

Online Supplemental Documents

Borek A, Wanat M, Atkins L, et al. **Optimising antimicrobial stewardship interventions in English primary care: a behavioural analysis of qualitative and intervention studies**. *BMJ Open* 2020. doi:10.1136/bmjopen-2020-039284

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Supplemental Document 1. Search strategy to identify qualitative studies

The search strategy was performed in Medline database and adapted for other databases as necessary (with the same search terms).

- 1 exp Respiratory Tract Infections/
- 2 ((respiratory or chest) adj3 (infect* or inflam*)).ti,ab.
- 3 (ARI or ARTI or URTI or LRT).ti,ab.
- 4 (pharyngit* or nasopharyngit* or naso-pharyngit* or rhinopharyngit* or rhino-pharyngit* or sinusit* or nasosinusit* or naso-sinusit* or rhinosinusit* or rhino-sinosit* or rhinit* or rhinorrhoea or rhinorrhea or ((runny or running or discharg* or congest* or blocked or stuff* or dripping or runn*) adj2 (nose* or nasal))).ti,ab.
- 5 ((throat* adj3 (sore or pain or inflam* or infect*)) or tonsillit* or laryngit* or rhinolaryngit* or rhino-laryngit* or nasolaryngit* or naso-laryngit* or sinonasal* or sino-nasal*).ti,ab.
- 6 (croup or pseudocroup or tracheitis or tracheobronchit* or laryngotracheobronchit* or bronchit* or bronchiolit* or pneumon* or pleuropneumon* or bronchopneumon* or pleurisy).ti,ab.
- 7 (cough or sneez* or common cold).ti,ab.
- 8 (influenza or flu).ti,ab.
- 9 (otitis media or aom or ome or earache*).ti,ab.
- 10 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9
- 11 exp Anti-Bacterial Agents/
- 12 (antibiotic* or anti-biotic* or antibacterial* or anti-bacterial* or antimicrobial* or anti-microbial* or macrolide* or beta-lactam* or penicillin or methicillin or ampicillin or azithromycin or cephalixin).ti,ab.
- 13 11 or 12
- 14 Inappropriate Prescribing/
- 15 exp Prescriptions/
- 16 Practice Patterns, Physicians'/
- 17 (prescribing or prescription?).ti,ab.
- 18 ((antibiotic* or anti-biotic* or antibacterial* or anti-bacterial* or antimicrobial* or anti-microbial* or macrolide* or beta-lactam* or penicillin or methicillin or ampicillin or azithromycin or cephalixin) adj3 ("use" or overuse or overprescri* or usage or consum* or uptake or delay* or demand? or reduc* or discontinu* or stop*)).ti,ab.
- 19 stewardship.ti,ab.
- 20 14 or 15 or 16 or 17 or 18 or 19

- 21 Ambulatory Care/ or exp Ambulatory Care Facilities/
22 exp general practice/ or exp general practitioners/ or exp physicians, family/ or exp
physicians, primary care/ or exp Primary Health Care/ or exp Office Visits/
23 COMMUNITY PHARMACY SERVICES/ or PHARMACY/
24 Pharmacists/
25 (ambulatory adj3 (care or setting? or facilit* or ward? or department? or service?)).ti,ab.
26 ((general or family) adj2 (practi* or physician? or doctor?)).ti,ab.
27 (primary care or primary health care or primary healthcare).ti,ab.
28 (after hour? or afterhour? or "out of hour?" or ooh).ti,ab.
29 ((health* or medical) adj2 (center? or centre?)).ti,ab.
30 (clinic? or visit?).ti,ab.
31 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30
32 attitude/ or exp "attitude of health personnel"/ or exp attitude to health/
33 (attitude? or knowledge or view? or opinion? or experience?).ti,ab.
34 (barrier? or challeng* or obstacle? or facilitat* or enab* or opportunit* or
implement*).ti,ab.
35 32 or 33 or 34
36 10 and 13 and 20 and 31
37 10 and 13 and 20 and 31 and 35
38 (Qualitative systematic review* or (systematic review and qualitative)).ti,ab.
39 (evidence synthesis or realist synthesis or realist review).ti,ab.
40 (Qualitative and synthesis).ti,ab.
41 (meta-synthesis* or meta synthesis* or metasynthesis).ti,ab.
42 (meta-ethnograph* or metaethnograph* or meta ethnograph*).ti,ab.
43 (meta-study or metastudy or meta study).ti,ab.
44 systematic review*.ti,ab. and qualitative research/
45 38 or 39 or 40 or 41 or 42 or 43 or 44
46 36 and 45
47 limit 46 to (english language and yr="2000 -Current")
48 qualitative research/
49 *interviews as topic/ or focus groups/ or narration/

- 50 observation.ti.
- 51 interview?.ti,ab.
- 52 (qualitative adj2 (interview* or study or research)).ti,ab.
- 53 qualitative.ti.
- 54 (focus group? or story or stories or narration or narrative* or discourse or discursive or grounded theory or ethnogra* or phenomenolog*).ti,ab.
- 55 "Surveys and Questionnaires"/
- 56 (questionnaire? or survey?).ti,ab.
- 57 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56
- 58 37 and 57
- 59 limit 58 to (english language and yr="2000 -Current")
- 60 47 or 59

Note: Results of the search in line 47 were used to identify systematic reviews of qualitative studies, whereas results of the search in line 60 were used to identify individual qualitative studies.

