviewee 3, first opinion, between five and 10 years of experience

D13 Emotion

Veterinarians concern for animal welfare

Some participants have linked their antimicrobial prescribing behaviors to animal welfare in different ways. On the one hand, almost half of the veterinarians highlighted the key role that antimicrobials could play in ensuring animal welfare, therefore, the need to preserve their efficacy and use them responsibly. While on the other hand, one participant justified AMU without testing on animal welfare grounds.

> 'Sometimes animal welfare needs to be prioritized and sometimes we know that we need to give antibiotics for something but we don't have culture sensitivity for a variety of reasons, I need to give antibiotics for animal welfare but I am not sure if I am giving the right antibiotics and if there will be resistance to the antibiotic I am giving.'
>
> Interviewee 1, first opinion, less than 5 years of experience

Fear of consequences of not using antimicrobials

A key driver of irresponsible prescribing mentioned by some participants was related to fear. These feelings related to concerns around the negative consequences that not treating an infection could have for animal health and welfare, but also for themselves professionally. Although veterinarians were aware of AMR, the fear of the situation getting worse could still influence their antimicrobial prescribing behavior.

> 'I suppose there's a few, so there's the genuine risk, so not using antibiotics where they would have been appropriate and allowing infections to get out of control, resulting in illness for those animals, and again if taken to extremes, if you're not using antibiotics

when you should have done, they could become very ill, they could potentially die. But there's also less tangible risks that are more client based, so if you decline to prescribe antibiotics and a client has a view that their animal has become sick because of it, whether or not that is true, then that potentially results in a lot of stress for the clinician, possibly inquiries being raised, and the potentially claims against the member of staff getting raised, that is really difficult to deal with as a practice and as an individual. It would make you worried for your status as a vet (…) So, it's deeply unpleasant from that point of view, which I think is a lot of what people will often prescribe antibiotics just to be safe for that reason. And I suppose the other consequences, if you think you might need antibiotics and you don't prescribe them and you were wrong, there is the fear of getting that wrong and having the responsibility for that animal getting sick on your hands so there's the emotional consequence there, if you make the wrong decision.'

Interviewee 10, first opinion, less than five years

Discussion

Our findings illustrate barriers and enablers at the individual, interpersonal, and environmental levels influencing AMU among participating veterinarians working with companion animals in the UK. They illustrate the complexity of the behavior under study, as suggested by the research analyzed during the literature review phase. Factors identified included the level of awareness of veterinarians on AMR, need to educate companion animal owners on AMR, training and access to information (capability), use of laboratory testing, type of practice, workplace policies, availability of alternatives to antimicrobials, ease of administration of formulations, and social influences from peers, employers and companion animal owners (opportunity), perceived veterinarians' professional role on tackling AMR, beliefs about the consequences of AMR, concerns for animal welfare and fear of the consequences of not using antimicrobials (motivation).

The findings will be discussed hereafter according to the COM-B model sources of behavior.

Capability reflects veterinarians' psychological and physical ability to engage in the desired behavior (14).

Knowledge of AMR was identified as a driver of the capability of veterinarians to engage in responsible antimicrobial prescribing behaviors. Yet, even if veterinarians demonstrated a clear understanding of the mechanisms of the development of AMR, there was also a negative perception among participants on the quality of the training and education received in terms of AMU at vet

school. The training programs were often perceived as basic, repetitive, and poor in terms of their practical implementation.

Based on the intervention functions of the behavior change wheel, education and training can be useful to ensure veterinarians have adequate knowledge of the positive consequences of responsible AMU (14). Additionally, the provision of high-quality veterinary education is key to equipping potential veterinarians with the necessary knowledge to perform efficiently. In this regard, at the national level, the RCVS considers responsible and correct antimicrobial prescribing practices as part of the skills needed for veterinary students upon graduation to ensure that they are prepared for their first role in the profession and it is safe for them to practice independently (62). At the global level, WOAH provides guidelines on the veterinary education core curriculum as well as recommendations on the competencies of graduating veterinarians (60). Both documents address the need to develop capacities on AMU. To make sure that these recommendations are well implemented at the national level, WOAH has developed a Veterinary Education Twinning Programme providing the opportunity for education establishments to modernize their curriculum and the ways in which it is delivered (63). This could be considered as an intervention to address the needs identified by the participants.

