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Influences on nurses' engagement in antimicrobial stewardship behaviours: A multi-country survey using the Theoretical Domains Framework

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ABSTRACT

Background: Antimicrobial resistance (AMR) is significantly affected by inappropriate antibiotic use, and is one of the greatest threats to human health. Antimicrobial stewardship (AMS) is a programme of actions promoting responsible antimicrobial use, and is essential for limiting AMR. Nurses have an important role to play in this context. **Aim**: This study investigated the determinants of nurse AMS behaviours and the impact of past training.

Method: A cross-sectional multi-country survey design with mixed methods was employed. Participants were 262 nurses (223 female; mean age = 44.45; *SD* = 10.77) from ten nationalities, with individual survey links sent via professional networks in 5 countries. Nine AMS behaviours and 14 behavioural determinants were quantitatively assessed using the Theoretical Domains Framework (TDF), and mapped to the COM-B (Capability, Opportunity, Motivation – Behaviour) model. Analysis identified differences between nurses with and without AMS training. The influence of COVID-19 on AMS behaviour was qualitatively investigated using free text data.

Findings: Nurses performed all nine AMS behaviours, which were significantly higher ($t(238) = -4.14$, $p < .001$), by those who had training ($M = 53.15$; SD = 7.40) compared to those who had not ($M = 48.30$; $SD = 10.75$). Those with AMS training scored significantly higher in all of the TDF domains, with 'Skills' and 'Behavioural Regulation' (e.g. ability to self-monitor and plan), being the most predictive of AMS behaviour ($R^2 = .27$). Both of these domains are situated in the Capability construct of COM-B, which can be enhanced with the intervention strategies of education and training. An increase in AMS behaviours was reported since COVID-19, regardless of previous training. Six core themes were linked to AMS: *1) Infection prevention and control, 2) Antimicrobials and antimicrobial resistance, 3) The diagnosis of infection and the use of antibiotics, 4) Antimicrobial prescribing practice, 5) Person-centred care,* and *6) Interprofessional collaborative practice.*

Conclusion:

This research, has identified the significant benefit of nurse training on AMS behaviour, and its determinants. AMS education and training should be offered to nurses to enhance Knowledge, Skills, Social/Professional role and identity, Beliefs about capabilities, Optimism, Beliefs about consequences, Reinforcement, Intentions, Goals, Memory, attention and decision making, Environmental context and resources, Social influences, Emotion, and Behavioural regulation. Future research should consider the optimal level of training to optimise AMS behaviour, with a focus on developing skills and behavioural regulation.

INTRODUCTION

There is a significantly higher use of antimicrobials per capita in both high and low-middle income countries, than in previous decades [1-2]. Antimicrobial resistance (AMR) which is affected by inappropriate antibiotic use, is one of the greatest threats to human health. It causes an estimated 4.95 million annual deaths associated with bacterial AMR, including 1.27 million deaths directly attributable to bacterial AMR [3]. This figure is predicted to rise to 10 million deaths per year, alongside a cumulative cost of $100 trillion, by 2050 if no action is taken [4].

Antimicrobial stewardship (AMS), a programme of actions promoting optimal antimicrobial use, is recognized as essential for limiting AMR [5]. Restrictive and persuasive activities and strategies are commonly included within these programmes [6]. Nurses play an important role in AMS efforts [7-11], with evidence suggesting that AMS interventions targeting nurses, can lead to improvements in overall volume and quality of antibiotic use [12-13]. Nurses worldwide perform numerous activities that are integral to successful antimicrobial stewardship including antibiotic prescribing [14,8], antibiotic preparation, administration, specimen collection, reporting and interpretation of laboratory results, monitoring treatment and reporting of adverse events, which all align with nursing roles [15]. Although an applied discipline, nursing is implemented differently based upon the social, political, and cultural climate within which it is practiced. However, international [16], and national [17] nursing definitions and descriptions share key features including a common purpose, values, and functions, incorporating as its clientele, individuals of all ages, families and groups [17]. The rapid emergence and transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has also highlighted multiple areas in which competencies in AMS by nurses can support response efforts [18]. These areas include the ability to differentiate between viral and bacterial infections, implement infection prevention and control (IPC) measures to prevent transmisison, practice collaboratively with multi-healthcare professionals and question the use of antibiotics and so reduce their unnecessary use [18].

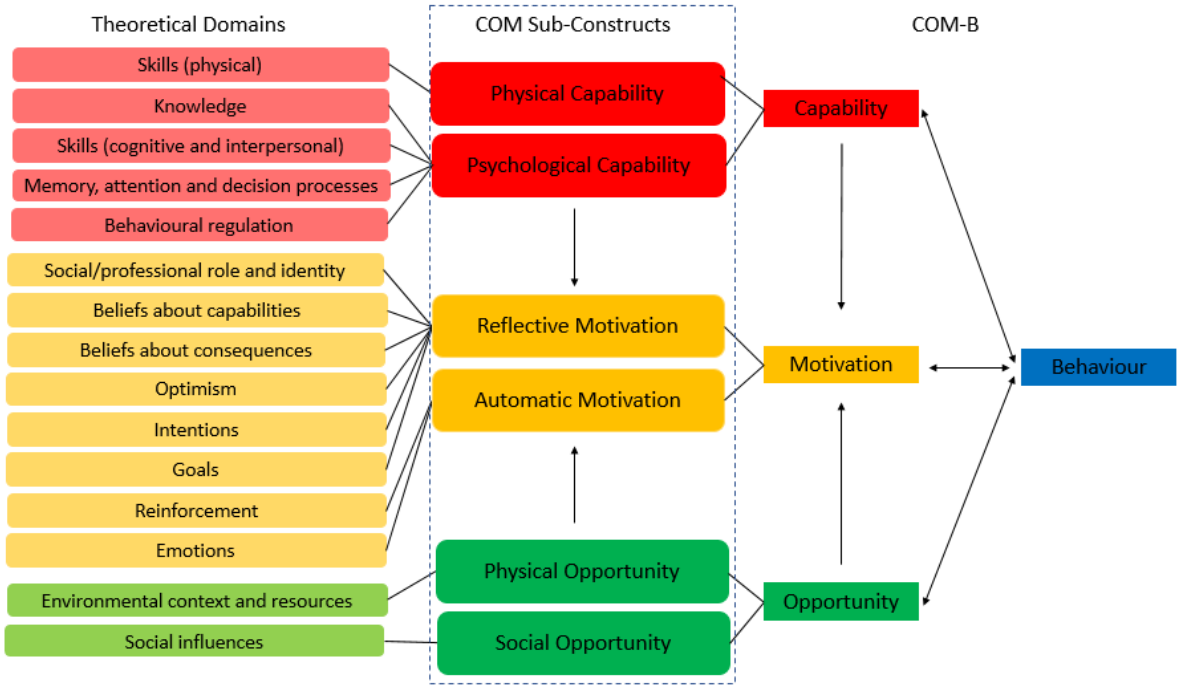
The role of nurses within AMS programmes is not clearly articulated, and nurses' impact on AMS is not clearly understood [19-20]. There is evidence available that has identified barriers to nurses engagement in AMS. These include AMS not being taught in undergraduate nurse education programmes [21, 22], nurses reporting poor knowledge of antibiotics and AMS [23-24], professional relations and hierarchies [25], a lack of involvement by nurses into AMS programmes, a lack of empowerment in terms of interprofessional roles and teamwork, and a lack of clarity around the roles and responsibility of nursing within new AMS driven procedures [26].