Supplemental Document 2. Search strategy to identify research interventions

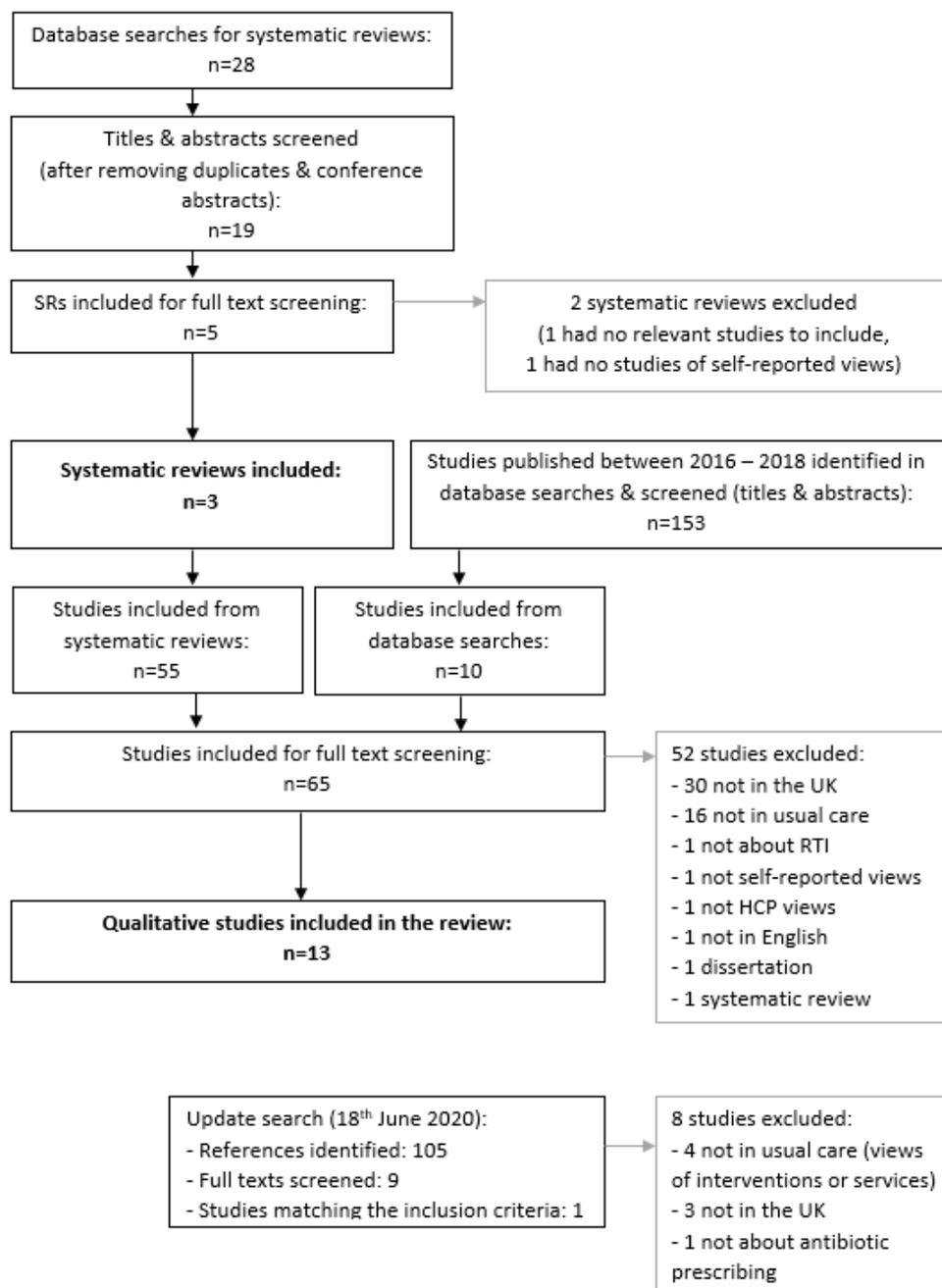
The search strategy was performed in Medline database and adapted for other databases as necessary (with the same search terms).

- 1 exp Respiratory Tract Infections/
- 2 ((respiratory or chest) adj3 (infect* or inflam*)).ti,ab.
- 3 (ARI or ARTI or URTI or LRT).ti,ab.
- 4 (pharyngit* or nasopharyngit* or naso-pharyngit* or rhinopharyngit* or rhino-pharyngit* or sinusit* or nasosinusit* or naso-sinusit* or rhinosinusit* or rhino-sinosit* or rhinit* or rhinorrhoea or rhinorrhea or ((runny or running or discharg* or congest* or blocked or stuff* or dripping or runn*) adj2 (nose* or nasal))).ti,ab.
- 5 ((throat* adj3 (sore or pain or inflam* or infect*)) or tonsillit* or laryngit* or rhinolaryngit* or rhino-laryngit* or nasolaryngit* or naso-laryngit* or sinonasal* or sino-nasal*).ti,ab.
- 6 (croup or pseudocroup or tracheitis or tracheobronchit* or laryngotracheobronchit* or bronchit* or bronchiolit* or pneumon* or pleuropneumon* or bronchopneumon* or pleurisy).ti,ab.
- 7 (cough or sneez* or common cold).ti,ab.
- 8 (influenza or flu).ti,ab.
- 9 (otitis media or aom or ome or earache*).ti,ab.
- 10 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9
- 11 exp Anti-Bacterial Agents/
- 12 (antibiotic* or anti-biotic* or antibacterial* or anti-bacterial* or antimicrobial* or anti-microbial* or macrolide* or beta-lactam* or penicillin or methicillin or ampicillin or azithromycin or cephalixin).ti,ab.
- 13 11 or 12
- 14 Inappropriate Prescribing/
- 15 exp Prescriptions/
- 16 Practice Patterns, Physicians'/
- 17 (prescribing or prescription?).ti,ab.
- 18 ((antibiotic* or anti-biotic* or antibacterial* or anti-bacterial* or antimicrobial* or anti-microbial* or macrolide* or beta-lactam* or penicillin or methicillin or ampicillin or azithromycin or cephalixin) adj3 ("use" or overuse or overprescri* or usage or consum* or uptake or delay* or demand? or reduc* or discontinu* or stop*)).ti,ab.
- 19 stewardship.ti,ab.
- 20 14 or 15 or 16 or 17 or 18 or 19

- 21 Ambulatory Care/ or exp Ambulatory Care Facilities/
- 22 exp general practice/ or exp general practitioners/ or exp physicians, family/ or exp physicians, primary care/ or exp Primary Health Care/ or exp Office Visits/
- 23 COMMUNITY PHARMACY SERVICES/ or PHARMACY/
- 24 Pharmacists/
- 25 (ambulatory adj3 (care or setting? or facilit* or ward? or department? or service?)).ti,ab.
- 26 ((general or family) adj2 (practi* or physician? or doctor?)).ti,ab.
- 27 (primary care or primary health care or primary healthcare).ti,ab.
- 28 (after hour? or afterhour? or "out of hour?" or ooh or walk-in or walkin).ti,ab.
- 29 ((health* or medical) adj2 (center? or centre?)).ti,ab.
- 30 (clinic? or visit?).ti,ab.
- 31 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30
- 32 10 and 13 and 20 and 31
- 33 limit 32 to "reviews (maximizes specificity)"
- 34 limit 33 to (english language and yr="2000 -Current")
- 35 randomized controlled trial.pt.
- 36 controlled clinical trial.pt.
- 37 randomized.ab.
- 38 placebo.ab.
- 39 clinical trials as topic.sh.
- 40 randomly.ab.
- 41 trial.ti.
- 42 35 or 36 or 37 or 38 or 39 or 40 or 41
- 43 exp animals/ not humans.sh.
- 44 42 not 43
- 45 32 and 44
- 46 limit 45 to (english language and yr="2000 -Current")

Note: Results of the search in line 34 were used to identify systematic reviews of research studies, whereas results of the search in line 46 were used to identify individual research studies.