At the same time, behavior change interventions should also focus on the continuous training of veterinarians on AMU, as none of the participants in the study reported to have ever chosen this topic as part of their CPD. The need to improve ongoing training has been also reported previously in the literature. A study conducted in Ireland with veterinarians working on dairy farms concluded that access to training on AMR and reducing AMU could be improved (64). An option that could be explored as a way of overcoming this barrier would be introducing AMU as a compulsory element of the CPD programs for veterinarians or offering compensation to those taking part in them, as a way to encourage professionals.

While veterinarians who participated in this study are aware to some extent of the existence of guidelines on AMU at national and regional levels, they also seem to ignore the resources available at global level. A better dissemination is needed in order to make sure that they have access to this comprehensive set of recommendations too. Further studies to assess the effectiveness of guidelines to change prescribing behaviors could also be an asset.

This study also suggests that companion animal owners should be better educated about the risks associated with AMR to improve the relationship with veterinarians when it comes to optimizing AMU. This is in line with objective one of WOAH's *Strategy on AMR and the Prudent Use of Antimicrobials* in animals, which is to improve awareness and understanding of AMR through effective

communication, education, and training (12). Communication and marketing interventions should be evaluated in this regard, including the development of specific tools targeted at general audiences that use plain language to educate on AMR, as suggested by some participants. According to past research, these tools should be part of a multi-modal education campaign coupled with stewardship actions conducted by the veterinarian in order to be effective (65).

Opportunities are all the factors that lie outside the individual and make responsible antimicrobial use possible or prompt it (66).

The impact of cost and time on the possibility to perform antimicrobial susceptibility testing has been reported by veterinarians previously in other studies. For instance, companion animal veterinarians working in the UK have also acknowledged not using diagnostics as much as they should due to these reasons (41). A study conducted in Italy has also shown that the rate of use of laboratory tests to support prescribing decisions can be very low. In this retrospective, cross-sectional study, over 1000 antimicrobial prescriptions not related to a surgical procedure were analyzed. According to the findings, antimicrobials prescribed with the support of microbiological analyses and susceptibility testing were less than 5% (44). The development of more affordable and rapid diagnostic tests could improve their use, enabling the prescription of the most suitable antimicrobial. New business models for small animal clinics could also be introduced as a way of integrating testing into packages of subscription-based services making them more affordable for companion animal owners.

Accessibility to alternatives could also influence decision-making in antimicrobial prescribing. The findings of this study suggest that most veterinarians would recommend alternatives to antimicrobials to companion animal owners when they are as effective as antimicrobials, yet only half of the participants perceived that more alternatives are currently available in the market compared to when they graduated from university. While the literature suggests that ongoing research is likely to generate new methods of disease control, few of these methods will become available in the near future (67). According to the Global Leaders Group on AMR, research and development (R&D) on AMR in animals is weak: nearly 90% of R&D investments are in human health, whereas 70% of antimicrobial consumption is in animals (68). More investments in the animal health sector are needed to achieve sustained progress in this area. In a similar way, investment in the development of new formulations could also support responsible AMU, considering that ease of administration was identified as another factor influencing antimicrobial prescription in this study as well as in a survey conducted by the Heads of Medicines Agencies and the FVE in 2013. This survey was completed by 3004 practitioners from 25 European countries. The mean score of importance given by companion animal veterinarians from seven different countries for the ease of administration was 2.80 on a scale of 0–4 (0 – not important; 4 – most important) (69).

The findings of this study suggest that behavior change interventions should take into account the various social influences from peers, managers and companion animal owners on veterinarian prescribing practices.