Barriers to engagement in AMS activities must be addressed to successfully change behaviour. Growing evidence supports the use of theory to identify barriers and facilitators to changing practitioner behaviour [27-28]. The use of theoretical frameworks in order to understand behaviour [29] has previously been applied to gain insight into antibiotic prescribing of nurses [30]. The Theoretical Domains Framework (TDF) [31] provides a theoretical lens to understand the determinants of behaviour. It was developed from 33 evidence-based theories and models in behavioural science and health psychology and provides a conceptual framework for the design of interventions to enhance healthcare and to understand behaviour-change processes [31-32]. The TDF combines complex theories of behaviour into a simplified and accessible framework that consists of 14 domains (*1.Knowledge, 2.Skills (psychological and physical), 3.Social/Professional role and identity, 4.Beliefs about capabilities, 5.Optimism, 6.Beliefs about consequences, 7.Reinforcement, 8.Intentions, 9.Goals, 10.Memory, attention and decision making, 11.Environmental context and resources, 12.Social influences, 13.Emotion, 14.Behavioural regulation*) related to the underpinning of behaviour. The TDF has been used widely, including to understand prescribing behaviour [30, 33, 34].

Once determinants of behaviour are identified and understood, targeted interventions can be developed. The Behaviour Change Wheel (BCW) [29] is a three-layered whole-system approach to intervention design, delivery and evaluation. The TDF has been incorporated into the BCW as a fourth layer, and mapped to the hub of the wheel [29], known as the COM-B model. A visual representation of these theoretical constructs can be seen in Figure 1. The COM-B highlights the importance of specifying a 'problem' (e.g. AMR) in behavioural terms (e.g. AMS behaviours), and then considers three key contructs: Capability, Opportunity and Motivation, (COM) that influence Behaviour (hence COM-B). Once TDF and COM-B barriers and facilitators have been identified, intervention functions (e.g. education, training, modelling) can be used to intervene with and/or promote these COM factors. The final layer of the BCW considers policy categories that can support structural level change. The COM-B model can enable a behavioural diagnosis by understanding the determinants of behaviour, highlighting an individual's capability, both physical (such as skills) and psychological (such as knowledge); their opportunity, both social (e.g. norms of practice) and physical (e.g. time/space); and motivation, both reflective (e.g. beliefs in capabilities and consequences) and automatic (e.g. emotion).

Figure 1

The Theoretical Domains Framework mapped to the sub-constructs of capability, opportunity and motivation from the COM-B model



AIM

This study aimed to investigate nurse's engagement in AMS behaviours, and what might influence this using the TDF. It further sought to understand if AMS training had any influence on the TDF determinants and AMS behaviour. And finally, whether AMS behaviour changed as a result of COVID-19.

METHOD

Ethical consideration: The School of Healthcare Sciences Research Governance and Ethics Committee, Cardiff University, provided ethical approval (reference number REC743). Additional ethical approval was provided by the University of Sao Paulo Human Research Ethics Committee (reference number: 4.362.076) and Pro-Cardiaco Hospital, ESHO Hospital Services Company Research Ethics Committee (reference number: 4.564.698).

Design*:* Cross-sectional survey design.

Recruitment and Participants: One hundred and seventy-six personalised study invitation links were emailed to potential participants (frontline, patient-facing registered nurses), across

five countries (UK, Brazil, USA, South Africa, Spain), with 136 completing this version of the survey (77.27% response rate). An additional public link was used via social media, from which a further 126 participants responded. This yielded a total of 262 responses from the following nationalities: British (n = 134; *[which included Scottish n = 11; Welsh – 5]*), Portuguese (n = 43), Brazilian (n = 19), South African (n = 14), Spanish (n = 13), American (n = 12), African (n = 12), Asian (n = 5), Irish (n = 2), Australian (n = 1) and 7 undisclosed. The mean age was 44.45 years (*SD* = 10.77; range = 23 - 70), with 223 female, 37 male, 1 non-binary and 1 non-disclosed.

Materials: 'Online Surveys' (a tool for creating web surveys) was used to host the three-section survey (see Supplementary file 1) for data collection. This was presented in English and Portuguese to represent the settings in which the research team were based. Translation was performed by a team of Brazilian researchers, checked for back translation and piloted with three volunteers. Section One invited participants to indicate (using a 7-point Likert scale; 1 = none of the time; 7 = all of the time) the extent to which they undertook nine AMS behaviours designed to promote responsible antibiotic use (based on Courtneay et al., 2019) [39]. Example questions were '*Apply standard infection control precautions in healthcare environments'; 'Recognise and act upon the signs and symptoms of infection and isolate patients as appropriate'; 'Collaborate with the interprofessional team, ensuring appropriate antimicrobial use'.* At the end of this section, participants were invited to indicate if their AMS behaviours had changed, increased or decreased since COVID-19. A free text comment box was provided for participants to describe their AMS behaviours since COVID-19. A total of 182 participants (69.5% of total sample) provided qualitative data.

Using a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree), Section Two assessed the 14 TDF factors that may influence nurses' engagement in AMS. Wording formats based on work by Huijg et al (2014) were used. These researchers identified 32 generic items (questions) to provide a robust basis for the development of a questionnaire to measure TDF-based determinants of healthcare professional implementation behaviour taking into consideration different target, action, context, and time. Questions for each domain include: 1) Knowledge (4 items) 'I know the content and objectives of the local/national guidelines that promote responsible antimicrobial use'; 2) Skills (3 items) 'I have the skills to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues'; 3) Social/professional role and identity (4 items) 'Doing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and colleagues is consistent with my role as a nurse'; 4) Beliefs about capabilities (4 items) 'I am confident that

if I wanted, I could perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues'; 5) Optimism (2 items) 'With regard to the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I'm always optimistic about the future'; 6) Beliefs about consequences (2 items) 'If I perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, it will benefit public health'; 7) Reinforcement (2 items) 'Whenever I perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I feel like I am making a difference'; 8) Intentions (4 items) 'I intend to perform the actions that promote responsible antimicrobial use within a hospital/community setting with patients, their carers and/or colleagues during my next shift'; 9) Goals (3 items) 'During my shift, something else on my agenda often takes precedence over the actions that promote responsible antimicrobial use with patients, their carers and/or colleague'; 10) Memory, attention and decision processes (4 items) 'During my shift within a hospital/community setting with patients, their carers and/or colleagues, I often forget to perform the actions that promote responsible antimicrobial use'; 11) Environmental context and resources (2 items) 'Within the socio-political context there is sufficient financial support (e.g. from local authorities/high administration) to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues'; 12) Social influences (2 items) 'Most people whose opinion I value would approve of me performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues'; 13) Emotion (3 items) 'During my shift, I am able to enjoy my normal day-to-day activities'; 14) Behavioural regulation (4 items) 'I have a clear plan about how I will perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues'.

Section Three collected general demographic information including age, gender, nationality, work/care setting, length of time in post, length of time qualified as a nurse. This section also collected details on training in AMS, asking the question '*Have you received any training in AMS?*' This was followed by '*If so how long was this training i.e. days/weeks/months'*. The full questionnaire was piloted on eight international participants (not included in the final study) in December 2020 prior to the main study data collection. No changes were necessary. Participants were able to complete the questionnaire without any difficulties.

Procedure: An opportunistic sampling method was used to recruit nurses, internationally. An email containing brief details about the study was sent by project collaborators, via a wide range of established nursing networks (e.g. The Infection Prevention and Control Network, Royal College of Nursing, the Infection Prevention Society, the Scottish Antimicrobial Nursing Group, the Critical Care Society of South Africa), to front-line patient-facing registered nurses. Nurses who were keen to take part, were invited to contact MC and provided with the opportunity to discuss any queries they might have. MC then emailed potential participants an information sheet and a personalised link to the online survey. Completion of the questionnaire implied consent to participate, all responses were anonymous. Data collection took place during February to June 2021, during the COVID-19 pandemic. The return of responses was slow. Feedback from networks via project collaborators was that, due to the pandemic situation, nurses were exhausted, working long hours with no time to complete the survey. The decision was made to copy the survey, making a second survey accessible via a public link. The public link was sent out via Twitter.