Supplemental Document 3. Flow chart of selection process of qualitative studies



Supplemental Document 4. Characteristics of included qualitative studies

First author, year, title (reference)	Study aim	Design / Methods	Setting & Participants	Key findings (related to HCP views, based on paper abstracts)
Ashdown 2016 , Prescribing antibiotics to 'at-risk' children with influenza-like illness in primary care: qualitative study (1)	To investigate GPs' accounts of factors influencing their decision-making about antibiotic prescribing in the management of at-risk children with influenza-like illness.	Semi-structured telephone interviews (with a case vignette); maximum variation sampling; thematic analysis	General practice: 41 GPs: 40 in England, 1 in Northern Ireland	There was considerable uncertainty and variation in the way GPs responded to the case and difference of opinion about how long-term comorbidities should affect their antibiotic prescribing pattern. Factors influencing their decision included the child's case history and clinical examination; the GP's view of the parent's ability to self-manage; the GP's own confidence and experiences of managing sick children and assessment of individual versus abstract risk. GPs rarely mentioned potential influenza infection or asked about immunisation status. All said that they would want to see the child; views about delayed prescribing varied in relation to local health service provision including options for follow-up and paediatric services.
Brookes-Howell 2012a , Clinical influences on antibiotic prescribing decisions for lower respiratory tract infection: a nine country qualitative study of variation in care (2)	To investigate clinicians' accounts of clinical influences on antibiotic prescribing decisions for LRTI to better understand variation and identify opportunities for improvement.	Semi-structured interviews (with a scenario to reflect); randomly selected sample; 5-stage (thematic) analytic framework approach	General practice: 80 GPs from the UK and 6 other countries, including: 6 GPs in	Four main individual clinical factors guided clinicians' antibiotic prescribing decision: auscultation, fever, discoloured sputum and breathlessness. These were considered alongside a general impression of the patient derived from building a picture of the illness course, using intuition and familiarity with the patient. Comorbidity and older age were considered main risk factors for poor outcomes. Clinical factors were similar across networks, apart from C reactive protein near patient testing in Tromsø. Clinicians developed ways to handle diagnostic and management uncertainty through their own clinical routines.

			England, and 8 GPs in Wales	
Brookes-Howell 2012b , Understanding variation in primary medical care: a nine-country qualitative study of clinicians' accounts of the nonclinical factors that shape antibiotic prescribing decisions for lower respiratory tract infection (3)	To investigate clinicians' accounts of non-clinical factors that influence their antibiotic prescribing decision for patients with LRTI, to understand variation and identify opportunities for addressing possible unhelpful variation.	Semi-structured interviews (with a scenario to reflect); randomly selected sample; 5-stage (thematic) analytic framework approach	General practice: 80 GPs from the UK and 6 other countries, including: 6 GPs in England and 8 GPs in Wales	Non-clinical factors imposed by the healthcare system operating within specific regional primary care research networks: patient access to antibiotics before consulting a doctor (Barcelona and Milan), systems to reduce patient expectations for antibiotics (Southampton and Antwerp) and lack of consistent treatment guidelines (Balatonfüred and Łódz). Secondly, accounts revealed factors related to specific characteristics of clinicians regardless of network (professional ethos, self-belief in decision-making and commitment to shared decision-making).
Cabral 2015 , 'It's safer to ...' parent consulting and clinician antibiotic prescribing decisions for children with respiratory tract infections: an analysis across four qualitative studies (4)	To understand the drivers of parental consulting and clinician prescribing behaviour when children under 12 years consult primary care with acute RTI.	Cross-study analysis of 4 studies: A. focus groups with parents; B. interviews with parents; C. interviews with clinicians on experiences of RTI consultations with children (ref. to conference paper);	General practice: Study C: 28 professionals, including 22 GPs and 6 nurses in England	Four overarching themes were identified: the perceived vulnerability of children; seeking safety in the face of uncertainty; seeking safety from social disapproval; and experience and perception of safety. The social construction of children as vulnerable and normative beliefs about the roles of parents and clinicians were reflected in parents' and clinicians' beliefs and decision making when a child had an RTI. Consulting and prescribing antibiotics were both perceived as the safer course of action. Therefore perception of a threat or uncertainty about that threat tended to lead to parental consulting and clinician antibiotic prescribing. Clinician and parent experience could influence the perception of safety in either direction, depending on

		D. systematic review synthesising parent and clinician views of prescribing for children with acute illness. Themes and common patterns identified across dataset through iterative approach, translating common themes across studies and re-organising themes into conceptual groups.		whether previous action had resulted in perceived increases or decreases in safety.
Cabral 2016, Influence of clinical communication on parents' antibiotic expectations for children with respiratory tract infections (5)	To understand clinicians' and parents' perceptions of communication within consultations for RTI in children and what influence clinician communication had	Video recordings of 60 consultations for children with RTIs and cough in 6 general practices; purposive sampling of 27 parents and 13	General practice: 13 clinicians, including 9 GPs, 3 nurse prescribers and 1 physician	While clinicians commonly told parents that antibiotics are not effective against viruses, this did not have much impact on parents' beliefs about the need to consult or on their expectations concerning antibiotics. Parents believed that antibiotics were needed to treat more severe illnesses, a belief that was supported by the way clinicians accompanied viral diagnoses with problem minimizing language and antibiotic prescriptions with more problem-oriented language. Antibiotic prescriptions tended to confirm parents'