Peers can play an important role in the decision-making process for antimicrobial prescription. According to this study, most veterinarians felt positively supported by colleagues within their close circles. A systematic review also found that social norms and peer-to-peer influence were important for veterinarians in changing their AMU, with more experienced veterinarians influencing younger professionals' treatment plans but younger veterinarians increasingly becoming a source of advice on preventive management practices for older veterinarians (70). These findings highlight how peer-to-peer problem-sharing and learning could be an excellent way of promoting responsible antimicrobial use by veterinarians. Therefore, peer support groups could contribute to veterinarians' intention to change their behaviors. Developing supportive communities to enable veterinarians working on farms to champion good antimicrobial stewardship is also proposed as an intervention by Regan *et al.* (2023), addressing stakeholder feedback as well as design and delivery of this initiative. In the same study, the idea of creating a forum for veterinarians to address mutual challenges and learn about feasible alternatives within their own practices was considered as a positive initiative by the participants (71).

Client pressure has largely been reported in the literature as a barrier to responsible AMU by veterinarians working with different animal species, either in the agri-food sector (70), or with companion animals (72). Yet, according to a study conducted by Smith *et al.* (2018) and in contrast to vet perspectives, companion animal owners, on the whole, denied that they would be dissatisfied if their pets were not prescribed antimicrobials. This suggests a shared tendency among companion animal owners and veterinarians to externalize the drivers of inappropriate prescribing (72). Enabling better communication between companion animal owners and veterinarians regarding antimicrobials could prove useful to manage expectations of animal care, including AMU. Interventions should include professional development for veterinarians, particularly those in the early stages of their careers, to better guide conversations about AMU. Sufficient time within consultations is needed to allow veterinarians to provide relevant information and educate companion animal owners around alternatives to antimicrobials, as suggested by one participant. Indeed, a survey conducted by Corah *et al.* (2019) with 307 respondents working in first-opinion practices reported a growing call in the UK for longer consults. According to the survey results, veterinary consults were scheduled for 15 minutes (153/307, 49.8%) with the second most commonly scheduled allocation being 10 minutes (121/307, 39.4%) (73). Additionally, opportunities for experienced veterinarians to share how they handled certain clinical situations, particularly those which may have involved a difficult client may

help improve veterinarians' confidence in their knowledge and decision-making and minimize the effect of companion animal owners' pressure on the selection of animal therapy. All these efforts could lead to improved recognition and management of situations where companion animal owners exert pressure to prescribe antimicrobials. Previous research also suggests that interventions for veterinarians should be run in parallel with complementary ones for companion animal owners (72).

Participants within this study did not experience a similar pressure from their employers. The same was observed in a study conducted in Australia where veterinarians, as well as doctors and dentists, did not perceive pressure from supervisors or colleagues as a barrier to prescribing antimicrobials (74). Yet, some veterinarians interviewed in this study reported that practice owners could influence their prescribing behaviors through the development of policies or protocols on AMU in the clinic. Most of these policies were reported to be influenced by financial factors, in addition to supply or stock reasons when they were related to the availability of antimicrobials in the practice. Therefore, interventions that address the financial aspects of prescribing have the potential to improve decision-making in veterinary medicine. Some employers may benefit from further education on the business opportunities of sales of vaccination to prevent disease as opposed to sales of antimicrobials to treat disease, while helping to slow the emergence of AMR. Employers should also be aware of the potential impact of the control of prescribing practices of their employees, as it could be perceived as restriction of their clinical autonomy, as suggested in the literature (72).

Motivation reflects the brain's processes which energize and direct behavior (66).

All the participants interviewed in this study acknowledged the shared responsibility of veterinarians in this global health challenge, which differs from the views of veterinary students in the UK reported by Golding *et al.* (2022) (46). Yet, some of them also expressed that they were less concerned about the development of AMR than farmers and veterinarians working with food-producing animals.

Veterinarians also seem to be well aware of the AMR consequences in different areas such as human health, animal production, and animal welfare, among others. Smith *et al.* (2018) reported that potential, ambiguous and future consequences of AMR for veterinarians were not as determinant on AMU as the present lived experiences of pressure from companion animal owners, and business pressures around client satisfaction (72). Yet, some participants in this study mentioned that they are already experiencing the consequences of AMR in their daily practices and, therefore, this might be influencing their antimicrobial prescribing behaviors.

