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

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Keywords: Nurse, AMS, Antimicrobial stewardship, Drug resistance, bacterial, Anti-bacterial agents, TDF, Theoretical Domains Framework, COM-B, COVID-19, Interpersonal relations, Patient-centred care

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 years) from ten nationalities, with individual survey links sent via professional networks in 5 countries, alongside Twitter. 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. The TDF was able to explain 27% of the variance in behaviour, with 'Skills' and 'Behavioural Regulation' (e.g. ability to self-monitor and plan), shown to be the most predictive of AMS actions. 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. Those who had training, scored higher in all TDF determinants of behaviour, compared to those who had had no training, resulting in higher Capability, Opportunity and Motivation to perform AMS behaviours. AMS education and training should be offered to nurses to enhance these factors. Future research should consider the optimal level of training to optimise AMS behaviour, with a focus on developing skills and behavioural regulation.

INTRODUCTION

Antimicrobials are used significantly more per person than in previous decades [1] and are associated with an increase in antimicrobial resistance (AMR) [2]. The timeline with regards to the public health threat from AMR, has escalated during the COVID-19 pandemic as a result of increased use of antimicrobials [3]. AMR is one of the greatest threats to human health, and it causes an estimated 4.95 million annual deaths associated with bacterial AMR, including 1.27 million deaths directly attributable to bacterial AMR [4]. 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 [2]. Antimicrobial stewardship (AMS), a programme of actions promoting optimal antimicrobial use, has been identified as essential for limiting AMR [5].

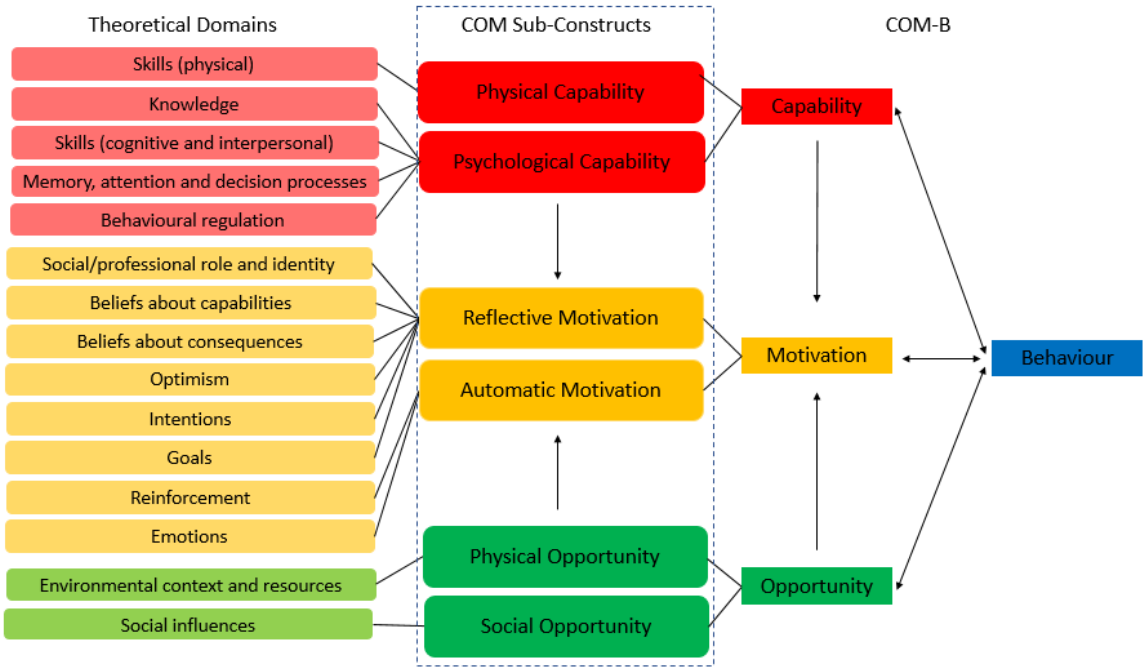
Internationally, interprofessional collaboration and teamwork are recognised as key features of the nurses role, and essential for safe quality patient care [6]. Collaboration between healthcare professionals is also a key feature of AMS with many daily nursing activities intrinsically interwoven into the fabric of AMS [7] and integral to its success [8-10]. The 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 [11]. However, although there are calls for a nursing role in AMS [12], this role, unlike the roles of pharmacists or doctors, is not clearly described [13].

There is evidence available that has identified barriers to nurses engagement in AMS. These include AMS not being taught in undergraduate nurse education programmes [14-15], nurses reporting poor knowledge of antibiotics and AMS [16-17], professional relations and hierarchies [18], 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 [19]. 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 [20-21]. The use of theoretical frameworks in order to understand behaviour [22] has previously been applied to gain insight into antibiotic prescribing of nurses [23]. The Theoretical Domains Framework (TDF) [24] 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 [24-25]. The TDF combines complex theories of behaviour into a simplified and accessible framework with 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) that underpin behaviour. The TDF has been used widely to understand prescribing behaviour [23, 26, 27].