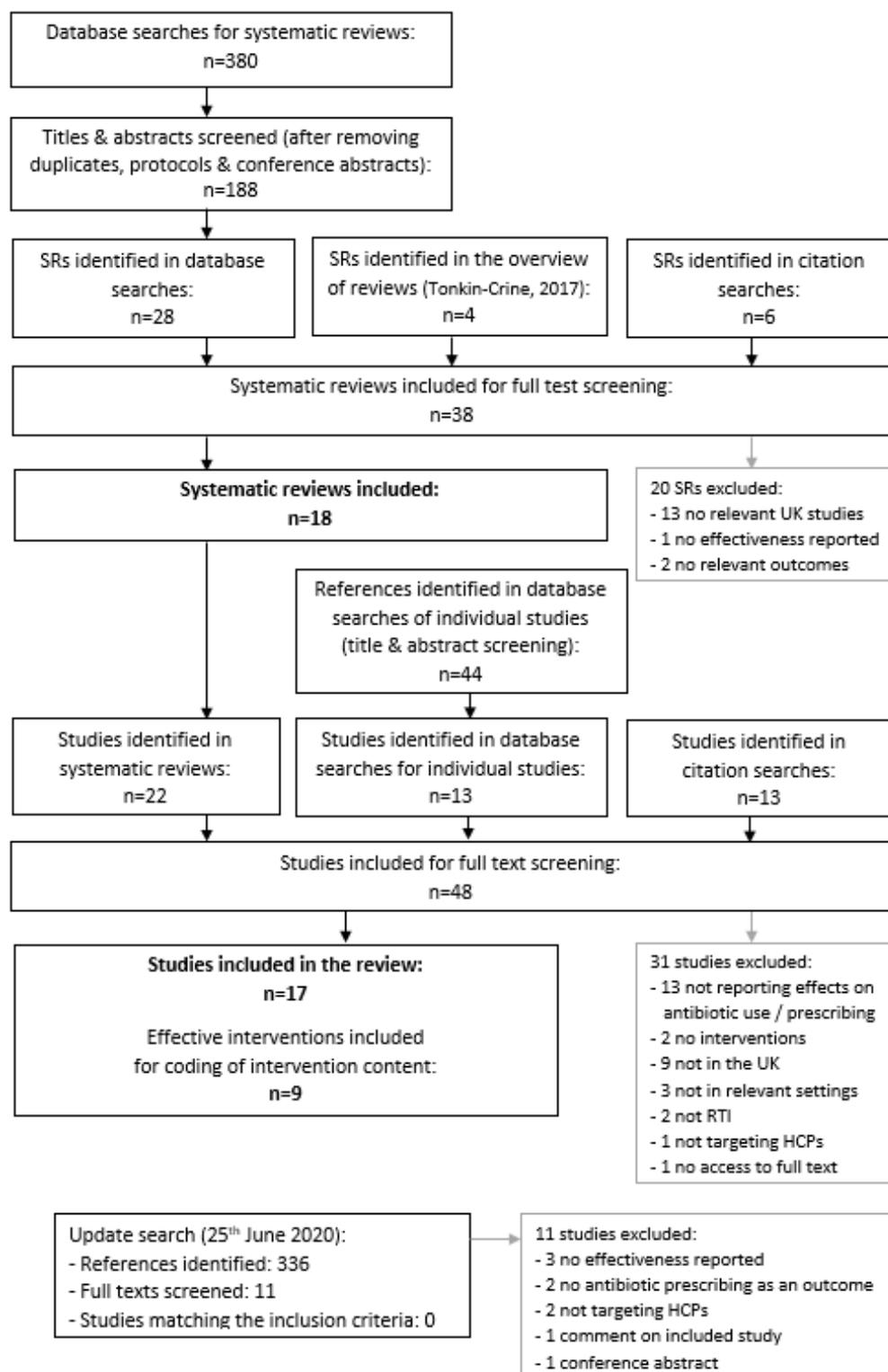
	on parents' understanding of antibiotic treatment.	clinicians for semi-structured video-elicited interviews; thematic analysis	assistant in England	beliefs about what indicated illness severity, which often took into account the wider impact on a child's life.
Courtenay 2017, Antibiotics for acute respiratory tract infections: a mixed-methods study of patient experiences of non-medical prescriber management (6)	To (1) explore patients' expectations and experiences of nurse and pharmacist non-medical prescriber management of RTIs, (2) examine whether patient expectations for antibiotics affect the likelihood of receiving them and (3) understand factors influencing patient satisfaction with RTI consultations.	Mixed methods: (i) questionnaires with 120 patients, (ii) interviews with 22 patients, (iii) interviews with 16 nurse and pharmacist non-medical prescribers; qualitative analysis informed by quantitative findings, inductive thematic analysis	General practice: 16 nurse and pharmacist non-medical prescribers: 7 in England, 5 in Scotland and 4 in Wales	There was alignment between self-reported patient expectations and those perceived by non-medical prescribers. 'Patient-centred' management strategies (including reassurance and providing information) were received by 86.7% of patients. Regardless of patients' expectations or the management strategy employed, high levels of satisfaction were reported for all aspects of the consultation. Taking concerns seriously, conducting a physical examination, communicating the treatment plan, explaining treatment decisions and lack of time restrictions were each reported to contribute to patient satisfaction.
Horwood 2016, Primary care clinician antibiotic prescribing decisions in consultations for children with RTIs: a	To investigate healthcare professional (HCP) diagnostic and antibiotic prescribing	Semi-structured interviews; purposive maximum-variation	General practice & walk-in centre:	HCPs varied in the symptom and clinical examination findings used to identify children they thought might benefit from antibiotics. Their diagnostic reasoning and assessment of perceived clinical need for antibiotics used a dual process, combining an initial rapid assessment with subsequent detailed deductive reasoning. HCPs reported confidence

qualitative interview study (7)	decisions for children with RTIs.	sampling; thematic analysis	22 GPs and 6 nurses from 6 general practices and one walk-in centre (unclear if they were in England or across the UK)	diagnosing and managing most minor and severe RTIs. However, residual prognostic uncertainty, particularly for the intermediate illness severity group, frequently led to antibiotic prescribing to mitigate the perceived risk of subsequent illness deterioration. Some HCPs perceived a need for more paediatrics training to aid treatment decisions. The study also identified a number of non-clinical factors influencing prescribing.
Kumar 2003, Why do general practitioners prescribe antibiotics for sore throat? Grounded theory interview study (8)	To understand why GPs prescribe antibiotics for some cases of sore throat and to explore the factors that influence their prescribing.	Open-ended interviews using an interview guide; purposive and theoretical sampling; grounded theory, constant comparative analysis	General practice: 40 GPs (unclear if they were in England or across the UK)	GPs are uncertain which patients will benefit from antibiotics but prescribe for sicker patients and for patients from socioeconomically deprived backgrounds because of concerns about complications. They are also more likely to prescribe in pressured clinical contexts. Doctors are mostly comfortable with their prescribing decisions and are not prescribing to maintain the doctor-patient relationship.
Mustafa 2014, Managing expectations of antibiotics for upper respiratory tract infections: a qualitative study (9)	To explore the views and experiences of GPs about asking patients directly whether they expect to receive antibiotics & focusing on the problem of eliciting	Semi-structured interviews; convenience sampling (all GPs in the area invited, interviewed those	General practice: 20 GPs in Wales	Physicians assumed most patients or parents wanted antibiotics, as well as wanting to be “checked out” to make sure the illness was “nothing serious.” Physicians said they did not ask direct questions about expectations, as that might lead to confrontation. They preferred to elicit expectations for antibiotics in an indirect manner, before performing a physical examination. The majority described reporting their findings of the

	expectations of antibiotics as a possible treatment for URTIs.	who responded); thematic analysis		examination as a “running commentary” so as to influence expectations and help avoid generating resistance to a soon-to-be-made-explicit plan not to prescribe antibiotics. The physicians used the running commentary to preserve and enhance the physician-patient relationship.
Rowbotham 2012, Challenges to nurse prescribers of a no-antibiotic prescribing strategy for managing self-limiting respiratory tract infections (10)	To explore the experiences of nurse prescribers in managing patients with self-limiting RTIs.	Semi-structured interviews and focus groups; purposive maximum-variation sampling; qualitative approach to develop conceptual categories and themes	General practice: Interviews: 15 nurses; 3 focus groups with 21 nurses (5, 4 and 12 in each) (unclear if they were in England or across the UK)	Although participants reported experiencing numerous challenges within these consultations, they believed that they possessed some of the communication skills to deal effectively with patients without prescribing antibiotics. Participants reported that protocols supported their decision-making and welcomed the benefits of peer support in dealing with ‘demanding’ patients. However, the newness of nurses and other non-medical prescribers to the prescribing role meant that some were cautious in dealing with patients with respiratory tract infections.
Tonkin-Crine 2011, GPs’ views in five European countries of interventions to promote prudent antibiotic use (11)	To explore GPs’ views and experiences of strategies to promote a more prudent use of antibiotics.	Semi-structured, telephone (in UK) interviews; purposive sampling from high and low-prescribing practices; thematic and	General practice: 52 GPs from the UK and 4 other countries, including 11 GPs in the UK	Themes were remarkably consistent across the countries. GPs had a preference for interventions that allowed discussion and comparison with local colleagues, which helped them to identify how their practice could improve. Other popular components of interventions included the use of near-patient tests to reduce diagnostic uncertainty, and the involvement of other health professionals to increase their responsibility for prescribing.

