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Article title

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A short running title

Theoretically based antimicrobial prescribing interventions: a systematic review

Abstract

Introduction: This systematic review (SR) reviews the evidence on use of theory in developing and evaluating behaviour change interventions (BCI) to improve clinicians' antimicrobial prescribing (AP).

Method: The SR protocol was registered with PROSPERO. Eleven databases were searched from inception to October 2018 for peer-reviewed, English-language, primary literature in any healthcare setting and for any medical condition. This included research on changing behavioural intentions (e.g. in simulated scenarios) and research measuring actual AP. All study designs/methodologies were included. Excluded were: grey literature and / or did not state a theory. Two reviewers independently extracted data / quality assessed. The Theory Coding Scheme (TCS) evaluated the extent of the use of theory.

Results: Searches found 4227 potentially relevant papers after duplicate removal. Screening of titles/abstracts led to dual assessment of 38 full-text papers. Ten (five quantitative, three qualitative and two mixed-methods), met the inclusion criteria. Studies were conducted in the UK (n=8), Canada (n=1) and Sweden (n=1), most in primary care settings (n=9), targeting respiratory tract infections (n=8), targeting medical doctors (n=10). Most common theories used: Theory of Planned Behaviour (n = 7), Social Cognitive Theory (n = 5) and Operant Learning Theory (n = 5). The use of theory to inform the design and choice of intervention varied, with no optimal use as recommended in the TCS.

Discussion: This SR is the first to investigate theoretically based BCIs around AP. Few studies were identified; most were suboptimal in theory use. There is a need to consider how theory is used and reported and the systematic use of the TCS could help.

Introduction

Many countries have developed antimicrobial stewardship (AMS) interventions with strategies to improve antimicrobial prescribing behaviour, minimise antimicrobial resistance (AMR) and improve patient outcomes.[1] There are, however, large differences in improvement in prescribing behaviours reported between studies testing similar types of interventions. Davey et al. described how the effect size of educational interventions varied between 3.1% and 50.1% and that few studies reported sustained improvements in prescribing behaviours. [2]

In the field of behavioural science, behaviour change interventions are defined as 'coordinated sets of activities designed to change specified behaviour patterns'. [3] These are often 'complex' and challenging for several reasons, including the number of interacting components, the number and difficulty of behaviours required to deliver the intervention and the number and variability of outcomes. [4] Such interventions are known as 'behaviour change techniques' (BCTs), themselves defined as 'observable and replicable components designed to change behaviour'. [4,5] BCTs can be mapped to specific theoretical determinants which are identified as leading to the suboptimal behaviour. Interventions aimed at changing antimicrobial prescribing are 'complex' given the clinician diversity (countries of training and previous practice, specialties, professional grade, status, etc.), the nature and difficulty in understanding the behaviours around antimicrobial prescribing and failure of previous attempts to alter these behaviours. [6,7]

Literature shows that theory provides a useful basis for developing and evaluating interventions which aim to change human behaviour. [8] The term 'theory' is derived from ancient Greek 'theoria', meaning 'looking at' or 'being aware of'. [9] It has been defined as 'a set of concepts, definitions, and propositions that explain or predict events or situations by illustrating the relationships between variables'. [10] While the use of theory cannot guarantee intervention success, there are several advantages to considering it at the outset of planning interventions. These advantages include enhancing the robustness and rigour of studies and thus the potential impact of the research findings. [9] In addition, theories summarise the state of cumulative knowledge by describing the

facilitators which contribute to successful interventions and barriers contributing to unsuccessful interventions. [8,11]

The use of theory is recommended as an integral step in intervention development and evaluation by the UK Medical Research Council (MRC) guidance on "Developing and implementing complex interventions" which gives theory a central role within the process. [4] This guidance describes an internationally accepted framework of four phases: Development, Feasibility/Pilot testing, Evaluation and Implementation. Applying the UK MRC Guidance and embedding theory in intervention development has the potential to result in successful intervention outcomes. [4]

Rationale

The rationale for this review includes the fact that a number of published systematic reviews have focussed on the impact of interventions (e.g. shared decision-making strategies, delayed prescribing strategies, communication skills training) on antimicrobial prescribing [2, 12, 13, 14, 15, 16, 17, 18, 19] with a wide range of effects. One factor which may have contributed to lack of intervention success is the apparent lack of theory in the primary research reported in these systematic reviews.

The authors of three of these systematic reviews highlighted the lack of theory. A systematic review of 10 studies examining the effectiveness of interventions to influence antimicrobial prescribing behaviour in acute care reported that the lack of consideration of theories to inform the design and choice of interventions was an inherent drawback of most studies. [14] A further systematic review of 116 studies evaluating the extent to which BCTs were used in interventions designed to improve antibiotic prescribing in hospital inpatients reported that both the content and reporting of interventions fell short of scientific principles and practices. [5]

A more recent systematic review of 221 studies investigating the impact of broad categories of interventions, restriction and enablement, on improving antibiotic

prescribing in hospital inpatients confirmed that theories of behaviour and behaviour change had been inadequately used in the development of these interventions. [20]

To address this gap, the systematic review presented in this paper aimed to systematically review, critically appraise, and synthesise the evidence on the application and use of theory in the development and evaluation of behaviour change interventions designed to improve clinicians' antimicrobial prescribing.

The review sought to answer the following questions linked to the UK MRC Guidance in relation to the development and evaluation of behaviour change interventions designed to improve clinicians' antimicrobial prescribing:

1. Which theories have been used and why?
2. To what extent have these interventions been feasibility and pilot tested, in what context (i.e. medical condition, healthcare setting and country) and what were the findings?
3. To what extent have these interventions been evaluated, what outcome measures have been reported and what were the findings?

Methods

The systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) [21] and reported in this paper broadly in line with 'Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement'. [22]

Eligibility criteria

Peer-reviewed, English-language primary research studies investigating any type of theoretically based behaviour change interventions designed to improve clinicians' (i.e. including non-medical prescribers') antimicrobial prescribing behaviour. Any prescribing behaviour was included in this systematic review (e.g. decision to prescribe or not, type of antimicrobial, duration of treatment etc.) in any healthcare setting and for any

medical condition, with no date limit up to October 2018. Furthermore, e-mail alerts were set up on Medline® to ensure that no recent papers were missed during the time of writing (September 2019).

All study designs and methodologies including quantitative, qualitative and mixed-methods were considered. Studies were excluded if they did not state a theory (or synonym, e.g. model, framework etc.) underpinning their intervention or intervention components. Grey literature (e.g. government reports), abstracts, conference proceedings and literature reviews were also excluded due to the lack of detail for quality assessment and data extraction.

Information sources and search

The search strategy applied to Medline® is illustrated in Table 1 and adapted for PubMed®, The Cumulative Index of Nursing and Allied Health Literature (CINAHL®), International Pharmaceutical Abstracts (IPA®), PsycINFO®, ScienceDirect, The Cochrane Database of Systematic Reviews (CDSR), The Centre for Reviews and Dissemination (CRD), The Database of Abstracts of Reviews of Effectiveness (DARE), Joanna Briggs Institute Library (JBI) and Google Scholar. The reference lists of all included papers and previous systematic reviews identified through application of the search strategy in electronic data bases were screened manually to identify any additional records.