Data analysis: IBM SPSS (version 26) was used to clean data, code free text (e.g. to determine whether participants had previous training in AMS; changes since COVID-19), and screen for impossible values. A total score was created for the AMS behavioural questions (x9). Six of the TDF items required reverse coding (questions 31, 39, 40, 41, 43, 50). Reliability analysis was performed on the TDF domains, and means for each domain were calculated. Survey totals and means are presented as descriptive data, followed by inferential statitistics to assess 1) differences in AMS and TDF scores based on training using an independent t-test; 2) the ability of the TDF to predict AMS behaviours using a multiple regression with the additional presentation of correlational data; 3) the mapping of TDF data to the COM-B. Thematic analysis [35] and Content conceptual analysis [36] was used to qualitatively analyse free text data. This qualitative analysis involved the initial identification of commonly occurring themes, representing the range of responses. These themes were then broken down into mutually exclusive and exhaustive categories, and responses were assigned to categories and coded. The frequency of different thematic responses was then counted. This approach was chosen to allow data to be both analysed qualitatively, then transformed quantitatively to be used alongside the survey data.

RESULTS

Nurses performed all of the AMS behaviours (see Table 1), most commonly *'applying standard infection control precautions'*. The least performed behaviour was *'initiating the switch from intravenous antimicrobials to oral therapy and/or the discontinuation of antimicrobial therapy'.*

Totalling the AMS constellation of behaviours (9 items) provided good reliability at α = .84, with a range of scores from 12 – 62 (scale range = 7 - 63).

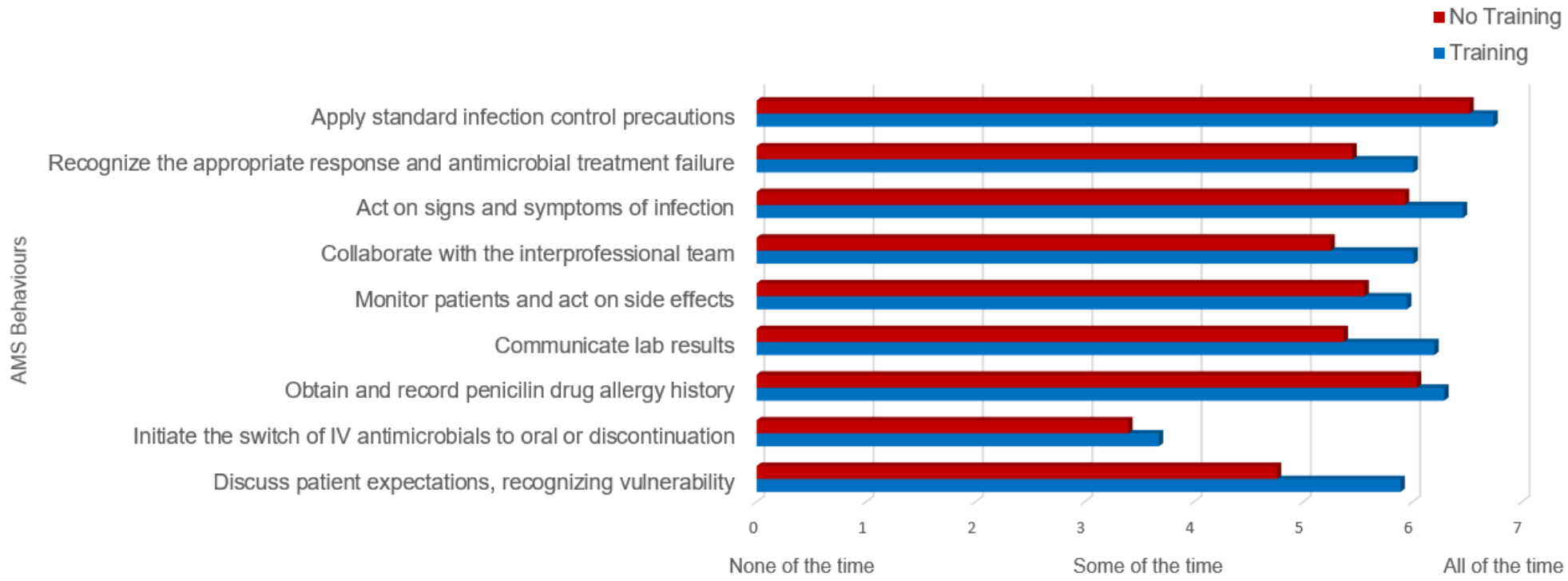
Table 1: Antimicrobial stewardship behaviours, total and with or without training (N=267)

Questions (scoring 1 = none of the time; 7 = all of the time)	Training						Difference		Total	
	No			Yes				Sig. (2-tailed)		
	Range	Mean	SD	Range	Mean	SD	*t*	*p*	Mean	SD
1. Apply standard infection control precautions in healthcare environment	1-7	6.52	1.03	3-7	6.74	.65	-2.05	***.041***	6.66	.83
2. Recognize the appropriate response to antimicrobial treatment and the main signs that demonstrate antimicrobial treatment failures	1-7	5.45	1.59	2-7	6.01	1.20	-3.15	***.002***	5.78	1.39
3. Recognise and act upon the signs and symptoms of infection and isolate patients as appropriate	1-7	5.93	1.67	3-7	6.38	.74	-3.17	***.002***	6.25	1.32
4. Collaborate with the interprofessional team, ensuring appropriate antimicrobial use	1-7	5.25	1.89	2-7	5.50	1.51	-3.93	***.000***	5.69	1.55
5. Monitor patients on antimicrobial therapy and act upon the common side effects associated with these antimicrobials	1-7	5.56	1.78	1-7	5.95	1.37	-1.94	***.054***	5.78	1.56
6. Communicate promptly when receiving laboratory results (i.e. culture and sensitivity) and review therapy	1-7	5.37	1.93	1-7	6.20	1.39	-3.98	***.000***	5.86	1.67
7. Obtain and record an accurate penicillin drug allergy history	1-7	6.04	1.62	1-7	6.29	1.50	-1.26	.211	6.19	1.54
8. Initiate the switch from intravenous antimicrobials to oral therapy and/or the discontinuation of antimicrobial therapy	1-6	3.40	1.77	1-6	3.68	1.89	-1.20	.231	3.59	1.85
9. Discuss with patient/carer their expectations of antimicrobials and the need to use them appropriately, recognizing patient vulnerability and those that need support	1-7	4.76	2.09	1-7	5.89	1.47	-5.02	***.000***	5.44	1.82

AMS total behaviour	12-62	48.30	10.75	27-62	53.15	7.40	-4.14	***.000***	51.22	9.16

Figure 2

AMS behaviours of nurses with and without additional AMS training



AMS Training

Of the 254 respondents for this question, *n* = 106 (41.7%) reported never having AMS training before, with *n* = 148 (58.3%) reporting having had some training. This training varied from two hours up to several hours and was updated yearly or comprised extended modules on the topic of AMS. The performance of combined AMS behaviours was significantly higher ($t(238) = -4.14$, $p < .001$), by those who had training ($M = 53.15$; $SD = 7.40$) compared to those who had not ($M = 48.30$; $SD = 10.75$). Looking at the AMS behaviours separately (see Figure 2), those who had received training scored significantly higher for seven of the nine behaviours, compared to those who had no training (see Table 1).