Once determinants of behaviour are identified and understood, targeted interventions can be developed. The Behaviour Change Wheel (BCW) [22] 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 [22], known as the COM-B model. A visual representation 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 support structural level change. The COM-B model enables 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, and 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 nurses' 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 distribution 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, which 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) [28]. 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 previous research [29-30] 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 question 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 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 by the last author and re-tweeted by the team and the wider Twitter community.

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 [31] and Content conceptual analysis [30] 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.

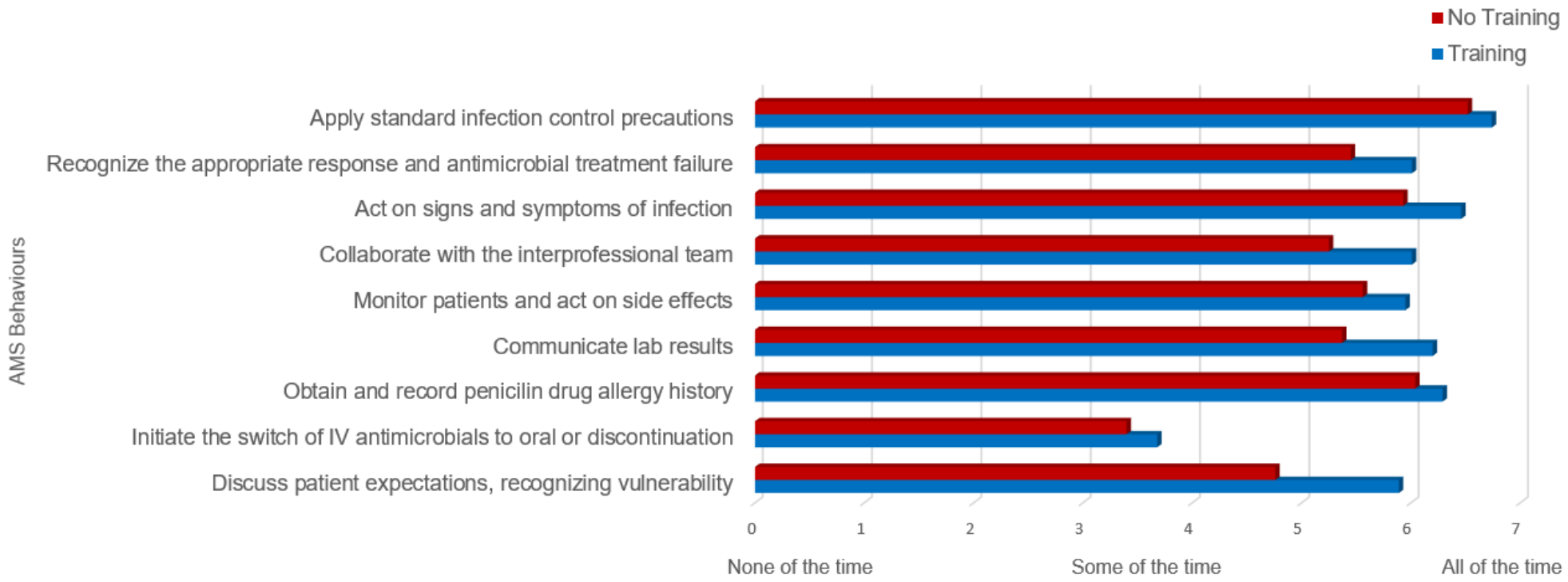
RESULTS

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 $\alpha = .84$, with a range of scores from 12 – 62 (scale range = 7 - 63).

Table 1: Antimicrobial stewardship behaviours, total and with or without training (N=262)

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 dif.	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 3). 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

This study revealed 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 [26], and nurses' antibiotic prescribing behaviour [23]. 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 [32 and dental practitioners [33].

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. Their intentions and goals towards AMS were higher, 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 nurses, has been identified as a key activity for the containment of AMR [34] with the inclusion of AMS in undergraduate nurse education programmes recommended (6, 35]. The current study provides new 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 [23] to support AMS should also be considered in this context.

While AMS behaviour since COVID-19 did not differ between those who had, and had not received training, it did appear to increase across the cohort suggesting that nurses were being extra vigilent. 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 [7] and recently included within pre-registration nurse education programmes [15].

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.

There are some limitations to our research. Single Likert scales with no before-and-after comparison are problematic and can be subjective in nature. Yet this study adds evidence that there may have been changes in nurses' AMS behaviour since the pandemic. While multiple items were used to measure the TDF, based on previously published wording formats [29-30] there is no standardised or validated scale in the field to draw upon. Reliability of the scales were tested and deemed acceptable, however, the interpretation of the questions may be subjective, and therefore limit the interpretation of the findings. 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 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. It would also be important to determine the different types of training across the globe, and ways to standardise future education and training efforts to optimise AMS behaviour.

A high proportion of the sample was from the UK, which may make the results less generalizable internationally. Results may be further limited by the varying roles of nurses across different countries, such as their ability to prescribe antimicrobials, however, this is not essential for AMS. Due to the use of a public link to increase the response rate, we were also unable to then measure the response rate accurately, and we had no way of knowing how many people viewed the call for recruitment. There are also the usual limitations of self-report measures, such as subjective interpretation and desirability bias, 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 focus on determinants of behaviour 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. This evidence 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

FUNDING SOURCE

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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