[INSERT TABLE 1]

Study selection

The inclusion process was performed by HT and a random sample of 10% of titles, abstracts and full-texts was reviewed independently by SC. Any disagreements arising about studies' eligibility were resolved through face-to-face discussion to reach consensus or by consultation with a third research team member.

Data extraction

Data extraction was performed independently by two research team members, with a third included if any disagreement arose. Data extracted were: year of publication, country of origin, methods, study aim/objective, setting, participants, medical condition, type of intervention, underpinning theory, outcome measures and key findings/results.

Quality assessment

Methodological quality was independently assessed by two research team members (i.e. HT plus one other) using three adapted reporting tools: Consolidated Standards of Reporting Trials (CONSORT) for randomised controlled,[23] CONSORT for randomised feasibility/piloting trials [24] and Consolidated Criteria for Reporting Qualitative Research (COREQ) for qualitative studies. [25]

Assessment of theory

The TCS was independently applied by two research team members to assess the methods by which theories had been applied and used. [26] It consists of 19 items providing a detailed method for assessing the extent to which behaviour change interventions are theoretically based. Any disagreement was resolved through face-to-face discussion to reach consensus or by consultation with a third research team member.

Data synthesis

Due to clinical and methodological heterogeneity in study designs, data collection tools, type of interventions, theoretical underpinnings and outcome measures, a narrative approach to data synthesis was chosen.

Results

Searching

In October 2018, the electronic search resulted in 7311 potentially relevant articles. An additional 10 articles were identified from other sources (e.g. reference lists, email

alerts, etc.). Removal of duplicates resulted in 4227 articles, 4217 of which were excluded based on assessment of title, abstract or full-text. Ten studies (which originated from six bodies of research), met the inclusion criteria and were included in in the final review and narrative synthesis. The e-mail alerts identified no further studies to include up to September 2019. The PRISMA flow chart is given in Figure 1 below. [27]

[INSERT FIGURE 1]

Table 2 below presents mapping of the included ten studies to the phases of the UK MRC Guidance. Note that studies which related to and originated from the same body of research are presented consecutively.

[INSERT TABLE 2]

Of the ten studies, four reported intervention development, [28, 29, 30, 31] one reported feasibility/pilot testing [32] and the remaining five reported intervention evaluation. [33, 34, 35, 36, 37]

Five studies employed quantitative designs (mainly cross-sectional surveys) [29, 33, 34, 35, 37] and three employed qualitative designs (mainly semi-structured interviews). [28, 30, 36] The remaining two were sequential explanatory, mixed-methods studies of cross-sectional survey followed by either semi-structured interviews [32] or focus groups. [31]

Characteristics of studies included (n = 10)

The extracted data are summarised in Table 3 in relation to the phases of the UK MRC Guidance.

[INSERT TABLE 3]

All studies were conducted in high-income countries, the majority in the UK (n = 8), [28, 29, 30, 32, 33, 35, 36, 37] followed by one study each for Canada [31] and Sweden. [34] Out of ten studies, two were published in 2008 [28, 33] and two were published in 2017, [30, 32] while the remaining six were published as one study each in 2010, [36] 2012, [37] 2013, [34] 2014, [29] 2016 [35] and 2018. [31]

The majority of studies were carried out in primary care settings (n = 9), [28, 29, 30, 32, 33, 34, 35, 36, 37] targeting respiratory tract infections (n = 8). [28, 29, 30, 32, 33, 34, 35, 37] Studies' participants were: GPs only (n = 5), [28, 29, 33, 34, 35] GPs and nurses (n = 2), [36, 37] GPs and carers/parents (n=1), [30] GPs, nurses and carers/parents (n = 1), [32] and GPs, nurses and infection control practitioners in Canadian Long Term Care Facility (LTCF) settings (n = 1). [31]

All of the interventions included were complex in nature and consisted of various behavioural and educational techniques, including online learning, [30, 32, 36, 37] practice-based seminars, [36, 37] printed leaflets intended for patients or carers, [30, 32] feedback,[31] reminders, [31] clinical scenarios, [28, 29, 33, 35, 36, 37] reflection on own practice [34, 36, 37] and provision of research evidence/guidelines. [30, 36, 37]

Use of theory to inform the design and choice of intervention varied considerably across the studies. The most common theories were: Theory of Planned Behaviour (TPB) (n = 7), [28, 29, 33, 34, 35, 36, 37] Social Cognitive Theory (SCT) (n = 5) [28, 29, 33, 34, 35] and Operant Learning Theory (OLT) (n = 5). [28, 29, 33, 34, 35]

Methodological quality of included studies

Tables 4 and 5 present the quality assessment of data collection/generation in feasibility/pilot testing and evaluation studies using CONSORT and COREQ tools. The remaining development studies were assessed using the TCS tool (i.e. see *Data synthesis*). Blair et al. Part 2 was a mixed-methods study [32] hence assessed using both CONSORT and COREQ.

[INSERT TABLE 4 and TABLE 5]

For the quantitative designs, [32, 33, 34, 35, 37] key areas of strength were the clarity of reporting of study aim/objectives and description of participants, settings/locations where data collected and outcome measures. It is worth noting that one study [37] focussed on a primary outcome of antibiotics dispensed rather than prescribing only and so this introduces an element of patient behaviour to the outcome. Fewer studies provided information regarding blinding and follow-up.

For the qualitative designs, [32,36] key areas of strength were aspects of research trustworthiness (e.g. representing the participants' voices by illustrative quotes). Areas of weakness were the lack of details around the methodological orientation (e.g. phenomenology, grounded theory) and description of approaches to data saturation.

Data synthesis

The heterogeneity of the studies included limited the approach to data synthesis.

<u>Use of theory in intervention development, feasibility/pilot testing and evaluation</u>

Tables 6 illustrates the assessment of the use of theory (i.e., the extent to which researchers had employed the theory with fidelity) in the ten studies included, highlighting the lack of homogeneity in theory use in each. Studies which related and originated from the same body of research (i.e. the studies were linked) are presented consecutively.

[INSERT TABLE 6]

As shown in Table 6, all six bodies of research were based on multiple theories/frameworks and all mentioned targeted theoretical constructs (i.e. as predictors of behaviour). Out of six bodies of research, two (n = 2) used a combination of TPB, SCT and OLT, [28, 33, 34] one used a combination of TPB, SCT, OLT and the Theoretical Domains

Framework (TDF) [29, 35] and one used both TPB and Social Learning Theory (SLT). [36, 37] One body of research used the Green and Krueter's Precede/Proceed logic model (i.e. draws on social cognitive theories), [30, 32] whereas another used the TDF [31]

The majority of bodies of research provided some justification for the choice of theory (n =5), [28, 29, 30, 32, 33, 35, 36, 37] while one referenced an earlier research. [34] Table 7 below presents the justifications of chosen theories as reported by study authors.