Concerns for animal welfare were reported as a barrier to responsible AMU in this study. Similarly, in a survey conducted in Europe, veterinarians working with different types of animals acknowledged

not taking responsible use warnings into account because they did not want the animals to suffer longer than necessary (34). Infection prevention and control factors were identified as enablers of appropriate prescribing (41) and could be introduced as a way to change behaviors through the availability of alternatives to ensure animal health and welfare. As previously mentioned, it can be recommended to policy makers that they develop continuous training programs for veterinarians on alternatives to AMU, including vaccines, as well as on how to encourage uptake among companion animal owners to overcome this barrier and reassure veterinarians that it is possible to maintain animal welfare while prescribing antimicrobials responsibly.

Findings from this study suggest that veterinarians have strong emotions associated with reducing AMU and thus any intervention in this area has to address these feelings. Some participants described the cautionary prescribing antimicrobials to mitigate against potential future clinical complications or damage to their reputation. These results echo a study investigating prescribing behavior in cattle veterinarians in Ireland where several non-clinical issues were found to influence the decision on whether or not to prescribe antimicrobials, such as the fear of being blamed should antimicrobial therapy prove necessary later on and the potential legal consequences (75).

The adoption of the COM-B model in this study has provided a better understanding of the underlying mechanisms which influence veterinarians' behavior related to AMU in companion animals.

Limitations

The author acknowledges that there are a number of caveats to the design of the present study that could be addressed in future research. First, even if the author reached data saturation, the sample size is small and may not allow extrapolation of results to the whole companion animal veterinarians population in the UK. However, time limitations did not allow for the sample size to be enlarged. Second, the possibility of selection bias may limit our findings. Veterinarians who opted to participate in the study may be particularly motivated to participate in research about AMR. Therefore, they could be more informed on best practices regarding AMU and more adherent to the guidance available. Third, the author acknowledges that some participants might have provided the answers that they thought were ‘correct’, in particular for sensitive questions, so there could be a response bias. Fourth, all the interviewees were women, regardless of the intention to have gender diversity in the sample. This could be linked to the continuing ‘feminization’ of the veterinary profession. A survey conducted across Europe by FVE in 2018 states that while the sector remains somewhat gender balanced there has been a slight increase in the proportion of female veterinarians since 2015 (from 53% to 58%). In particular, in the UK, 55% of veterinarians are female (76). Further research is needed to ensure gender diversity in the findings. Lastly, we recruited participants working only in the UK, which may not be representative of practices in other countries.

Utility of the TDF and COM-B model

The COM-B model offered a systematic, theory-driven approach to identifying barriers and enablers to responsible AMU among veterinarians working with companion animals. Overall, by using this framework, we were able to first conceptualize the findings more broadly within veterinarians' capability, opportunity, and motivation, and then use the TDF domains to provide a more granular understanding of the barriers and enablers. Using this deductive analysis approach can potentially restrict findings to the COM-B components and TDF domains; however, by using a thematic analysis with a mixed approach that combined a deductive with an inductive analysis, we were able to identify overarching themes of barriers and enablers to responsible antimicrobial prescription. The next step will be to implement the behavior change wheel to identify intervention components aimed at overcoming the barriers and enhancing the enablers presented in this study. Additionally, further research with veterinarians could contribute to triangulate our findings or identify additional barriers and enablers.

Conclusion

This research provides an insight into veterinarians' AMU behaviors in the UK. To the author's knowledge, this is the first study of the enablers and barriers to responsible antimicrobial use in companion animals in the UK that uses the COM-B model, although several studies have examined attitudes and knowledge about AMR and the impact of AMU in companion animals, as well as in other animal species.