Theoretical Domains Framework

Reliability analysis indicated that 10 of the 14 TDF domains had a high or acceptable Cronbachs alpha (above .6) showing measurement consistency (see Supplementary file 2). The TDF domains that did not perform as well were; Beliefs about consequences α = .47 (2 items); Reinforcement α = .51 (2 items), Goals α = .03 (increasing to .33 when question 40 '*During my shift, something else on my agenda often takes precedence over the actions that promote responsible antimicrobial use with patients, their carers and/or colleagues'* was removed), and Memory, attention and decision making α = .34.

Influence of AMS Training to TDF domains

Independent t-tests showed that there were significant differences in all of the TDF domains between those who had and those who had not had training in AMS activities (see Table 2). In all cases, those who had training, scored higher in the determinants of behaviour, than those who had had no training. Linking these scores to the COM-B model (see Table 2), this shows that those who have had training had higher Capability, Opportunity and Motivation to perform AMS behaviours.

Correlational relationships

There were statistically significant correlations between the majority of the variables (see Table 3). Using an enter method to force all variables to be considered, the TDF was able to explain 27% of the variance in total AMS behaviours ($p = <.001$). Looking at the co-efficients, the significant influences within the model were 'Skills' ($p = .04$), 'Social/Professional role and identity' ($p = .02$), 'Beliefs about consequences' ($p = .04$), and 'Behavioural regulation' ($p = .02$); with a trend for Intentions ($p = .056$). A forward stepwise regression was then performed to identify which TDF items were best able to predict AMS behaviours. Two TDF items, 'Behavioural regulation' and 'Skills' were highlighted as responsible for the variance in AMS

behaviours. Together they achieved an R^2 of .21, with Behavioural regulation contributing an R^2 of .18 to the model, and Skills a further .03 R^2 change.

Table 2: Differences between TDF domains and AMS behaviour grouped by training

TDF domain and AMS	COM-B	Training	Mean	SD	df	Mean difference	t-test	p value
Knowledge	Capability	No	4.88	1.66	252	-1.11	-6.19	***.000***
		Yes	5.99	1.21				
Skills		No	5.10	1.82	252	-1.20	-6.43	***.000***
		Yes	6.30	1.15				
Memory, attention and decision making		No	4.66	1.23	252	-.39	-2.76	***.006***
		Yes	5.05	1.04				
Behavioural regulation		No	4.23	1.36	251	-.93	-6.07	***.000***
		Yes	5.16	1.09				
Social influences	Opportunity	No	5.03	1.61	251	-.81	-4.20	***.000***
		Yes	5.84	1.44				
Environmental context and resources		No	4.34	1.61	251	-.61	-3.09	***.002***
		Yes	4.95	1.49				
Social/Professional role and identity	Motivation	No	5.56	1.89	252	-.93	-4.94	***.000***
		Yes	6.49	1.10				
Beliefs about capabilities		No	5.15	1.75	252	-.97	-5.24	***.000***
		Yes	6.12	1.19				
Optimism		No	5.27	1.75	252	-.76	-4.21	***.000***
		Yes	6.03	1.11				
Beliefs about consequences		No	5.59	1.73	252	-.49	-2.55	***.011***
		Yes	6.08	1.33				
Intentions		No	5.50	1.85	252	-.85	-4.52	***.000***
		Yes	6.35	1.17				
Goals		No	4.15	1.18	252	-.49	-3.30	***.001***
		Yes	4.64	1.12				
Reinforcement		No	4.57	1.67	252	-.41	-2.16	***.032***
		Yes	4.98	1.35				
Emotion		No	4.67	1.51	251	-.69	-4.07	***.000***
		Yes	5.36	1.19				
AMS Behaviour	Behaviour	No	48.30	10.75	238	-4.85	-4.14	***.000***
		Yes	53.15	7.40				

Table 3

Correlations between TDF domains and AMS behaviour

Correlations between variables labelled below (horizontal and vertical axis are mirrored)		**1**	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**AMS Behaviour**	1														
2	Knowledge	**.39*****	1													
3	Skills	**.40*****	.78***	1												
4	Social/ Professional role and identity	**.29*****	.71***	.81***	1											
5	Belief about capabilities	**.36*****	.74***	.79***	.84***	1										
6	Optimism	**.32*****	.64***	.69***	.72***	.71***	1									
7	Belief about consequences	.07	.43***	.46***	.53***	.44***	.52***	1								
8	Reinforcement	**.23*****	.40***	.42***	.42***	.51***	.58***	.25***	1							
9	Intentions	**.34*****	.67***	.74***	.84***	.77***	.76***	.57***	.50***	1						
10	Goals	**.33*****	.50***	.52***	.50***	.59***	.45***	.33***	.34***	.48***	1					
11	Memory, attention and decision making	**.25*****	.47***	.45***	.44***	.51***	.50***	.39***	.40***	.43***	.48***	1				
12	Environmental context and resources	**.30*****	.39***	.46***	.41***	.45***	.44***	.19**	.38***	.42***	.42***	.32***	1			
13	Social influences	**.28*****	.62***	.65***	.64***	.65***	.60***	.43***	.43***	.71***	.45***	.43***	.44***	1		
14	Emotion	**.25*****	.56***	.57***	.57***	.60***	.65***	.46***	.48***	.55***	.50***	.58***	.45***	.47***	1	
15	Behavioural regulation	**.43*****	.60***	.60***	.56***	.62***	.50***	.19**	.43***	.54***	.53***	.39***	.45***	.51***	.42***	1

**Correlation is significant at the .01 level
***Correlation is significant at the .001 level

Changes since COVID-19

When asked if AMS behaviours had changed since COVID-19, on a scale of 1-7 (1 = strongly disagree; 7 = strongly agree), nurses responded with a mean of 4.35 (*SD* = 2.31), suggesting there was some agreement that AMS behaviours had changed. There was no real difference between those who had (*M* = 4.36; *SD* = 2.30) and had not (*M* = 4.40; *SD* = 2.3) received training. When asked whether AMS behaviours had increased, nurses responded with a mean average of 4.46 (*SD* = 2.24), suggesting that there had been some increase. Again there was no real difference between those who had (*M* = 4.44; *SD* = 2.25) and had not (*M* = 4.48; *SD* = 2.20) received training. Finally, when asked if their AMS behaviours had decreased since COVID-19, nurses responded much lower with a mean of 2.02 (SD = 1.63), closer to the 'strongely disagree' anchor, suggesting their AMS behaviour was less likely to have decreased. There was again no real difference between those who had (*M* = 2.01; *SD* = 1.60) and had not (*M* = 2.08; *SD* = 1.70) received training.

Qualitative findings

Free text comments reported the adoption of a number of AMS behaviours following COVID–19 (see Supplementary File 2). This included greater infection prevention and control (IPC) practices (i.e. increased use of PPE, hand hygiene and use of masks (n=11), greater cleaning of surfaces (n=3). Increased behaviours involving a) antimicrobials and the prevention of AMR (i.e. greater use of guidelines and diagnostic tests (n=1), increased monitoring of antimicrobial use (n=1)), b) the diagnosis of infection and the use of antimicrobials (including patient monitoring (n=2), access to timely treatments (n=2), testing (n=5), safety measures (including reviewing treatments prescribed by doctors to ensure appropriate and within guidlines) (n=5)) and, c) changes to antimicrobial prescribing practice (i.e. vigilant antimicrobial use (n=10), prophylactic use of antimicrobials (n=4)). Participants had also spent more time on patient-centred behaviours (including a greater number of virtual consultations (n=4), increased prescribing (n=3) and education (n=2)) and interprofessional collaborative practice (including greater communication with team members (n=5), and multi-disciplinary ward rounds (n=1)).