[INSERT TABLE 7]

Most bodies of research (n = 5) did not use theory/predictors to select intervention recipients. [28, 30, 32, 31, 33, 34, 36, 37] While all bodies of research included used theory/predictors to select/develop intervention techniques, none used theory/predictors to tailor intervention techniques to recipients. The majority of bodies of research (n = 4) did not test/measure the underpinning theory [32, 34, 35, 36, 37] or clearly report the quality of measures of theory-relevant constructs/predictors (n = 6). [32, 33, 34, 35, 36, 37] In addition, the majority of bodies of research (n = 5) did not carry out a mediational analysis of constructs/predictors [32, 33, 34, 35, 36, 37] or discuss the results in relation to theory (n =3). [32, 34, 36, 37] Notably, none of the bodies of research included reported theory refinement based on the study results/findings.

<u>Extent and context of intervention development, feasibility/pilot testing and evaluation</u>

In 2008, the development of two paper-based behavioural interventions: "graded task", targeting the theoretical construct of self-efficacy, and "persuasive communication", targeting the theoretical constructs of anticipated consequences and risk perception, was reported by Hrisos et al. Part 1. [28] The two interventions were evaluated in a partner study for effect on general practitioners' (GPs') behavioural intention (i.e. by questionnaire) and stimulated behaviour (i.e. by clinical scenarios), in relation to managing urinary tract infections without antibiotics in UK primary care. [33] The authors indicated that each intervention had a significant effect on its targeted theoretical

construct, compared to a control group. While intervention 2 had a significant effect on GPs' behavioural intention (Beta = 0.90, 95% CI = 0.41 to 1.38) and simulated behaviour (Beta = 0.47, 95% CI = 0.19 to 0.74), intervention 1 did not. [33]

In 2013, Milos et al. replicated and evaluated the two interventions in primary care in Sweden to assess the rate of prescription of antibiotics by GPs against URTI using data from the Swedish National Pharmacy Register. [34] There was no significant difference in the prescription rates before and after the interventions when patients of all ages were analysed. [34] However, for patients aged 0–6 years, there was a significantly lower prescription rate (P = 0.037).

In 2014, Treweek et al. Part 1 replicated the "persuasive communication" intervention, but in a web-based format, as well as developing a new web-based intervention: "action plan", targeting two theoretical domains of beliefs about capabilities, and behavioural regulation. [29] Similarly to Hrisos et al. [33] Treweek et al. Part 2 reported the evaluation of these two web-based interventions on GPs' behavioural intention and stimulated behaviour in a sister study in 2016. [35] This study revealed that both interventions had a significant effect on GPs' simulated behaviour, compared to a control group as in the earlier work. [33] However, behavioural intention was unaffected by both interventions. [35]

In 2010, Bekkers et al. Part 1 reported the evaluation (i.e. by interviews) of GPs' and nurses' views (e.g. delivery fidelity, feasibility, efficacy and area of refinement) on the Stemming the Tide of Antibiotic Resistance (STAR) educational intervention, which aimed to enhance the quality of antibiotic prescribing and raise awareness about antibiotic resistance in UK primary care. [36] This STAR intervention produced wide-ranging, positive changes in participants' attitudes and clinical practice. In a linked study, the effectiveness of the STAR intervention was evaluated by assessing numbers of antibiotics dispensed for all causes per 1000 practice patients in the year following the intervention, using the Prescribing Audit Reports and Prescribing Catalogues. [37] Re-consultations, admissions to hospital for selected causes and costs were also assessed using the Patient Episode Database for Wales. The authors concluded that the STAR intervention led to reductions in all cause oral antibiotic dispensing over the subsequent year with no

significant change in admissions to hospital, re-consultations, or costs. Notably, neither the development nor the feasibility/pilot testing of the STAR intervention was reported.
In 2017, Lucas et al. Part 1 described the development of a web-based intervention, "within-consultation" tool, to reduce GPs' and nurses' prescribing of antibiotics for childhood coughs in UK primary care, using previous findings of a multi-method programme of research (i.e. five systematic reviews and four primary studies, three qualitative and one cohort). [30] A sister study investigating the feasibility of that intervention (i.e. recruitment and retention, data collection methods and acceptability) was assessed by recording the number of times the clinicians used the intervention and time spent on each page of the website. [32] Clinicians and parents were invited to participate in semi-structured interviews to explore their views of web-based data collection and the intervention. It was found that the overall antibiotic prescribing rates for children's RTIs were 25% and 15.8% (p=0.018) in the intervention and control groups respectively. This was attributed to differential recruitment (i.e. the intervention children were more unwell and over half of them were recruited by prescribing nurses compared with less than a third in the control arm) and potential Hawthorne effect. In their conclusion, the authors advocate avoiding patient recruitment at the clinicians' level and using data already routinely collected by the practices themselves.
More recent work from Canada described the development of a multifaceted intervention focusing on barriers and facilitators, identified from a mixed-methods survey and from focus groups with stakeholders working in long-term care, to antibiotic overuse for asymptomatic bacteriuria. [31] In this work, 19 different barriers and facilitators were mapped to eight corresponding theoretical domains (i.e. relevant to practice change) and nine implementation strategies were selected. The authors concluded that the stepped approach employed helped to ensure that local barriers and facilitators to change were addressed.

Discussion

Summary of evidence

This systematic review has highlighted that there is a lack of theoretically based interventions to improve clinicians' antimicrobial prescribing. Only ten studies (from six bodies of research) were retrieved, with no optimal use of theory as recommended in the TCS.

Our synthesis has shown that there is a lack of theoretically based interventions around antimicrobial prescribing. Despite the apparent advantages of applying theory to behaviour change interventions, [3, 8, 9, 11] interventions identified were suboptimal in terms of the TCS criteria. [26] In particular, details relating to the way in which theory was used to select intervention recipients or tailor intervention techniques to recipients were lacking. This could be attributed to the fact that the UK MRC Guidance does not give detailed guidance on how to use theory to develop or evaluate complex interventions. [40]

Reflecting on the applicability of the TCS, some aspects may be challenging to understand for non-psychologists. Michie et al [26] provide some explanation of what is intended by each of the criteria set within the TCS. For example, it should be noted that for 'Criterion 3: Intervention based on single theory' there is elaboration of this and additional guidance within the paper which states that 'The intervention is based on a single theory (rather than a combination of theories or theory + predictors)' They also indicate that interventions that are based on several different theories make the understanding of links between the theory and the intervention more complicated and difficult to comprehend. Michie at al [26] also indicate that this in turn makes subsequent theory testing more difficult. It is also worth noting that studies can use a wide variety of multiple behaviour change techniques endeavouring to effect a 'change' without specifying what the expected 'change' is. This too makes linkage to multiple theories that may have been used to develop the intervention even more difficult. For Criterion 6: 'Theory/ predictors used to tailor intervention techniques to recipients' Michie et al [26] explain that there may be a necessity to vary the intervention dependent on particular

circumstances. An example of this may be where behaviours are influenced by the particular 'stage of change' the person is located at. In relation to antimicrobial prescribing if someone was at the 'pre-contemplation stage' of behaviour change then an intervention around provision of positive information about the benefits of reducing antimicrobial prescribing may motivate them to move 'stage of change' – if individuals are at the 'action' stage then provision of more detailed information on drug choice and prescribing may be more appropriate.