		framework analysis	(unclear if they were in England or across the UK)	
Williams 2017, General practitioner and nurse prescriber experiences of prescribing antibiotics for respiratory tract infections in UK primary care out-of-hours services (the UNITE study) (12)	To explore GP and nurse prescriber (NP) views on and experiences of prescribing antibiotics for RTIs in primary care OOH services.	Semi-structured interviews; purposive maximum-variation sampling supported by snowball/chain sampling; inductive thematic analysis	Out-of-hours: 30: 15 GPs and 15 nurse prescribers in England	The research shows that factors particular to OOH influence antibiotic prescribing, including a lack of patient follow-up, access to patient GP records, consultation time, working contracts and implementation of feedback, audit and supervision. Nurse prescribers reported perceptions of greater accountability for their prescribing compared with GPs and reported they had longer consultations during which they were able to discuss decisions with patients. Participants agreed that more complex cases should be seen by GPs and highlighted the importance of consistency of decision making, illness explanations to patients as well as a perception that differences in clinical training influence communication with patients and antibiotic prescribing decisions.
Wood 2007, Socially responsible antibiotic choices in primary care: a qualitative study of GPs' decisions to prescribe broad-spectrum and fluoroquinolone antibiotics (13)	To explore the reasons for GPs' choice of prescribed antibiotic, in particular their decision to prescribe fluoroquinolones.	Interviews; purposive and theoretical sampling; grounded theory approach, data indexed into analytical categories	General practice: 40 GPs in Wales	Choosing to prescribe a broad-spectrum antibiotic such as a fluoroquinolone, rather than a narrow-spectrum antibiotic, related to a number of clinical considerations, perceptions of patient expectations and organizational influences. GPs from high fluoroquinolone prescribing practices were more likely to prioritize patients' immediate needs, whereas GPs from average prescribing practices were more likely to consider longer term issues. GPs from both high and average fluoroquinolone prescribing practices justified their antibiotic choices on the basis of a desire to do their best for their patients and society.

Supplemental Document 5. Flow chart of selection process of intervention studies



Supplemental Document 6. Characteristics of included studies

First author, year, title (study name, reference)	Study design	Setting & participants	Interventions & comparators	Outcomes measured	Key results (on effectiveness of interventions on antibiotic prescribing/use; green shading indicates effective interventions)
McNulty 2018, Effects of primary care antimicrobial stewardship outreach on antibiotic use by general practice staff: pragmatic randomized controlled trial of the TARGET antibiotics workshop (14)	McNulty-Zelen RCT (a form of cluster-RCT where practices were not aware that they were taking part in a trial)	General practice: 152 practices England	1) TARGET workshop (1 hour workshop facilitated by existing NHS healthcare staff with promotion of the TARGET website resources) 2) Control (no workshop offered)	Antibiotics dispensed per 1000 practice patients; workshop uptake; dispensing of antibiotics typically prescribed for RTIs, UTIs and broad-spectrum antibiotics	Antibiotics dispensing was 2.7% lower in intervention practices (95% CI -5.5% to 1%, P = 0.06) compared with controls. Dispensing in intervention practices was 4.4% lower for amoxicillin / ampicillin (95% CI 0.6%–8%, P=0.02); 5.6% lower for trimethoprim (95% CI 0.7%–10.2%, P=0.03); and a non-significant 7.1% higher for nitrofurantoin (95% CI 0.03 to 15%, P=0.06).
Ward 2018, Point-of-care C-reactive protein testing to optimise antibiotic use in a primary care urgent care centre setting (15)	Service evaluation	Urgent care centre / walk-in service: Prescribers England	CRP POCT (Alere Afinion) (no comparator group)	Use of CRP POCT; type of antibiotics prescription (immediate, delayed or no prescription)	Pre-test decision (i.e. the decision that would have been made if no test was available): 72/141 (51.1%) patients would have been given an immediate antibiotic prescription, 6 (4.2%) would have been given a delayed prescription and 63 (44.1%) would not have received an antibiotic. Decision after doing CRP tests: 32 (22.7%) patients received an immediate antibiotic, 22 (15.6%)

					received a delayed prescription and 87 (61.7%) received no antibiotic.
Blair 2017, Feasibility cluster randomised controlled trial of a within-consultation intervention to reduce antibiotic prescribing for children presenting to primary care with acute respiratory tract infection and cough (CHICO) (16)	Cluster RCT (feasibility study)	General practice: 32 practices, including: 501 children (3 months – 11 years) with acute cough and RTI England	1) Within-consultation complex intervention (interactive web-based tool, including: recording symptoms and signs, elicitation and recording of carers' concerns, guidelines on antibiotics associated with risk strata, personalised printout for carers) 2) Control (Usual care)	Feasibility and acceptability; use of intervention; RTI-related antibiotic prescriptions; re-consultations; RTI-related hospitalisations	The overall antibiotic prescribing rates for children's RTIs were 25% (19.9% immediate and 5.1% delayed) in intervention group and 15.8% (p=0.018) in control group. <i>(In the Discussion, the authors suggest that this result might be due to a post-randomisation differential recruitment (with intervention arm having more children with more severe baseline characteristics) that might have biased the estimated intervention effect.)</i>
Hallsworth 2016, Provision of social norm feedback to high prescribers of antibiotics in general practice: a pragmatic national randomised controlled trial (17)	RCT	General practice: 1581 practices with antibiotic prescribing rates in the top 20% of the NHS Local Area England	1) Prescribing feedback (a letter from England's Chief Medical Officer stating that the practice was at a higher rate of antibiotic prescribing than 80% of practices in its area + a patient leaflet), 2) patient-focused information (promoting reduced use of antibiotics), 3) Control (no intervention)	Antibiotic items dispensed per 1000 weighted population, controlling for past prescribing	1) Feedback intervention: difference of 4.27 (3.3%; incidence rate ratio 0.967 [95% CI 0.957–0.977]; p<0.0001), representing an estimated 73 406 fewer antibiotic items dispensed. 2) Patient-focused intervention: incidence rate ratio for difference between groups 1.01, 95% CI 1.00–1.02; p=0.105.
Thornley 2016, A feasibility service evaluation of screening	Service evaluation	Community pharmacy:	Sore throat test-and-treat service (assessing patient's condition using the Centor score and patients meeting	Uptake of the throat swab testing;	Following screening by pharmacy staff, 149/367 (40.6%) patients were eligible for throat swab testing. Of these, only 36/149 (24.2%) were

and treatment of group A streptococcal pharyngitis in community pharmacies (18)		35 pharmacies, including 367 patients England	3 or all 4 Centor criteria were offered a throat swab test) (no comparator group)	antibiotic provision by the pharmacist	positive for group A streptococci. Antibiotics were supplied to 9.8% (n=36/367) of all patients accessing the service.
Gulliford 2014 , Electronic health records for intervention research: a cluster randomized trial to reduce antibiotic prescribing in primary care (eCRT study) (19)	Cluster RCT	General practice: 100 practices, including 603,409 patients (aged 18-59) with RTIs England (50 practices), Scotland (50 practices)	1) Decision support tools (electronically delivered & remotely installed, accessed during the consultations), 2) Control (usual care)	Proportion of consultations for RTIs with antibiotic prescriptions	Reduction in proportion of consultations with antibiotic prescriptions of 1.85% (95% CI, 0.10%-3.59%, P = 0.038) and in the rate of antibiotic prescriptions for RTIs (9.69%; 95% CI, 0.75%-18.63%, fewer prescriptions per 1,000 patient-years, P = 0.034).
Little 2014 , Delayed antibiotic prescribing strategies for respiratory tract infections in primary care: pragmatic, factorial, randomised controlled trial (20)	RCT	General practice: 25 practices, 889 patients (aged 3+) with RTIs UK	4 delayed prescribing strategies: 1) Re-contact for antibiotics, 2) Post-dated prescription, 3) Collection of prescription, 4) Antibiotic prescription given to patient, 5) No antibiotic prescription	Symptom severity; antibiotic use; patients' beliefs in effectiveness of antibiotic use; secondary: comparison of delayed prescription strategies with immediate antibiotics	Modest and non-significant difference between the randomised delayed prescribing groups in antibiotic use (26%, 37%, 37%, 33%, 39%; 4.96, P = 0.292). 97% of patients given immediate antibiotics used them but with no benefit for symptom severity or duration.
Little 2013a , Effects of internet-based training on antibiotic prescribing rates for acute respiratory-tract infections: a	Cluster RCT	General practice: 246 practices, 4264 patients with RTIs	1) Training in the use of CRP POCT , 2) Training in enhanced communication skills ,	Antibiotic prescriptions; secondary: re-consultations; new signs; hospital	Antibiotic prescribing was lower with CRP POCT training than without (33% vs 48%, adjusted risk ratio 0.54, 95% CI 0.42–0.69) and with enhanced communication skills training than without (36% vs 45%, 0.69, 0.54–