DISCUSSION

Behaviour change theory highlights the importance of understanding behaviour and the determinants of behaviour to facilitate the selection of intervention strategies and behaviour change techniques to change behaviour. This study has revealed that nurses engaged in all behaviours related to AMS, and to a higher level by those who had previous training. In understanding the determinants of AMS behaviours, ten of the TDF domains were found to significantly influence AMS behaviour, with Skills and Behavioural Regulation (e.g. the ability to self-monitor and makes plans) having the strongest predictive influence. This finding is in-

line with previous evidence that has used the TDF to explore nurses prescribing behaviour [33], and nurses antibiotic prescribing behaviour [30]. Behavioural Regulation has also been identified as an important strategy for antimicrobial stewardship in research with health professionals (including nurses) working in long-term care facitlities [37] and dental practitioners [38].

Those who reported receiving training in the area of AMS, reported significantly higher levels of knowledge and skills and had stronger beliefs around their social and professional role and identity in relation to AMS. They also held higher beliefs in their capability (confidence) to engage in AMS, were more optimistic and held more positive beliefs in the outcome (consequences) of AMS behaviours. Intentions and goals towards AMS were higher in those with past training, they engaged in better behavioural regulation, had higher memory,attention and decision making capability, and greater positive social influences and environmental opportunity to engage in AMS. They were furthermore more capable of regulating their emotion and less influenced by reinforcement (from their environment) than those without training. This gives a novel insight into the relevance of these factors that might influence AMS behaviour, and highlights the importance of education, training and environment in optimising nurses' engagement in AMS.

The education of undergraduate healthcare professional students, such as nurses, has been identified as a key activity for the containment of AMR [39]. Furthermore, the International Council of Nurses (ICN) [16] and nurse regulatory bodies [10] recommend the inclusion of AMS in undergraduate nurse education programmes. The current study provides evidence in support of these recommendations and highlights that the TDF determinants of AMS behaviour, and AMS behaviour itself are more favourable in those who had AMS training. Moreover, the most predictive domains of the TDF to AMS behaviours were 'Behavioural regulation' and 'Skills', both of which fall into the Capability construct of the COM-B model. Intervention functions most commonly used to address these constructs are education, training and enablement. AMS taught in UK pre-registration nurse education programmes is, however, inconsistent [24]. Educators, commissioners, regulators and healthcare leads, should, therefore, consider widening and providing nurse training in AMS. Environmental and social structures (e.g. local and national guidelines and point of care testing [30]) to support AMS should also be considered in this context.

While AMS behaviour since COVID-19 did not appear to differ between those who had, and had not received training, it did appear to increase across the cohort. These actions covered areas including; infection prevention and control, antimicrobials and antimicrobial resistance,

the diagnosis of infection and use of antimicrobials, antimicrobial prescribing practice, patient centred care and interprofessional collaborative practice. These areas have been identified previously as aligning with the nursing role [40] and recently included within pre-registration nurse education programmes [41]. This suggests that nurses were being extra vigilant since the COVID-19 pandemic.

STUDY STRENGTHS AND LIMITATIONS

The study drew from a wealth of expertise in a wide international collaboration of professionals working in nursing and AMS. It used a widely recognised theoretical approach that can be used for intervention development, providing considerable strength to the interpretation of data and future use of the evidence presented.

However, there are some limitations to our research. Single Likert scales with no before and after comparison are problematic, yet this study adds evidence that there may have been changes in nurses' AMS behaviour since the pandemic. Further research with better data collection methods is needed to see if nurses have had any impact globally on the actual use of antimicrobials during the COVID-19 pandemic.

While this study set out to look at nurse training, it was limited by the way the training was disclosed. Training varied from as little as a couple of hours once, up to several hours that was updated yearly or extended modules on the topic of AMS. Types of training were not identified, and future research should use better methodology for collecting such data. Here, where people reported doing their own research, this was not counted as training, as this may not have been focused and structured, with skill development. However, given the differing nature of the training disclosed, future research should consider more specific categorisation, or ways to assess professional development in this area. It would be of interest to consider the dose and frequency of training, type of delivery involved and whether there was any assessment, formative or summative.

The study findings may be limited further due to a high proportion of the sample coming from the UK, which may make the results less generalizable internationally. Results may be further limited by the varying roles of nurses across different counties, such as their ability to prescribe antimicrobials, however, this is not essential for AMS. There are also the usual limitations of self-report measures, that should be considered when interpreting evidence presented here.

CONCLUSION

This research, from an international nurse population, has identified the significant benefit of training on AMS behaviour, and the determinants of behaviour in relation to enhanced Knowledge, Skills, Social/Professional role and identity, Beliefs about capabilities, Optimism, Beliefs about consequences, Reinforcement, Intentions, Goals, Memory, attention and decision making, Environmental context and resources, Social influences, Emotion, and Behavioural regulation. This adds a novel contribution to the understanding of AMS by nurses, highlighting that the most significant predictors of AMS behaviour were skills and ability to regulate own AMS behaviour. COVID-19 led to an increase in AMS behaviours, regardless of previous training, though further research is needed to determine the impact nurses have on the use of antimicrobials globally. Evidence presented here offers a basis for future intervention development to optimise AMS behaviours, with education and training considered a priority worthy of investment and evaluation.

DECLARATION OF INTEREST

Declarations of interest: none

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Supplementary file 1: AMS and TDF Questionnaire

	TDF Questionnaire to understand what influences nurses engagement in antimicrobial stewardship (AMS) **Questionário TDF para compreender os fatores que influenciam o envolvimento dos enfermeiros em programas de gerenciamento de antimicrobianos (Antimicrobial Stewardship - AMS)**		
TDF domain **Domínio TDF**	**Question (1 strongly agree, 7 strongly disagree)** **Questão (1; concordo plenamente, 7 discordo totalmente)**	**1**	**2**
Knowledge **Conhecimento**			
1	I am aware of the content and objectives of local/national guidelines that promote responsible antimicrobial use Estou informado do conteúdo e dos objetivos das diretrizes locais/nacionais que promovem o uso responsável de antimicrobianos	1	2
2	I know the content and objectives of the local/national guidelines that promote responsible antimicrobial use Eu conheço o conteúdo e os objetivos das diretrizes locais/nacionais que promovem o uso responsável de antibióticos	1	2
3	I am familiar with the content and objectives of the local/national guidelines that promote responsible antimicrobial use Eu estou familiarizado com o conteúdo e os objetivos das diretrizes locais/nacionais que promovem o uso responsável de antimicrobianos	1	2
4	I am aware of how to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu estou informado de como executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário com pacientes, seus cuidadores e/ou colegas durante o meu turno	1	2
Skills **Habilidades**			
5	I have been trained in how to perform the actions that promote responsible antimicrobial use in a hospital/community setting during my shift with patients, their carers and/or colleagues Eu fui treinado em como executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar / comunitário com pacientes, seus cuidadores e/ou colegas durante o meu turno de trabalho	1	2
6	I have the skills to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu tenho as habilidades necessárias para executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar / comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
7	I have practiced the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu tenho praticado as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar / comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas.	1	2