The majority of studies identified in previous systematic reviews failed to pay attention to the use of theory. [2, 5, 20] This appears to explain our findings on the suboptimal use of theory. Where a theoretical basis was included, there was seldom reference to a method explaining how the theory informed the development and evaluation of the intervention.[11] It is therefore uncertain why some published, theoretically based interventions succeed and others do not.

It should be acknowledged that it may not only be theory-based interventions that are effective in effecting change. However, the rationale for the use of theory is that it is perhaps more likely to result in interventions that have positive process, clinical and implementation outcomes (eg around feasibility, acceptability, economic etc) since they will have, through the use of theory, addressed many of the barriers and enhanced the facilitators to implementation. In summary, it is important to acknowledge that neither approach is likely to always be perfect but the use of theory may enhance the trustworthiness (credibility, transferability, dependability and confirmability etc) of the developed interventions and so ultimately the process, clinical and implementation outcomes.

In addition, this review has mapped existing antimicrobial prescribing interventions in relation to the phases of the UK MRC Guidance. [4] However, there was a lack of systematic application of all phases of the framework amongst the included studies.

While most of antibiotics are prescribed in low- and middle-income countries, [41] the majority of studies identified originated from high-income, western countries, predominantly from the UK. Given the differences in healthcare systems, processes, cultures etc., findings of studies cannot necessarily be generalised or translated to other settings. Although non-medical prescribers (e.g. pharmacists, nurses, etc.), of whom there are 35 000 across the UK, predominantly prescribe independently in primary care for respiratory conditions and infections, [42] we have found that the main profession targeted was medical doctors (i.e. mainly GPs). This emphasises the potential of multidisciplinary, theoretically based interventions around antimicrobial prescribing, targeting non-medical prescribers.

This systematic review demonstrates the need for further theoretically based primary research, targeting multidisciplinary professions (e.g. non-medical prescribers) and more medical conditions. This review was designed to include articles from any healthcare setting. Most studies identified were either conducted in primary care or LTCF settings and so there seems to be a gap in the use of theory for developing and evaluating AMS interventions in the acute care hospital setting which needs addressed. Considering the underrepresentation of studies from low- and middle-income countries, the development and evaluation of similar interventions within such areas are also needed. [43] Moreover, outcome measures need to be standardised to enable pooling of data and meta-synthesis/meta-analysis.

Strengths and limitations

The systematic review was conducted according to best practice and reported in accordance with the PRISMA standards. [27] The use of TCS is original, providing a reliable and systematic method of assessing the degree to which behaviour change interventions were theoretically based. [26] Furthermore, theoretically based interventions identified were mapped to the phases of the UK MRC Guidance. [4]

Review limitations include restricting study inclusion to peer reviewed, English, primary literature. It should also be noted that it is likely that some papers were excluded based on their title and abstract for not having mention of the use of theory or a theory-based intervention. Systematic review methodology dictates that stringent parameters must be set for the criteria used to search for and select studies. It was therefore decided that this review would focus on literature with clear reporting of theory within the papers.

Although this could be considered a limitation, such an approach ensures a robust and resource-efficient approach to searching, study selection and other steps of the review process, including only those studies that clearly showed that they had considered the use of theory. No studies have yet completed all steps of the UK MRC Guidance [4] but it was felt that any studies that did not include 'theory' or related terms in the title or abstract were not likely to have had a systematic and comprehensive approach to the use of theory. This, therefore, was to be the main focus of this review in line with the UK MRC Guidance [4] which has clear recommendations around the advantages of the use of theory.

The current reporting of implementation research in AMS generally is lacking in the detail and focus on the use of theory in studies. For those studies identified in this systematic review the extent of inclusion of structured information on the rationale for and use of theory was lacking. It is possible therefore that the focussed criteria set for this review may have resulted in some studies not being identified for consideration. An approach to improve this situation would be for researchers to consider and adopt the TCS to help develop studies and support and frame the reporting of theory-based interventions.

This paper stresses the potential for theory-based interventions. It should be recognised however that developing interventions using co-design approaches or using qualitative methods to identify the needs of target populations (and barriers and facilitators to target behaviours) are also useful in developing effective interventions and these have

been shown to work for AMS interventions.[2,20] Additionally, it should be noted that there are a number of examples of AMS interventions, particularly in general practice in Europe, which have been shown to be effective at reducing antibiotic prescribing.[12,15,16] It is important to consider the development and implementation of theory-based interventions in order to develop even more robust and effective evidence-based approaches, however non-theory based interventions may sometimes offer value. Researchers and clinicians should consider the use of a combination of contextual and theory-based approaches.

Conclusion

This systematic review has identified a limited evidence base on theoretically based interventions around antimicrobial prescribing and the need for researchers to consider carefully how they use and report theory in their efforts to develop effective evidence-based interventions. An approach that could help includes the systematic use of the TCS. Findings of this review may influence the direction of future research and policy around AMS interventions, thereby contributing to regional and global efforts to slow down the progression of AMR. Future research should be designed to overcome the biases encountered in current publications.

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Transparency declarations

None to declare.

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Table 1. The search strategy applied to Medline®

Concepts	Search terms	Search options
1. Antimicrobial agents	1.1 Antimicrob*	TI OR AB
	1.2 Antibiotic*	TI OR AB
	1.3 Anti-bacterial agents	MeSH+
	1.4 Anti-infective agents ▪ Antifungal agents (MeSH) ▪ Antiparasitic agents (MeSH) ▪ Antiviral agents (MeSH)	MeSH+
2. Prescribing	2.1 Prescrib*	TI OR AB
	2.2 Therapeutics ▪ Inappropriate prescribing (MeSH) ▪ Drug prescriptions (MeSH) ▪ Deprescriptions (MeSH) ▪ Medication errors (MeSH)	MeSH+
	2.3 Delivery of health care ▪ Practice patterns, physicians' (MeSH) ▪ Practice patterns, nurses' (MeSH) ▪ Professional practice gaps (MeSH)	MeSH+
3. Theory	3.1 Theor*	TX All Text
	3.2 Principle*	TX All Text
	3.3 Construct*	TX All Text
	3.4 Framework*	TX All Text
	3.5 Concept*	TX All Text
	3.6 Psychological phenomena and processes	MeSH+
	3.7 Behavior	MeSH+
4. Interventions	4.1 Intervention*	TX All Text