<p>multinational, cluster, randomised, factorial, controlled trial</p> <p>(GRACE INTRO) (21)</p>		<p>England and Wales</p>	<p>3) Combined training in the use of CRP and in enhanced communication skills,</p> <p>4) Control (usual care)</p>	<p>admission; symptom severity and duration</p>	<p>0.87). The combined intervention (CRP POCT + communication skills training) was associated with the greatest reduction in prescribing rate (CRP risk ratio 0.53, 95% CI 0.36–0.74, p<0.0001; enhanced communication 0.68, 0.50–0.89, p=0.003; combined 0.38, 0.25–0.55, p<0.0001).</p>
<p>Little 2013b, Clinical score and rapid antigen detection test to guide antibiotic use for sore throats: randomised controlled trial of PRISM (primary care streptococcal management) (22)</p>	<p>Cluster RCT</p>	<p>General practice: 21 practices, 631 patients (aged 3+) with a sore throat England</p>	<p>1) Delayed prescription to be collected after 3-5 days if symptoms are not better or get worse,</p> <p>2) Clinical score (FeverPAIN),</p> <p>3) Rapid antigen test (RADT; rapid streptococcal antigen detection test) used with clinical score (FeverPAIN)</p>	<p>Patient-reported symptom severity; duration of symptoms; patient-reported antibiotic use</p>	<p>1) In delayed prescription group, 75/164 (46%) patients used antibiotics.</p> <p>2) In the clinical score group antibiotic use (60/161) was 29% lower (adjusted risk ratio 0.71, 95% CI 0.50-0.95; p=0.02).</p> <p>3) In the RADT + clinical score group antibiotic use (58/164) was 27% lower (0.73, 0.52-0.98; p=0.03).</p>
<p>Butler 2012, Effectiveness of multifaceted educational programme to reduce antibiotic dispensing in primary care: practice based randomised controlled trial (STAR) (23)</p>	<p>Cluster RCT</p>	<p>General practice: 68 practices, 263 GPs Wales</p>	<p>1) Communication skills training (including a practice seminar, online training and practising consulting skills),</p> <p>2) Control (usual care)</p>	<p>Antibiotic items dispensed per 1000 practice patients in the year after the intervention, adjusted for the previous year's dispensing; secondary: re-consultations; hospital admissions; costs.</p>	<p>Antibiotics dispensed decreased by 14.1 in the intervention group but increased by 12.1 in the control group, a net difference of 26.1. After adjustment for baseline dispensing rate, this amounted to a 4.2% (95% CI 0.6%-7.7%) reduction in total oral antibiotic dispensing for the year in the intervention group relative to the control group (p=0.02).</p>

<p>Francis 2009, Effect of using an interactive booklet about childhood respiratory tract infections in primary care consultations on reconsulting and antibiotic prescribing: a cluster randomised controlled trial (24)</p>	Cluster RCT	<p>General practice: 61 practices, 558 children (6 months - 14 years) with RTIs England (25 practices), Wales (36 practices)</p>	<p>1) Training in the use of interactive booklet on RTIs & use of the booklet in consultations, 2) Control (usual care)</p>	<p>Proportion of children re-consulting during 2 week follow-up; secondary: antibiotic use; future consulting intentions; parental satisfaction; reassurance; enablement.</p>	<p>Antibiotics were prescribed at index consultation to 19.5% of children in the intervention group and 40.8% of children in the control group (absolute risk reduction 21.3%, 95% CI 13.7-28.9), p<0.001). A significant difference was still present after adjusting for clustering (odds ratio 0.29; 0.14 to 0.60).</p>
<p>Little 2005, Information leaflet and antibiotic prescribing strategies for acute lower respiratory tract infection: a randomized controlled trial (25)</p>	RCT	<p>General practice: 37 GPs, 807 patients (aged 3+) with cough as the main symptom England</p>	<p>1) Patient leaflet (information on natural history of lower RTI addressing patient concerns) 2) No patient leaflet 3) Immediate antibiotic prescription 4) No antibiotic prescription 5) Delayed prescription (on request if symptoms don't resolve after 14 days)</p>	<p>Symptom severity and duration; patient-reported antibiotic use.</p>	<p>Fewer patients in the delayed prescribing and no antibiotic prescription groups used antibiotics compared with the immediate antibiotics group (20%, 16%, 96%, respectively; p=0.001). 57% patients used antibiotics in the no leaflet group compared with 55% in the leaflet group (p=0.58).</p>
<p>Macfarlane 2002, Reducing antibiotic use for acute bronchitis in primary care: blinded, randomised controlled</p>	RCT	<p>General practice: 3 practices, 259 adults (aged 16+) with acute bronchitis England</p>	<p>Patients judged to not need antibiotics: 1) Delayed prescription + verbal reassurance (prescription given to</p>	<p>Antibiotic use in the next two weeks; re-consultation for the same symptoms in the next month.</p>	<p>Fewer patients who received leaflet took antibiotics compared with those who did not receive the leaflet: 49 (23.1%) v 63 (29.7%) out of 212, risk ratio 0.76, 95% CI 0.59 to 0.97, p=0.04.</p>