Social/professional role and identity **Papel e identidade social/ profissional**			
8	Performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues is part of my work as a nurse Executar as ações que promovam o uso responsável de antimicrobianos em ambiente hospitalar / comunitário com pacientes, seus cuidadores e/ou colegas durante o meu turno faz parte do meu trabalho como enfermeiro(a)	1	2
9	As a nurse, it is my job to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Como um(a) enfermeiro(a), é meu serviço executar as ações que promovam o uso responsável de antibióticos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
10	It is my responsibility as a nurse to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues É minha responsabilidade, como um(a) enfermeiro(a), executar as ações que promovam o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
11	Doing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and colleagues is consistent with my role as a nurse Executar as ações que promovam o uso responsável de antimicrobianos em ambiente hospitalar/comunitário com pacientes, seus cuidadores e/ou colegas, durante o meu turno de trabalho, é coerente com o meu papel como enfermeiro(a)	1	2
Beliefs about capabilities **Crenças sobre capacidades**			
12	I am confident that I can perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues even when patients, their carers and/or colleagues are not motivated Eu estou confiante de que posso executar as ações que promovam o uso responsável de antimicrobianos em ambiente hospitalar/comunitário com pacientes, seus cuidadores e colegas, durante o meu turno de trabalho, mesmo quando pacientes, seus cuidadores e/ou colegas não estão motivados	1	2
13	I am confident that I can perform the actions within a hospital/community setting during my shift with patients, their carers and/or colleagues that promote responsible antimicrobial use even when there is little time to do so Eu estou confiante de que posso realizar as ações em ambiente hospitalar/comunitário com pacientes, seus cuidadores e/ou colegas, durante o meu turno de trabalho, que promovam o uso responsável de antimicrobianos mesmo quando há pouco tempo para isto	1	2
14	I am confident that if I wanted, I could perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu estou confiante de que, se eu quisesse, poderia executar as ações que promovem o uso responsável de antibióticos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
Optimism **Otimismo**			

16	With regard to the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I usually expect the best No que diz respeito às ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, eu geralmente espero o melhor	1	2
17	With regard to the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I'm always optimistic about the future No que diz respeito às ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, eu sou sempre otimista sobre o futuro	1	2
Beliefs about consequences **Crenças sobre consequências**			
18	If I perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, it will benefit public health Se eu executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, isso beneficiará a saúde pública	1	2
19	If I perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, it will disadvantage my relationship with patients, their carers and/or colleagues Se eu executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, isso prejudicará a minha relação com os pacientes, seus cuidadores e/ou colegas de trabalho	1	2
Reinforcement **Fortalecimento**			
21	Whenever I perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I get recognition from professionals who are important to me Sempre que eu realizo ações que promovem o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, recebo reconhecimento de profissionais que são importantes para mim	1	2
22	Whenever I perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I feel like I am making a difference Sempre que eu realizo ações que promovem o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e colegas, eu sinto que eu estou fazendo a diferença	1	2
Intentions **Intenções**			
23	I intend to perform the actions that promote responsible antimicrobial use for the next 10 patients within a hospital/community setting during my shift Eu pretendo realizar as ações que promovam o uso responsável de antimicrobianos para os próximos 10 pacientes em um ambiente hospitalar/comunitário, durante o meu turno de trabalho.	1	2

24	I will definitely perform the actions that promote responsible antimicrobial use within a hospital/community setting with patients, their carers and/or colleagues during my shift Eu certamente irei executar as ações que promovem o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário com pacientes, seus cuidadores e/ou colegas durante o meu turno de trabalho	1	2
25	I intend to perform the actions that promote responsible antimicrobial use within a hospital/community setting with patients, their carers and/or colleagues during my next shift Eu pretendo realizar ações que promovam o uso responsável de antimicrobinaos em ambiente hospitalar/comunitário com pacientes, seus cuidadores e/ou colegas durante o meu próximo turno de trabalho	1	2
26	My intention to perform the actions that promote responsible antimicrobial use with patients, their carers and/or colleagues within a hospital/community setting during my next shift is strong Minha intenção de realizar as ações que promovam o uso responsável de antibióticos com pacientes, seus cuidadores e/ou colegas em ambiente hospitalar/comunitário, durante o meu próximo turno de trabalho, é forte	1	2
Goals **Metas**			
27	I have a clear plan of how I will perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu tenho um plano claro de como executarei as ações que promovam o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
29	During my shift, something else on my agenda is often a higher priority than performing the actions that promote responsible antimicrobial use with patients, their carers and/or colleagues Durante meu turno, outra coisa em minha agenda, geralmente tem uma prioridade maior do que realizar as ações que promovam o uso responsável de antimicrobianos com pacientes, seus cuidadores e/ou colegas	1	2
30	During my shift, something else on my agenda often takes precedence over the actions that promote responsible antimicrobial use with patients, their carers and/or colleagues Durante o meu turno de trabalho, outra coisa na minha agenda, geralmente prevalecem sobre as ações que promovem o uso responsável de antimicrobianos	1	2
Memory, attention and decision processes **Memória, atenção e processos de decisão**			
31	During my shift within a hospital/community setting with patients, their carers and/or colleagues, I often forget to perform the actions that promote responsible antimicrobial use Durante meu turno de trabalho em um ambiente hospitalar/comunitário com pacientes, seus cuidadores e/ou colegas, eu frequentemente esqueço de executar as ações que promovem o uso responsável de antimicrobianos	1	2
32	When I need to concentrate on performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues I have no trouble focusing my attention Quando eu preciso me concentrar na execução de ações que promovam o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, eu não tenho problemas para manter o foco da minha atenção	1	2

33	When trying to focus my attention on performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues, I have difficulty blocking out distracting thoughts Ao tentar focar minha atenção na execução de ações que promovam o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, eu tenho dificuldade em evitar pensamentos que me distraem	1	2
34	When concentrating on performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues I can focus my attention so that I become unaware of what's going on around me Ao concentrar-me na execução de ações que promovam o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas, eu posso focar minha atenção de modo a não perceber o que está acontecendo ao meu redor	1	2
Environmental context and resources **Contexto e recursos ambientais**			
35	Within the socio-political context there is sufficient financial support (e.g. from local authorities/high administration) to perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Dentro do contexto sociopolítico, há apoio financeiro suficiente (ex: das autoridades locais, alta administração) para executar as ações que promovem o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
36	Within the socio-political context there are good networks between parties involved (e.g. doctors and nurses) in the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Dentro do contexto sociopolítico existem boas redes (*networks*) entre as partes envolvidas (por exemplo, médicos e enfermeiros) nas ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
Social influences **Influências sociais**			
37	Most people who are important to me think that I should perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues A maioria das pessoas importantes para mim pensam que eu deveria executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
38	Most people whose opinion I value would approve of me performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues A maioria das pessoas cujas opiniões eu valorizo me aprovaria na execução das ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2

Emotion **Emoção**			
39	During my shift, I am able to enjoy my normal day-to-day activities Durante o meu turno de trabalho, eu sou capaz de apreciar minhas atividades normais diárias	1	2
40	During my shift, I have been feeling unhappy or depressed Durante o meu turno de trabalho, tenho me sentido infeliz ou deprimido	1	2
41	Thinking about myself and how I normally feel as a professional, I generally feel inspired to perform the actions that promote responsible antimicrobial use within a hospital/community setting during your shift with patients, their carers and/or colleagues. Ao pensar sobre mim mesmo e como normalmente me sinto como um profissional, eu geralmente me sinto inspirado a realizar as ações que promovem o uso responsável de antimicrobianos em um hospital/comunidade durante seu turno de trabalho com pacientes, seus cuidadores e/ou colegas. .		
Behavioural Regulation **Regulação Comportamental**			
42	Performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues is something I do automatically Executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas é algo que eu faço automaticamente	1	2
43	Performing the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues is something I do without thinking Executar as ações que promovem o uso responsável de antimicrobianos em ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e colegas é algo que eu faço sem pensar	1	2
44	I keep track of times I have performed the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu registro as vezes que realizei ações que promovem o uso responsável de antimicrobianos em um ambiente hospitalar/comunitário, durante o meu turno de trabalho, com pacientes, seus cuidadores e/ou colegas	1	2
45	I have a clear plan about how I will perform the actions that promote responsible antimicrobial use within a hospital/community setting during my shift with patients, their carers and/or colleagues Eu tenho um plano claro sobre como irei realizar as ações que promovem o uso responsável de antimicrobianos em um ambiente hospitalar / comunitário, durante meu turno de trabalho, com os pacientes, seus cuidadores e/ ou colegas	1	2

Demographic details: - age, gender, ethnicity, practice setting, length of time since qualified, length of time in post, AfC, band/grade training in AMS

Detalhes demográficos: - idade, sexo, etnia, serviço de prática, tempo de profissão, tempo de pós-graduação, nível/grau, treinamento em AMS.