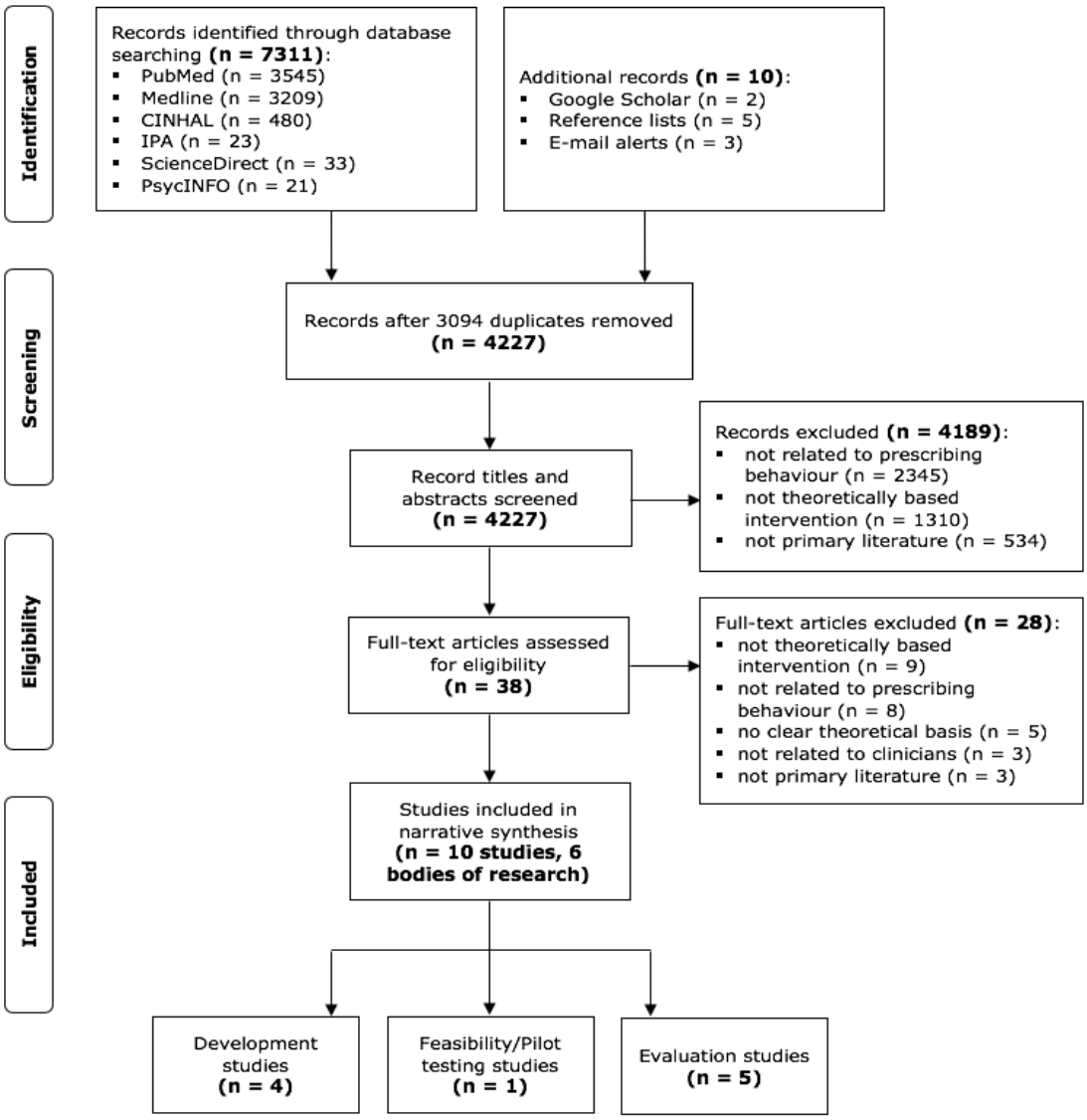

Figure 1. PRISMA flow chart presenting study selection process including reasons for inclusion/exclusion. [27]

Table 2. Mapping of included ten studies (i.e. six bodies of research) to the phases of the UK MRC Guidance.

Body of research number	Study authors	Phase 1: Development	Phase 2: Feasibility/Pilot testing	Phase 3: Evaluation
Body of research 1	Hrisos et al. Part 1 [28]	√		
	Hrisos et al. Part 2 [33]			√
Body of research 2	Milos et al. [34]			√
Body of research 3	Treweek et al. Part 1 [29]	√		
	Treweek et al. Part 2 [35]			√
Body of research 4	Bekkers et al. Part 1 [36]			√
	Butler et al. Part 2 [37]			√
Body of research 5	Lucas et al. Part 1 [30]	√		
	Blair et al. Part 2 [32]		√	
Body of research 6	Chambers et al. [31]	√		

Table 3. Characteristics and key findings of studies included (Spelling is as original papers) *(n = 10)*

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
Development studies *(n = 4)*							
Hrisos et al. (2008, UK) Part 1 [28]	To design two theoretically-based interventions to promote the management of URTI without prescribing antibiotics	Qualitative study applying the Intervention Modeling Process (IMP) and using previous findings of research [38, 39]	▪ Primary care ▪ GPs (sample size is published elsewhere, (n= 15 [38]; n=185 [39]) ▪ URTI	<u>Paper-based behavioural interventions:</u> 1. Graded task: targeted self-efficacy and required GPs to consider more difficult situations in a "graded task", to generate alternative strategies as a way of "rehearsing" alternative actions and to develop an "action plan" when confronted by a clinical situation in which a patient presented with an URTI 2. Persuasive communication: targeted anticipated consequences and required GPs to respond	Theory of Planned Behaviour, Social Cognitive Theory and Operant Learning Theory		It is feasible to systematically develop theoretically-based interventions to change professional practice. Two interventions were designed that differentially target generalisable constructs predictive of GP management of URTI

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
				to a "persuasive communication" containing a series of pictures representing the consequences of managing URTI with and without antibiotics			
Treweek et al. (2014, UK) Part 1 [29]	To evaluate the robustness of the Web-based Intervention Modeling Experiment (IME) methodology as a way of developing and testing behavioral change interventions before a full-scale trial by replicating an earlier paper-based IME	Online questionnaire survey	▪ Primary Care ▪ GPs (n=270) ▪ URTI	<u>Web-based behavior change interventions:</u> ▪ Persuasive communication [28] ▪ Action plan: targeted beliefs about capabilities, and behavioral regulation, asked GPs to make an action plan following a template, which included context and frequency	Theory of Planned Behavior, Social Cognitive Theory, Operant Learning Theory and Theoretical Domains Framework		The constructs that predicted simulated behavior and intention were attitude, perceived behavioral control, risk perception/anticipated consequences, and self-efficacy, which match the targets identified in the earlier paper-based IME. The choice of persuasive communication as an intervention in the earlier IME was also confirmed. A new intervention, an action plan, was developed
Lucas et al. (2017, UK) Part 1 [30]	To develop an evidence-based, theory-informed,	Qualitative study using previous findings of a	▪ Primary care ▪ Clinicians and parents (sample	<u>A web-based within-consultation intervention</u>: It comprised three	Green and Krueter's Precede/Proceed logic model		Current evidence suggests that interventions which reduce clinical