trial of patient information leaflet (26)			patients with advice to use it if they got worse), 2) Delayed prescription + verbal reassurance + leaflet (on natural course of lower RTI symptoms, pros and cons of antibiotic use), 3) Patients judged to need antibiotics and given immediate AP		44/47 (93.6%) patients judged to need antibiotics and given immediate antibiotic prescription took antibiotics.
Cox 2001 , Is it possible to decrease antibiotic prescribing in primary care? An analysis of outcomes in the management of patients with sore throats (27)	Observational (pre-post)	General practice: 1 practice, 785 patients (aged 2+) with a sore throat as the main complaint England	1) Old protocol for management of sore throats in practice, 2) Revised evidence-based protocol for management of uncomplicated sore throats (focused on low antibiotic use)	Antibiotic prescriptions; patient acceptability; recovery; consultation rates.	Antibiotic prescriptions decreased from 56% to 19% during the study (p<0.0001).
Dowell 2001 , A randomised controlled trial of delayed antibiotic prescribing as a strategy for managing uncomplicated respiratory tract infection in primary care (28)	RCT	General practice: 22 practices, 191 adults (aged 16+) with cough Scotland	1) Immediate antibiotic prescription 2) Delayed prescription (patients asked to wait a week before deciding whether to collect the prescription from reception)	Symptom duration; prescription uptake; patient satisfaction; patient enablement; subsequent consultation rates.	In delayed prescription group, 45% (43/95) patients picked up their prescription; 35% (12/34) waited 7 days as asked.
Little 2001 , Pragmatic randomised controlled trial of two	RCT	General practice: 65 practices,	1) Immediate antibiotic prescription + advice sheet ,	Symptom resolution; absence from school or nursery; paracetamol	132/134 (98.5%) participants who were given an immediate antibiotic prescription reported using antibiotics

prescribing strategies for childhood acute otitis media (29)		315 children (6 months - 10 years) presenting with otitis media England	2) Delayed prescription + advice sheets (patients asked to collect the prescription after 72 hours if no improvement)	consumption; collection of prescription; reported antibiotic use.	at some stage during the illness compared to 36/150 (24%) participants in the delayed prescription group.
McNulty 2000 , Primary care workshops can reduce and rationalize antibiotic prescribing (30)	Pre-post	General practice: 84 practices England	1) Workshops on antibiotic prescribing (1.5-2 hour, including presentation of a poster, discussion of new antibiotic prescribing guidelines, key messages), 2) Microbiology tutorials in practices, 3) Control (no intervention)	Dispensed antibiotics.	51 practices offered workshops decreased antibiotic prescribing by 3.4%, compared with 2.2% decrease in 33 practices not offered workshops ($p=0.09$). Broad-spectrum antibiotic prescriptions declined by 15.4% in practices receiving workshops, compared with a 6.5% increase in practices with tutorials ($p=0.002$). Use of narrow-spectrum antibiotics (encouraged) did not change in workshop practices, but decreased by 12% in tutorials practices ($p=0.003$).

Abbreviations used in the table: CI – confidence intervals, CRP – C-reactive protein, POCT – point-of-care test(ing), RAD – Rapid antigen detection test(ing).

Supplemental Document 7. Behavioural content of effective research interventions

First author, year, title (reference)	Setting: targeted HCPs	Intervention	BCTs	TDF domain	Intervention function
McNulty 2018, Effects of primary care antimicrobial stewardship outreach on antibiotic use by general practice staff: pragmatic randomized controlled trial of the TARGET antibiotics workshop (14)	General practice: all staff	TARGET workshop - 1 hour workshop facilitated by existing NHS healthcare staff with promotion of TARGET website resources	<ul style="list-style-type: none"> - Credible source - Information about health consequences - Information about social, environmental consequences - Instruction on how to perform behaviour - Feedback on behaviour - Social comparisons - Adding objects to the environment - Behavioural substitution - Action planning - Self-monitoring of behaviour - Monitoring of behaviour by others - Social support (practical) - Social support (unspecified) - Demonstrating behaviour - Incentive 	<ul style="list-style-type: none"> - Social influences - Beliefs about consequences - Environmental context and resources - Skills - Knowledge - Behavioural regulation 	<ul style="list-style-type: none"> - Environmental restructuring - Enablement - Incentivisation - Persuasion - Education - Training
Hallsworth 2016, Provision of social norm feedback to high prescribers of antibiotics in general practice: a pragmatic national randomised controlled trial (17)	General practice: prescribers	Feedback intervention - Letter from England's Chief Medical Officer stating that the practice was at a higher rate of	<ul style="list-style-type: none"> - Feedback on behaviour - Social comparisons - Credible source - Instruction on how to perform the behaviour - Adding objects to the environment - Behavioural substitution - Information about health consequences 	<ul style="list-style-type: none"> - Knowledge - Social influences - Skills - Environmental context and resources - Behavioural regulation - Optimism 	<ul style="list-style-type: none"> - Education - Persuasion - Training - Environmental restructuring - Enablement

		antibiotic prescribing than 80% of local practices), and including suggestions to address it (e.g. a patient leaflet)		- Beliefs about consequences	
Gulliford 2014 , Electronic health records for intervention research: a cluster randomized trial to reduce antibiotic prescribing in primary care (eCRT study) (19)	General practice: prescribers	Decision support tools , electronically delivered & remotely installed, accessed during consultations <i>[Reported issues: low utilization in some practices, perhaps as some GPs enter read codes after consultation; unable to ensure all prescribers saw the training materials and video]</i>	<ul style="list-style-type: none"> - Adding objects to the environment - Prompts, cues - Behaviour substitution - Instruction on how to perform behaviour - Demonstrating the behaviour - Information about health consequences - Information about social, environmental consequences - Verbal persuasion about capability - Social support (unspecified) 	<ul style="list-style-type: none"> - Environmental context and resources - Memory, attention, decision making - Behavioural regulation - Skills - Knowledge - Beliefs about consequences - Social influences 	<ul style="list-style-type: none"> - Environmental restructuring - Enablement - Training - Education - Persuasion
Little 2013a , Effects of internet-based training on antibiotic prescribing rates for acute	General practice: prescribers	1) CRP POCT - provision of testing equipment and training incl. instructions on when	<ul style="list-style-type: none"> - Adding object to the environment - Behaviour substitution - Instruction on how to perform behaviour - Demonstrating the behaviour - Social support (unspecified) 	<ul style="list-style-type: none"> - Environmental context and resources - Behavioural regulation - Skills 	<ul style="list-style-type: none"> - Environmental restructuring - Enablement - Training - Persuasion - Education

respiratory-tract infections: a multinational, cluster, randomised, factorial, controlled trial (GRACE INTRO) (21)		and how to use the tests 2) Training in enhanced communication skills - how to negotiate management decisions with patients	<ul style="list-style-type: none"> - Social support (practical) - Information about health consequences - Information about social, environmental consequences - Credible source 	<ul style="list-style-type: none"> - Social influences - Beliefs about consequences 	
Little 2013b , Clinical score and rapid antigen detection test to guide antibiotic use for sore throats: randomised controlled trial of PRISM (primary care streptococcal management) (22)	General practice: prescribers	<p>1) Delayed prescription to be collected after 3-5 days if symptoms are not better or get worse</p> <p>2) Clinical score (FeverPAIN),</p> <p>3) Rapid antigen test used with clinical score (FeverPAIN)</p>	<ul style="list-style-type: none"> - Adding object to the environment - Instruction on how to perform behaviour - Information about health consequences 	<ul style="list-style-type: none"> - Environmental context and resources - Skills - Beliefs about consequences 	<ul style="list-style-type: none"> - Environmental restructuring - Training - Education
Butler 2012 , Effectiveness of multifaceted educational programme to reduce	General practice: prescribers	Educational programme (STAR) including a practice seminar, online	<ul style="list-style-type: none"> - Self-monitoring of behaviour - Information about health consequences - Information about social and environmental consequences 	<ul style="list-style-type: none"> - Behavioural regulation - Beliefs about consequences - Skills 	<ul style="list-style-type: none"> - Enablement - Education - Training - Persuasion - Incentivisation