The below information will go at the front of the questionnaire survey so that participants can read it prior to completing the survey

As informações abaixo aparecerão na frente do questionário da pesquisa para que os participantes possam lê-la antes de concluir a pesquisa.

Behavioural definition and category

Target behaviour – Responsible antimicrobial use

Antimicrobial stewardship (AMS), is a coherent set of actions which promotes the responsible use of antimicrobial and is essential to contain AMR [Dyar et al 2017].

In the table below, is a list of the actions that nurses associate with promoting AMS. These actions fall within the 6 AMS Domains identified by Courtenay et al (2019)

Please indicate for each of these examples, the extent to which you undertake these activities.

Definição comportamental e categoria

Comportamento alvo - Uso responsável de antimicrobianos

Gestão de Antimicrobianos (AMS) é um conjunto coerente de ações que promove o uso responsável de antibióticos e é essencial para conter a resistência antimicrobiana [Dyar et al 2017].

No quadro abaixo, encontra-se uma lista das ações que os enfermeiros associam à promoção do AMS. Essas ações se enquadram nos 6 domínios AMS identificados por Courtenay et al (2019).

Por favor, indique para cada um desses exemplos, até que ponto você realiza essas atividades.

Actions that promote responsible antimicrobial use **Ações que promovem o uso responsável de antimicrobianos**	**(1 none o the time,** (1 nunca, todo o te	
Apply appropriate policies/procedures and guidelines when collecting and handling specimens and question the medical necessity of urine cultures Aplicar políticas/procedimentos e diretrizes apropriados ao coletar e manusear amostras e questionar a necessidade clínica de culturas de urina.	1	2
Apply standard infection control precautions in healthcare environments Aplicar as precauções padrão de controle de infecção em serviços de saúde.	1	2
Recognize the appropriate response to antimicrobial treatment and the main signs that demonstrate antimicrobial failures Reconhecer a resposta apropriada ao tratamento antimicrobiano e os principais sinais que demonstram falhas terapêuticas		
Recognise and act upon the signs and symptoms of infection and isolate patients as appropriate		

Reconhecer e agir de acordo com os sinais e sintomas da infecção e isolar os pacientes conforme o caso		
Collaborate with the interprofessional team, acting as the patient's advocate in challenging prescribing decisions, ensuring appropriate antimicrobial use Colaborar com a equipe interprofissional, atuando como advogado do paciente nas decisões desafiadoras de prescrição, garantindo o uso do antimicrobiano adequado		
Monitor patients on antimicrobial therapy and act upon the common side effects associated with these antimicrobials Monitorar pacientes em terapia antimicrobiana e atuar nos efeitos colaterais comuns associados a esses antimicrobianos		
Intervene promptly when receiving laboratory results (i.e. culture and sensitivity) and review therapy Intervir prontamente quando receber resultados laboratoriais (por exemplo, cultura e sensibilidade) e revisar a terapia		
Obtain and record an accurate penicillin drug allergy history Obter e registrar um histórico preciso de alergia medicamentosa a penicilina		
Initiate the switch from intravenous antimicrobials to oral therapy and/or the discontinuation of antimicrobial therapy Iniciar a mudança de antimicrobianos intravenosos para terapia oral e/ ou a descontinuação da terapia antimicrobiana		
Discuss with patient/carer their expectations of antimicrobials and the need to use them appropriately, recognizing patent vulnerability and those that need support. Discutir com o paciente/cuidador suas expectativas em relação aos antimicrobianos e a necessidade de usá-los adequadamente, reconhecendo pacientes vulneráveis e aqueles que precisam de apoio.		

Please indicate below if your AMS actions/behaviours have changed since COVID 19

Por favor, indique abaixo se suas ações/comportamentos relativos ao AMS mudaram desde o COVID 19.

	1 strongl strongly 1 discor concord	
My antimicrobial stewardship actions/behaviours have changed since COVID-19	1	2

Minhas ações/comportamentos relativos a gestão de antimicrobianos mudaram desde a COVID-19		
My antimicrobial stewardship actions/behaviours have increased since COVID-19 Minhas ações/comportamentos relativos a gestão de antimicrobianos aumentaram desde a COVID-19	1	2
My antimicrobial stewardship actions/behaviours have decreased since COVID-19 Minhas ações/comportamentos relativos gestão de antimicrobianos diminuiram desde a COVID-19	1	2
Please use the space below to tell us about your antimicrobial stewardship actions since COVID-19: Por favor, use o espaço abaixo para nos contar sobre suas ações relativas a gestão de antimicrobianos desde a COVID-19		

Reference

Referências

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Supplementary file 2: TDF scale items, reliability and descriptive statistics

Construct	# items	α	Mean	SD
Knowledge	4	.92	5.54	1.51
Skills	3	.94	5.81	1.56
Social/Professional role and identity	4	.97	6.11	1.53
Beliefs about capabilities	4	.91	5.74	1.51
Optimism	2	.83	5.73	1.45
Beliefs about consequences	2	.47	5.86	1.52
Reinforcement	2	.51	4.82	1.50
Intentions	4	.95	6.00	1.53
Goals *(prior to item removal)*	*3*	*.03*	*4.43*	*1.17*
Goals *(following removal of Q40)*	2	.33	4.78	1.47
Memory, attention and decision making	4	.34	4.89	1.13
Environmental context and resources	2	.75	4.71	1.56
Social influences	2	.79	5.50	1.56
Emotion	3	.64	5.06	1.37
Behavioural regulation	4	.63	4.79	1.29

Supplementary file 2: Qualitative analysis of comments from survey open text box

Theme	Categories and examples of interview quotes (those participants with AMS training)	Categories and examples of interview quotes (those participants with no AMS training)
Infection prevention and control	**Wearing of PPE, increased hand hygiene and use of masks** *I don't believe my antimicrobial stewardship has been altered dramatically during the pandemic other than the increased use of PPE* *Hand hygiene awareness and PPE awareness have increased immensely with Covid.* *Hand hygiene has been the main focus since Covid 19. Proper wearing of the PPE has been the emphasised and observed...training was crucial on the mode of transmission and wearing of mask the correct way and to change it after 12 hours of shift* *More prolific use of PPE, face masks and face visors. More aware of the importance of infection control and protection of patients from spread of infection.* *All staff are required to wear a face mask [type IIR] at all times on the ward, plus PPE as appropriate to the task being carried out.* *In 1st wave we wore 2 set of gloves and just changed top layer between patients when in the positive zone. Audits showed increase in cross contamination between patients so 2nd wave we were bare above elbow, washed hands again in between patients and changed gloves. Normally patients barrier nursed, not possible continued with routine testing weekly MRSA.* *Increased use of PPE.* *As per Welsh Assembly guidelines, social distancing when possible, wearing of PPE, Patients swabbed for Covid prior to admission, reduced visiting, emergency admission, isolated until covid status known*	**Wearing of PPE, increased hand hygiene and use of masks** *Wearing of PPE, increased hand hygiene and masks* *Always being aware of appropriate use of PPE, when appropriate distance with patients.* *Full use of PPE during normal course of duties and as per trust policy.*