This study identified the barriers faced by veterinarians which included a lack of adequate training, ease of administration of the different formulations, pressure from companion animal owners or employers, fear of the consequences of not prescribing antimicrobials and the need to educate companion animal owners. On the other hand, veterinarians having a good understanding of AMR and its consequences, acknowledging their role in this global health challenge, receiving positive peer support, and having access to information and alternatives to antimicrobials can play a role as enablers of responsible AMU. The type of practices and its policies, as well as the access to laboratory testing and concerns for animal welfare, could act either way as a barrier or as an enabler depending on the context and specific situation.

Applying the COM-B framework to understand behaviors has revealed opportunities for empowering veterinarians' involvement in supporting responsible AMU. Some of these opportunities address the need to enhance veterinarians' education and training on AMU as well as on how to communicate with companion animal owners, while others are targeted to the pharmaceutical industry to

encourage the development of rapid and affordable diagnostic tests, alternatives to antimicrobials and new formulations that can ease antimicrobial administration. Employers are also addressed as they could come up with new business models or protocols that foster the implementation of preventive measures, such as vaccines, and the performance of susceptibility testing. Therefore, the factors and recommendations presented in this research have positive implications as they could be used to identify interventions for promoting responsible AMU in the future.

Appendix

Mg/kg for dogs and cats

In this metric, 'mg' refers to the weight of antibiotic active ingredient sold for use in companion animals. Topical products (e.g. those for treating eye, ear and skin infections) are excluded. The denominator is the estimated weight of the whole companion animal population at risk. The total number of companion animals in the UK is estimated using statistics from the PDSA PAW report, which is a survey that is representative of the UK companion animal-owning population. This is then multiplied by the aggregated mean weight for all adult companion animals registered at practices participating in the Small Animal Veterinary Surveillance Network (SAVSNET) between 2013 and 2021 (excluding animals aged under 2 years, over 22.5 years for dogs and 27.5 years for cats and/or with unrealistic weight measurements) (19).

The metric is calculated separately for dogs and cats, with the amount of antibiotic active ingredient separated by dog and cat. For products licensed for more than one species, the relative amount of total product sold which is consumed by dogs and cats has been estimated. Estimates are obtained by the UK's Veterinary Medicines Directorate from stratification data provided by the Market Authorisation Holder (MAH) for each product. The stratification data indicates the percentage of each product which is estimated to have been used in dogs and in cats, respectively, in any given year. Only products which were licensed for dogs and/or cats +/- other species commonly seen in small animal practices (e.g. rabbits, rodents, and exotics) were considered. Products indicated for dogs and/or cats alongside horses and/or food-producing animals were not considered, as it is harder to accurately provide stratification estimates for these products, which are primarily injectables and are used increasingly in food-producing animals (19).

The average number of daily defined doses per animal per year (DDDVet/animal) for companion animals

The main issues with using mg/kg for trend monitoring in companion animals are that it underestimates the use of long-acting injectables (which are very commonly used in cats) and there are also some big variations in dose rate and drug potency. For example, marbofloxacin has a dose

rate of 2 mg/kg/day, whereas metronidazole has a dose rate of 50 mg/kg/day. For this reason, companion animal trend sales data for systemic antibiotics is presented and calculated using the average number of daily defined doses (DDDVet) per animal per year (DDDVet/animal) (19).

The DDDVet is defined as the assumed average dose per kg animal per species per day. These standard daily doses are extracted from the Summary of Product Characteristics (SPC) for each antibiotic product. If there is a dose range, then the lowest dose was chosen, and where the dose rate varies between products with the same active ingredient/route of administration, then the median dose rate was selected. For long-acting products, the DDDVet is calculated by dividing the daily dose rate with the length of activity for that product (19).

The DDDVet/animal is calculated (for each active ingredient/ route of administration and for both dogs and cats) using the method below:

$$\frac{\text{Total amount of active ingredient (mg)}}{\text{(DDDVet (mg/kg/day) * total animal population weight at risk (kg))}}$$

The results are then added together to get the total figure. The mg of antibiotic active ingredient and total weight of animal population at risk is calculated in the same way as described above for the mg/kg calculation (19).

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