antibiotic dispensing in primary care: practice based randomised controlled trial (STAR) (23)		training and practice of consulting skills	<ul style="list-style-type: none"> - Instruction on how to perform behaviour - Demonstrating the behaviour - Credible source - Behavioural practice / rehearsal - Social support (unspecified) - Social support (practical) - Feedback on behaviour - Feedback on outcome - Social comparisons - Non-specific reward 	<ul style="list-style-type: none"> - Social influences - Knowledge - Reinforcement 	
Francis 2009 , Effect of using an interactive booklet about childhood respiratory tract infections in primary care consultations on reconsulting and antibiotic prescribing: a cluster randomised controlled trial (24)	General practice: prescribers	Training in the use of interactive booklet on RTIs & use of the booklet in consultations	<ul style="list-style-type: none"> - Adding object to the environment - Behavioural substitution - Instruction on how to perform the behaviour - Social support (unspecified) - Prompts, cues - Demonstrating the behaviour 	<ul style="list-style-type: none"> - Environmental context and resources - Behavioural regulation - Skills - Social influences - Memory, attention, decision making 	<ul style="list-style-type: none"> - Environmental restructuring - Enablement - Training - Persuasion
Cox 2001 , Is it possible to decrease antibiotic prescribing in primary care? An analysis of outcomes in the management of	General practice: prescribers	Revised evidence-based protocol for management of uncomplicated sore throats (focused on low antibiotic use)	<ul style="list-style-type: none"> - Feedback on behaviour - Information about health consequences - Action planning - Instruction on how to perform the behaviour 	<ul style="list-style-type: none"> - Knowledge - Beliefs about consequences - Behavioural regulation - Skills 	<ul style="list-style-type: none"> - Education - Enablement

patients with sore throats (27)					
McNulty 2000 , Primary care workshops can reduce and rationalize antibiotic prescribing (30)	General practice: prescribers	Workshops on antibiotic prescribing - 1.5-2 hours, presentation of a poster, discussion of new antibiotic prescribing guidelines, key messages [compared to no workshops or tutorials by a microbiologist]	- Feedback on behaviour - Social comparisons - Instruction on how to perform the behaviour - Social support (unspecified)	- Knowledge - Social influences - Skills	- Education - Persuasion - Enablement

Supplemental Document 8. Theoretical congruence between intervention functions and key TDF domains

Key six TDF domains	Intervention functions (Number of interventions with components addressing each function; 26 national & 5 research interventions, max N=31)								
	Education (n=23)	Persuasion (n=12)	Incentivisation (n=9)	Coercion (n=2)	Training (n=27)	Restriction (n=0)	Environmental restructuring (n=6)	Modelling (n=3)	Enablement (n=24)
Beliefs about consequences	Green	Green						Green	
Social influences						Red	Green	Green	Green
Skills					Green				
Environmental context & resources					Green	Red	Green		Green
Intentions	Green	Green	Green	Green				Green	
Emotion		Green	Green	Green				Green	Green

Note: Green indicates where there is congruence between TDF domains and intervention functions addressed in interventions; red indicates lack of congruence, i.e. where there is a theoretical congruence between the domain and intervention function, but the function was not addressed in any interventions.

Supplemental Document 9. Theoretical congruence between BCTs and TDF domains

BCTs ^a	National interventions (n=26)	Research interventions (n=5)	Linked TDF domains (according to matrix; key domains in bold)	TDF domain ranking	Theoretical congruence between BCT & TDF domain ^b
Instruction on how to perform a behaviour*	24	5	Skills	3	High
Information about health consequences	14	3	Beliefs about consequences Knowledge	1 8	Medium
Adding objects to the environment	9	3	Environmental context & resources	4	High
Feedback on behaviour	7	2	Beliefs about consequences Knowledge Beliefs about capabilities Goals	1 8 9 0	Medium
Credible source	7	1	Beliefs about consequences Intentions Goals	1 5 0	High
Action planning	6	1	Intentions Goals Memory, attention, decision making Behavioural regulation	5 0 10 0	Medium
Demonstrating the behaviour	4	3	Social Influences Skills	2 3	High
Information about social, environmental consequences	5	2	Beliefs about consequences Knowledge	1 8	Medium
Social comparisons	6	1	Social influences	2	High
Social support (practical)	6	1	Social influences Intentions Beliefs about capabilities Social/professional role & identity Goals	2 5 9 7 0	High

Identification of self as a role model	6	0	Social influences	2	High
Self-monitoring of behaviour	6	0	Beliefs about consequences Skills Memory, attention, decision making Behavioural regulation Beliefs about capabilities	1 3 10 9 0	High
Social support (unspecified)	2	4	Social influences Social/professional role & identity	2 7	Medium
Behavioural substitution	2	3	Behavioural regulation	0	Low
Feedback on outcome of behaviour	5	0	Beliefs about consequences Knowledge Beliefs about capabilities Goals	1 8 9 0	Medium
Behavioural practice / rehearsal	3	0	Skills Beliefs about capabilities	3 9	Medium
Self-monitoring of outcomes	3	0	Beliefs about consequences Beliefs about capabilities Memory, attention, decision making	1 9 10	Medium
Prompts / cues	1	2	Environmental context & resources Memory, attention, decision making Behavioural regulation	4 10 0	Medium
Future punishment*	2	0	Intentions Emotions Goals Reinforcement	5 6 0 11	High
Non-specific reward	2	0	Skills Goals Reinforcement	3 0 11	Medium
Salience of consequences	2	0	Beliefs about consequences Knowledge	1 8	Medium
Social / non-material reward	2	0	Social Influences	2	High
Commitment	1	0	Intentions Goals	5 0	Medium

Focus on past success	1	0	Beliefs about capabilities	9	Low
Framing / reframing*	1	0	Beliefs about consequences Optimism	1 0	Medium
Goal setting	1	0	Skills Intentions Behavioural regulation Beliefs about capabilities Goals	3 5 0 9 0	High
Material reward	1	0	Skills Reinforcement	3 11	Medium
Pharmacological support*	1	0	Skills	3	High
Problem solving	1	0	Goals Beliefs about capabilities	0 9	Low
Pros and cons	1	0	Beliefs about consequences	1	High
Restructuring the physical environment	1	0	Environmental context & resources	4	High
Incentive	1	0	Skills	3	High
Monitoring of behaviour by others	1	0	Skills	3	High
Verbal persuasion about capabilities	0	1	Beliefs about capabilities Optimism Goals	9 0 0	Low

Notes:

^a BCTs marked with asterisk (*) were not included in the previously developed matrix (31) and were matched with theoretically congruent TDF domains based on a discussion with LA.

^b Following previously developed methods and matrix (31), 'high theoretical congruence' (green cells) between BCTs and TDF domains was defined as a BCT being paired with two or more of the theoretically-matching key TDF domains (or with one key TDF domain *if only one* domain was theoretically linked to that BCT); 'medium congruence' (orange cells) was defined as a BCT being paired with one key TDF domain (out of more than one domains theoretically linked in the matrix); 'low congruence' (red cells) was defined as a BCT not being paired with any of the key TDF domains.

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