	Infection control - use of sanitiser, masks, isolation of potentially infected patients **Cleaning of surfaces** *We have enhanced ward cleaning.*	**Cleaning of surfaces** *Wiping more surfaces more frequently including pens, mobile phones, id badges, break room surfaces.* *Disinfecting equipment and chairs etc*
Antimicrobials and antimicrobial resistance	**Guidelines and diagnostic tests** *In those cases, with unnecessary prescription, we have deprescribed.* *We have made accurate prescription guidelines. We have integrated diagnosis tests into our routine consultations to avoid unnecessary antimicrobial prescription.*	**Monitoring antimicrobial use** *Our AMS, even before COVID 19, has been very strict. We had a Acinetobacter outbreak a few years ago and since then we are very diligent with the use of antibiotics. So, even before Covid, we were monitoring antimicrobial use in ICU to an extreme.*
The diagnosis of infection and the use of antibiotics	**Patient monitoring** *Mostly monitoring patients infective parameters and reporting changes in patient condition with regards to antimicrobials.* **Testing** *We are using procalcitonin tests more frequently to guide us on infections being bacterial v viral* *All patients admitted febrile are now isolated until Covid negative confirmed.* *Continue to lead and remind the community nursing teams when it's appropriate to swab/ treat empirically/ recommend alternative treatment*	**Patient monitoring** *Monitoring of antibiotic course duration to stop immediately once duration lapse and ensuring dosage and intervals of administration are adhered to. Also, monitor temperature and laboratory blood infection markers then inform treating medical officer if PCT results are normal which indicates systemic bacterial infection and patient is normothermic to consider stopping of antimicrbial treatment.* **Testing** *Paying more attention to lab results and in a timely manner in order to update treatment as soon as possible (as well as culture results)* *We treat bacteria as to which they are the most susceptible to. If we could speed up this process of culturing bacteria, I think we can save more lives in*

	Safety measures *Support medical colleagues to work with micro/obtain micro guidance.* *Ensure stop/ r/v dates on medicines chart* **Access to timely treatment** *How to access timely help during lockdown. Electronic messaging with GP surgery, prompt discharge summaries after skin surgery. Easy access via photographs, communication to assess wounds without attending the hospital.* *At times it was difficult to maintain the golden hour due to workload at the pharmacy. Staff were overwhelmed by the workload during the second wave, so many actions in AMS were neglected e.g., administration times were not adhered to, or dosages missed.*	*the process as many people die in the first few days waiting for the results.* **Safety measures** *Since COVID- 19, I have become more aware of the importance of antimicrobial safety. I take extra steps to ensure safety. In fact, this entire pandemic taught me that we were not being as antimicrobial safe as we possibly could be.* *Being more conscientious about infection and antibiotics use in healthcare* *Even though COVID is caused by a virus , antibiotics are still administered to COVID positive patients who present with fever as there is always a chance that they may be having other infections which are treatable with broad spectrum antibiotics.* *I have become more aware that empirical treatment has been relied upon - busy clinicians have been less able to focus on reviewing antimicrobial therapy in patients not being treated for covid and therefore may not have had the most appropriate therapy*
Antimicrobial prescribing practice	**Vigilant antibiotic use** *When antibiotics is prescribed for a patient, I check to make sure there is start and end date and not more than 5 to 7 day. Also, I check patients' allergies and ask the doctors the indication for prescribing antibiotics.* *Only prescribe when it is clinically indicated.* *…,but as for my antimicrobial stewardship action is to make sure antibiotics are prescribed when really necessary, and not unnecessarily prolong the use of it.*	

	I always ask them (the patient) about allergies (including penicillin). If I assess a patient who is prescribed antibiotics, I check the person's blood results regarding whether their inflammatory markers are improving, as being medically unwell often impacts upon the mental state examinations. This has continued since the COVID-19. *I only prescribe for infections, this may be diagnosed by clinical assessment or by microbiology result.* *I spent a lot of 2020 shielding but when I returned there had been a big push into increasing awareness of correct antimicrobial therapy and also how misuse can increase infection rates of particular diseases.* *Once a new antibiotic is prescribed, I check the organism for which it was describe - sensitivity. Times for administering antibiotics is calculated to fall correctly with the initial stat/loading dose.* *My prescribing of oral and topical antibiotics has decreased. Monitoring of primary and secondary infection has increased. Reporting and monitoring of acute and long-term effects of infection, have increased e.g. national register for Covid 19 rashes.* *Much better at performing and far more aware of the need for timely review of results and the regularly and timely review of antibiotics in light of such results.* *Nursing and pharmacy staffing reached critical levels during the second wave; it made the timeous administration of antibiotics almost impossible.* **Prophylactic use of antibiotics** *More use of antibiotics prophylactically on patients with covid who are less well.* *Often have patients referred to our service from podiatry who have initiated oral antibiotics unnecessarily - have noticed this more during Covid because*	

	we have had more referrals/requests for advice due to changes in ways of working / GPs have been seeing fewer patients and expecting AHPs to see in first instance. *Most of the Covid patients got healthy without any antibiotic. Only symptoms were treated.* *Since Covid and the need to virtually manage outpatient care episodes, antibiotics are being prescribed symptomatically rather than actual clinical findings. This is in line with our national guidance.*	
Person-centred care	**Virtual consultations** *Take more time to evaluate the effectiveness of different antimicrobials if indicated and explaining my decision to the patient possibly due to virtual consultations giving more antibiotics than previously but hard to judge this.* *If COVID suspected, a PCR is requested in the first instance and guidelines followed appropriately for isolation. A follow up review by telephone is made. Patients with negative results will be reassessed for symptoms and treated accordingly.* **Increased prescribing** *More telephone triage. Less face-to-face consultations. Some increase in prescribing rather than delayed script* *I have prescribed more frequently on a clinical assessment via phone consultation that does not involve a physical examination.* *More telephone consultations, possibly lower threshold for treating with antibitoics.. More use of suggesting delayed prescriptions* **Education** *Increased discussions and explanations with patients regarding proper use of medications.*	**Virtual consultations** *Reduced face to face contact to clinically vulnerable patients at home. Telephone contact/support has increased.* *The only main change is fewer face to face clinical reviews to assess for infection and a move to virtual clinics.* **Education** *Giving advice to student's and members of the public to determine virus infection verses bacterial infections*

		as these are still possible seeking appropriate care as needed.
Interprofessional collaborative practice	**Multi-disciplinary rounds** *Wards rounds with specific focus on antimicrobials.* **Communication with team members** *Prior to Covid 19, multidisciplinary rounds were completed daily. Now since covid 19 many of the MDR are not being completed. I do feel that I continue to actively practice antimicrobial stewardship on a daily basis, the current process requires the nurse to seek out the team members to discuss creating some delay in previous actions.* *The situation enhanced the practice and behaviours drastically for all nurses.* *I consult with GPs more prior to prescribing.* *Mainly been following guidelines and advise from senior colleagues.* *Increased use of infection pathways and communication of this to rest of team. Increased communication links with infection control team and microbiologist.* *Being more aware of the importance of AMS in the wider sense.* *I apply and use all the tools available to ensure safe prescribing such as guidelines, senior colleagues and microbiologist. This is not always necessary though.*	**Communication with team members** *Always ensure doctor reviews if antibiotics can be changed from IV to oral sooner rather than later.*