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
	intervention to reduce antibiotic prescriptions in primary care for childhood RTI	multi-method programme of research	size is published elsewhere [32]) ▪ RTI	active elements: explicit elicitation of parent concerns and expectations (to reduced clinician-perceived pressure to prescribe), the results of a CPR accompanied by delayed or no-antibiotic guidance (to reduce clinical uncertainty), and provision of a personalized printout for carers (to provide an alternate treatment action for clinicians)	which draws on social cognitive theories		uncertainty, reduce clinician/parent miscommunication, elicit parent concerns, make clear delayed or no-antibiotic recommendations, and provide clinicians with alternate treatment actions have the best chance of success
Chambers et al. (2018, Canada)[31]	To better understand barriers and facilitators that contribute to antibiotic overuse in long-term care and to use this information to inform an evidence and theory-informed program	Online questionnaire survey and focus groups	▪ LTCFs ▪ Survey: infection control practitioners (n=643), anyone in LTCFs involved in the prevention, identification, diagnosis, and/or treatment of UTIs and LTCFs residents and families	<u>A multifaceted program:</u> 19 distinct barriers and facilitators were mapped to eight domains from the Theoretical Domains Framework (TDF): knowledge, skills, environmental context and resources, professional role or identity, beliefs about consequences, social influences, emotions, and	TDF		The use of a stepped approach was valuable to ensure that locally relevant barriers and facilitators to practice change were addressed in the development of a regional program to help long-term care facilities minimize antibiotic prescribing for asymptomatic bacteriuria.

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
			▪ Focus groups: staff from two LTCFs (n=9), including a nurse practitioner, registered nurses, the directors of care, the infection control lead, a physician and a staff member responsible for reporting and quality improvement ▪ ASB and UTIs	reinforcements. The assessment of barriers and facilitators informed the need for a multifaceted approach with the inclusion of strategies: (1) to establish buy-in for the changes; (2) to align organizational policies and procedures; (3) to provide education and ongoing coaching support to staff; (4) to provide information and education to residents and families; (5) to establish process surveillance with feedback to staff; and (6) to deliver reminders			
Feasibility/Pilot testing study *(n = 1)*							
Blair et al. (2017, UK) Part 2* [32]	To investigate recruitment and retention, data collection methods and the acceptability of a 'within-consultation'	Feasibility cluster RCT, using a web-based data collection tool and semi-structured interviews	▪ Primary care ▪ GPs and prescribing nurses (n=104 in the full trial), (n=28 in the interviews),	<u>Web-based within-consultation intervention:</u> Clinical rule to predict risk of future hospitalisation and printed leaflet with individualised child	Green and Krueter's Precede/Proceed logic model which draws on social cognitive theories	Assessing intervention use by recording number of times clinicians used intervention	Overall prescribing rates were 25% and 15.8% (p=0.018) in intervention and control groups. Evidence of postrandomisation

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
	complex intervention designed to reduce antibiotic prescribing		children (n=542 in the full trial) and carers (n=14 in the interviews) ▪ Acute cough and RTI	health information for carers <u>Controls:</u> Usual practice, with clinicians recording symptoms, signs, treatment decisions		and time spent. Medical notes reviews conducted to collect data on 30 days following recruitment consultation. Clinicians from both arms and carers from the intervention arm only invited to participate in interviews to explore their views	differential recruitment: number in intervention arm was higher (292 vs 209); over half recruited by nurses compared with less than a third in control arm; children in intervention arm were more unwell. Interviews with clinicians confirmed preferential recruitment of less unwell children in the control arm. Using intervention added around 5 min to consultation time
Evaluation studies *(n = 5)*							
Hrisos et al. (2008, UK) Part 2** [33]	To evaluate the effect of two theory-based interventions on the behavioural intention and simulated behaviour of GPs in relation to the management of uncomplicated URTI	2 × 2 factorial RCT using baseline and post intervention, postal questionnaire survey (randomisation is at a group level, general practices)	▪ Primary care ▪ GPs (n=1225) ▪ URTI	<u>Paper-based behavioural interventions designed to change beliefs, previously identified as predictors of prescribing</u>: 1. Graded task: targeted the theoretical construct of self-efficacy (SCT)	Theory of Planned Behaviour (TPB), Social Cognitive Theory (SCT) and Operant Learning Theory (OLT)	Assessing two theoretical constructs: ▪ Behavioural intention by questionnaire questions ▪ Behavioural simulation	GPs completing Intervention 1 reported stronger self-efficacy scores (Beta = 1.41, 95% CI: 0.64 to 2.25) and GPs completing Intervention 2 had more positive anticipated consequences scores (Beta = 0.98, 95% CI =

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
				using the behaviour change techniques of graded task, rehearsal and action planning 2. Persuasive communication: targeted the theoretical constructs of anticipated consequences and risk perception <u>Controls:</u> Not received intervention		by written scenarios (included in the questionn aire, informed by a previous study (Eccles et al., 2007) required the respondent to simulate the behaviour they would enact in the real situation	0.46 to 1.98). Intervention 2 had a significant effect on intention (Beta = 0.90, 95% CI = 0.41 to 1.38) and simulated behaviour (Beta = 0.47, 95% CI = 0.19 to 0.74)
Bekkers et al. (2010, UK) Part 1 [36]	To assess participants' views regarding their engagement with the Stemming the Tide of Antibiotic Resistance (STAR)	Semi-structured telephone interviews	▪ Primary Care ▪ GPs and nurses (n= 244 in the full trial), (n=31 in the interviews) ▪ Common infections	<u>The STAR intervention:</u> consisted of five core parts, supplemented with an ongoing web forum (part 6), and a booster session (part 7) provided approximately six months after completion of the	Theory of Planned Behaviour and Social Learning Theory	Assessing process evaluation components: i) intervention delivery fidelity, ii) feasibility and efficacy of the program in daily	Participants reported increased awareness of antibiotic resistance, greater self-confidence in reducing antibiotic prescribing and at least some change in consultation style and antibiotic prescribing

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
	Educational Program			core program. Steps 1-5 include online learning, face-to-face seminars and clinical video scenarios responses and reflections on practice		practice, and iii) areas for intervention refinement by the interview questions	behaviour. Reported practical changes included adopting a practice-wide policy of antibiotic prescription reduction. Many GPs also reported increased insight into patients' expectations, ultimately contributing to improved doctor-patient rapport
Butler et al. (2012, UK) Part 2+ [37]	To evaluate the effectiveness and costs of a multifaceted flexible educational programme aimed at reducing antibiotic dispensing at the practice level in primary care	RCT (randomisation is at a group level, general practices)	▪ Primary care ▪ GPs and nurses (n=263 in the full trial) ▪ RTI	The STAR intervention: A blended learning experience for participants that included various learning methods (reflection on own practice, provision of new research evidence and guidelines, video-rich material presenting communication skills based on motivational interviewing, practice in usual clinical contexts,	Theory of Planned Behaviour and Social Learning Theory	Assessing numbers of antibiotics dispensed for all causes per 1000 practice patients in the year after the intervention, by the Prescribing Audit Reports and Prescribing Catalogues, as well as reconsultations, admissions to hospital for selected	The STAR educational programme led to reductions in all cause antibiotic dispensing over the subsequent year with no significant change in admissions to hospital, reconsultations or costs. The rate of oral antibiotic dispensing decreased by 14.1 in the intervention group but increased by 12.1 in the control group, a net

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
				sharing experiences and views on a web form and participating in a facilitator led, practice-based seminar) <u>Controls:</u> Not exposed to intervention and provided usual care		causes and costs by the Patient Episode Database for Wales	difference of 26.1. Reductions were found for all classes of antibiotics other than penicillinase-resistant penicillins but were largest and significant individually for penicillin V (7.3%, 0.4% to 13.7%) and macrolides (7.7%, 1.1% to 13.8%)
Milos et al. (2013, Sweden) [34]	To study whether interventions based on behavioural theories can reduce the prescribing of antibiotics against URTIs in primary care	RCT using postal questionnaire survey (randomisation is at a group level, general practices)	▪ Primary care ▪ GPs (n=139) ▪ URTIs	<u>Paper-based behavioural interventions, validated in a previous study</u> [33]<u>:</u> ▪ A questionnaire assessing attitudes, beliefs and subjective norms were sent to all participants ▪ Intervention 1 group also received the graded task intervention (GTI): including a set of questions and the GP asked to describe a difficult situation	Social Cognitive Theory, Operant Learning Theory and Theory of Planned Behaviour	Assessing changes in the rate of prescription of antibiotics against URTIs in patients of all ages and in patients aged 0–6 years, before and after the interventions, and between the groups, by data from the Swedish National Pharmacy Register	No significant differences were seen in the prescription rates before and after the interventions when patients of all ages were analysed together. However, for patients aged 0–6 years, there was a significant lower rate in the PCI group (P = 0.037), but not the GTI group

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
				of managing a patient with URTI without antibiotics ▪ Intervention 2 group also received the persuasive communication intervention (PCI) aimed at influencing the GP's belief about the positive consequences of managing URTIs without antibiotics <u>Controls:</u> Received only the questionnaire			
Treweek et al. (2016, UK) Part 2[$] [35]	To test the Intervention Modeling Experiment (IME) methodology in a Web-based IME that replicated the trial component of an earlier, paper-based IME	Three-arm, web-based randomized evaluation using online questionnaire survey (no details about level of randomisation)	▪ Primary care ▪ GPs (n=198 in the full trial) ▪ URTI	<u>Web-based behavior change interventions:</u> ▪ Persuasive communication [28] ▪ Action plan [29] <u>Controls:</u> No intervention	Theory of Planned Behaviour, Social Cognitive Theory, Operant Learning Theory and Theoretical Domains Framework	Assessing two theoretical constructs: ▪ Behavioral intention by questionnaire questions ▪ Behavioral simulation by eight clinical scenarios	The persuasive communication group did not prescribe an antibiotic in 0.70 more scenarios (95% CI = 0.17-1.24) than those in the control arm. For the action plan, GPs did not prescribe an antibiotic in 0.63 (95% CI = 0.11-1.15) more scenarios than

Authors (year published, country of origin)	Study aim/objective	Methods	Setting, participants (n), medical condition	Type of intervention (s)	Underpinning theory/model /framework	Outcome measures	Key findings/results
							those in the control arm. Behavioral intention was unaffected by both interventions

*Linked to Lucas et al. Part 1 [30], **Linked to Hrisos et al. Part 1 [28], +Linked to Bekkers et al. Part 1 [36], $Linked to Treweek et al. Part 1 [29]

Abbreviations: GPs: General Practitioners, RTI: Respiratory Tract Infections, URTIs: Upper Respiratory Tract Infections, UTIs: Urinary Tract Infections, ASB: Asymptomatic Bacteriuria, LTCFs: Long-term care facilities, RCT: Randomised Controlled Trial

Table 4. Assessment of methodological quality of included quantitative designs using adapted Consolidated Standards of Reporting Trials 2010 [23,24]

Criteria		Hrisos et al. Part 2* [33]	Bulter et al. Part 2** [37]	Milos et al. [34]	Treweek et al. Part 2+ [35]	Blair et al. Part 2$ [32]
Objectives	Specific objectives/hypotheses	Yes	Yes	Yes	Partly	Yes
Trial design	Description of trial design including allocation ratio	Yes	Yes	Yes	Partly	Yes
	Important changes to methods after commencement, with reasons	Not reported	Not reported	Not relevant	Not reported	Not reported
Participants	Eligibility criteria for participants	Partly	Yes	Yes	Not reported	Yes
	Settings/locations where data collected	Yes	Yes	Yes	Yes	Yes
Interventions	Interventions for each group with sufficient details to allow replication	Yes	Yes	Partly	Partly	Yes
Outcomes	Prespecified assessments or measurements defined, including how/when assessed	Yes	Yes	Not reported	Yes	Yes
	Changes to assessments or measurements after commencement, with reasons	Not reported	Not reported	Not relevant	Not reported	Not reported
Sample size	How sample size was determined?	Yes	Yes	Yes	Yes	Yes
	When applicable, explanation of any interim analyses and stopping guidelines	Not reported	Not reported	Not relevant	Not relevant	Not reported
Randomisation	Method used to generate the random allocation sequence	Yes	Yes	Yes	Yes	Yes
	Type of randomisation(s); details of any restriction	Yes	Yes	Not relevant	Yes	Not reported
	Mechanism used to implement random allocation sequence	Not reported	Yes	Not reported	Not reported	Not relevant
	Who generated the random allocation sequence, enrolled participants and assigned participants to interventions	Not reported	Not reported	Not reported	Not reported	Not reported
Blinding	If done, who was blinded after assignment to interventions and how?	Not reported	Not relevant	Not relevant	Not reported	Not relevant
	If relevant, description of the similarity of interventions	Yes	Not relevant	Not relevant	Not reported	Not relevant
Participant flow	Participants who were approached/assessed for eligibility/randomly assigned, received intended treatment and were analysed	Yes	Yes	Yes	Yes	Yes
	Losses and exclusions after randomisation, together with reasons	Yes	Yes	Not reported	Yes	Yes

Criteria		Hrisos et al. Part 2* [33]	Bulter et al. Part 2** [37]	Milos et al. [34]	Treweek et al. Part 2+ [35]	Blair et al. Part 2$ [32]
Recruitment	Dates defining the periods of recruitment and follow-up	Yes	Not reported	Yes	Not reported	Not reported
	Why the trial ended or was stopped?	Yes	Not reported	Not reported	Not reported	Not relevant
Baseline data	Baseline demographic and clinical characteristics for each group	Yes	Partly	Yes	Yes	Yes
Numbers analysed	Number of participants included in each analysis	Yes	Yes	Partly	Yes	Yes
Outcomes and estimation	Results including expressions of uncertainty for any estimates	Yes	Not reported	Yes	Yes	Yes
Ancillary analyses	Results of any other analyses performed	Not reported	Not relevant	Partly	Not relevant	Not relevant
Harms	All-important harms or unintended effects in each group	Not relevant	Not reported	Not reported	Not relevant	Not reported
Limitations	Trial limitations, addressing sources of potential bias and imprecision	Yes	Yes	Yes	Yes	Yes
Funding	Sources of funding and other support, role of funders	Yes	Yes	Yes	Yes	Yes

*Linked to Hrisos et al. Part 1 [28], **Linked to Bekkers et al.Part 1 [36], +Linked to Treweek et al. Part 1 [29], $Linked to Lucas et al. Part 1 [30]

Table 5. Assessment of methodological quality of included qualitative designs using adapted Consolidated Criteria for Reporting Qualitative Research [25]

Criteria		Bekkers et al. Part 1 [36]	Blair et al. Part 2* [32]
Aim	Specific aim/objectives	Yes	Yes
Personal characteristics	Which author/s conducted the interview or focus group?	Yes	Not reported
	What characteristics were reported about the inter viewer/facilitator?	Not reported	Not reported
Methodological orientation	What methodological orientation was stated to underpin the study?	Not reported	Not reported
Sampling	How were participants selected?	Not reported	Yes
Method of approach	How were participants approached?	Yes	Not reported
Sample size	How many participants were in the study?	Yes	Yes
Non-participation	How many people refused to participate or dropped out? Reasons?	Not reported	Not reported
Setting of data collection	Where was the data collected?	Not reported	Not reported
Description of sample	What are the important characteristics of the sample?	Yes	Yes
Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	Partly	Not reported
Audio/visual recording	Did the research use audio or visual recording to collect the data?	Yes	Not reported
Field notes	Were field notes made during and/or after the interview or focus group?	Not reported	Not reported
Data saturation	Was data saturation discussed?	Not reported	Not reported
Number of data coders	How many data coders coded the data?	Yes	Yes
Description of the coding tree	Did authors provide a description of the coding tree?	Not reported	Not reported
Derivation of themes	Were themes identified in advance or derived from the data?	Yes	Not reported
Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified?	Yes	Yes
Data and findings consistent	Was there consistency between the data presented and the findings?	Yes	Yes

*Linked to Lucas et al. Part 1 [30]

Table 6. Assessment of the use of theory in the ten studies included using the Theory Coding Scheme [26]

Criteria	Body of research 1		Body of research 2	Body of research 3		Body of research 4		Body of research 5		Body of research 6
	Hrisos et al. Part 1 [28]	Hrisos et al. Part 2 [33]	Milos et al. [34]	Treweek et al. Part 1 [29]	Treweek et al. Part 2 [35]	Bekkers et al. Part 1 [36]	Butler et al. Part 2 [37]	Lucas et al. Part 1 [30]	Blair et al. Part 2 [32]	Chambers et al. [31]
1. Theory/model of behaviour mentioned	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Targeted construct mentioned as predictor of behaviour	Yes	Yes, in Part 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes, in Part 1	Yes
3. Intervention based on single theory	No	No	No	No	No	No	No	No	No	No
4. Theory/predictors used to select intervention recipients	No	No	No	Yes, in Part 2*	Yes	No	No	No	No	No
5. Theory/predictors used to select/develop intervention techniques	Yes	Yes	Yes	Yes	Yes	Yes	Yes, in Part 1	Yes	Yes, in Part 1	Yes
6. Theory/predictors used to tailor intervention techniques to recipients	No	No	No	No	No	No	No	No	No	No
7. All intervention techniques are explicitly linked to at least one theory relevant construct/predictor	Yes	Yes, in Part 1	Yes	Yes	Yes	No	No	No	No	Partly
8. At least one, but not all, of the intervention techniques are explicitly linked to at least one theory-relevant construct/predictor	No	No	No	No	Yes	No	No	No	No	No
9. Group of techniques are linked to a group of constructs/predictors	No	No	No	No	No	No	No	No	No	No
10. All theory-relevant constructs/predictors are explicitly linked to at least one intervention technique	No	No	No	Yes	No	No	No	No	No	Partly
11. At least one, but not all, of the theory relevant	Yes	Yes, in Part 1	Yes	No	Yes	No	No	No	No	No

Criteria	Body of research 1		Body of research 2	Body of research 3		Body of research 4		Body of research 5		Body of research 6
	Hrisos et al. Part 1 [28]	Hrisos et al. Part 2 [33]	Milos et al. [34]	Treweek et al. Part 1 [29]	Treweek et al. Part 2 [35]	Bekkers et al. Part 1 [36]	Butler et al. Part 2 [37]	Lucas et al. Part 1 [30]	Blair et al. Part 2 [32]	Chambers et al. [31]
constructs/predictors are explicitly linked to at least one intervention technique										
12. Theory-relevant constructs/predictors are measured		Yes	No		Yes	No	No		No	
13. Quality of measures		Partly	Partly		Partly	No	Partly		No	
14. Randomization of participants to condition		Yes	Yes		Yes	No	Yes		Partly	
15. Changes in measured theory-relevant constructs/predictor		Yes	No		No	No	No		No	
16. Mediational analysis of construct/s/predictors		Partly	No		No	No	No		No	
17. Results discussed in relation to theory		Yes	No		Yes	No	No		No	
18. Appropriate support for theory		Yes	No		No	No	No		No	
19. Results used to refine theory		No	No		No	No	No		No	

Table 7. Justifications of chosen theory as reported by study authors in included bodies of research *(n = 6)*

Body of research number	Underpinning theory/model/framework	Justification
Body of research 1 [28, 33]	TPB, SCT and OLT	A previous study found that three theories included constructs that predicted GPs' prescribing behaviour for URTI: TPB, SCT and OLT. These theories explain behaviour in terms of factors amenable to change [38]
Body of research 2 [34]	TPB, SCT and OLT	Based on the findings of research reported by Hrisos et al. [28, 29]
Body of research 3 [29, 35]	TPB, SCT, OLT and TDF	TPB, SCT and OLT: based on the findings of research reported by Hrisos et al. [28, 29] TDF: based on the methods proposed by Michie et al. [40] to map identified constructs onto behaviour change techniques. This was expected to lead to one or more potential interventions for evaluation
Body of research 4 [36, 37]	TPB and SLT	To addresses both the 'how' and the 'why' of clinician behaviour change
Body of research 5 [30, 32]	Green and Krueter's Precede/Proceed logic model	It draws on social cognitive theories which hypothesize that behaviour is influenced by context and by personal perceptions of costs, benefits and efficacy of actions
Body of research 6 [31]	TDF	It helps the user categorize known barriers and facilitators to practice change and select implementation strategies
Abbreviations: TPB: Theory of Planned Behaviour, SCT: Social Cognitive Theory, OLT: Operant Learning Theory, TDF: Theoretical Domains Framework, SLT: Social Learning Theory		