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Developing a behaviour change intervention using information about greenhouse gas emissions to reduce liquid antibiotic prescribing

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A B S T R A C T

Introduction: The determinants of antimicrobial prescribing often involve social influence, which can be harnessed through behaviour change techniques (BCTs). While previous studies have used BCTs to address antimicrobial resistance, there is a lack of evidence regarding their application to address climate change-related issues in antibiotic prescribing. This study aimed to develop a behaviour change intervention (BCI) using information about greenhouse gas emissions to reduce liquid antibiotic prescribing.

Methods: A convenience sample of participants from a primary care practice in North East England participated in semi-structured interviews. The intervention design was guided by the Theoretical Domains Framework (TDF) and the Capability, Opportunity, Motivation – Behaviour (COM-B) model. Data were analysed thematically, mapped to the TDF, and used to refine the BCI.

Findings: Participants identified motivating factors related to high rates of liquid prescribing, climate change, and solid oral dosage form (pill) aversion. The broader context of practice, such as initiatives reduce cost and improve sustainability, provided opportunities for intervention. Participants demonstrated the capability to change prescribing behaviours and expressed willingness to share resources within their teams.

Conclusion: This study underscores the potential of BCIs using greenhouse gas emissions data to reduce liquid antibiotic prescribing. Further research should focus on implementing and evaluating these interventions in practice settings.

1. Introduction

Determinants of antimicrobial prescribing are linked to social influence.[1] Social influence is akin to 'social media influencers', where key identities, personalities or 'well known' or 'well thought of' leaders in a field can cause behaviour changes in groups or populations.[2] The behaviour-changing power of social influence can be harnessed using behaviour change techniques (BCT).[3–5] Though there are many approaches to BCT with their own taxonomy and theoretical underpinning,[5] a relatively common BCT that uses social influence is a public health campaign, whereby leaders or experts use their social influence to normalise a behaviour.[6] This approach was used in 2016, to reduce antimicrobial prescribing.[6] The trial demonstrated providing prescribers with information about antimicrobial resistance, with alternative therapeutic options, led to a reduction in prescribing of Amoxicillin.[6] This evidence demonstrates prescribing practices can be changed by utilising BCTs in primary care.

Although previous work has used BCTs to reduce antibiotic prescribing and this remains problematic globally, an equally challenging and significant threat to health is climate change.[7,8] Multiple global organisations are working towards a carbon-neutral or 'Net Zero' outcome, to limit greenhouse gas emission and consequential climate change.[9] However, there is a paucity of evidence describing the use of BCTs focused on climate change to reduce antibiotic prescribing. Antibiotic use has been linked to greenhouse gas emissions in cattle.[10] Preliminary work (in humans) has demonstrated prescribing liquid antibiotics, compared to solid oral dosage forms, increases greenhouse gas emissions too.[11] This is important, as cognitive aversion to using solid oral dosage forms despite no neuromuscular dysphagia, also known as 'pill aversion', mean patients may be over using liquid medications.[12] Existing BCI are available which help patients overcome pill aversion, and can consequently reduce prescribing of liquid medications, potentially reducing greenhouse gas emissions.[13–16] This suggests there may be an emerging opportunity for behaviour change to reduce

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liquid prescribing, which utilizes information about the greenhouse gas emissions of antibiotic prescribing and combines this with resources to tackle pill aversion. However, there is limited work exploring how information about climate change can be used within a BCI.

The use of BCTs must consider the mode of delivery, the competency to deliver the technique and the level of the intervention as well as economic and social cost.[5,17] Although BCTs must be appropriately evaluated, there is contention about linking health outcomes (like weight loss) to a particular intervention (e.g. public health campaigns about obesity).[5] This is due to the many extraneous and compound variables, described by TDF, that influence behaviour in any given context.[17] Careful consideration must be given to the development of BCI which draws on empirical data from the target population – such as those in primary care prescribing liquid antibiotics. The aim of this study was to develop a BCI using information about greenhouse gas emissions to reduce antibiotic prescribing in primary care.

2. Methods

2.1. Participants

A convenience sample of participants were recruited from a single primary care practice in North East England. The practice was identified using OpenPrescribing data which demonstrated a high rate of prescribing liquid antibiotics compared to solid dosage form antibiotics in the region. Health professionals, administrators and managers at the practice were contacted to take part via email, which included an invitation to reply to coordinate a time convenient for the participant to take part in a semi-structured interview. Participants were provided with information about the study before agreeing to take part by replying to the email. Consent was taking prior to the interview taking place. Institutional ethical approval was given for the study.

2.2. Intervention design

The Theoretical Domains Framework (TDF) and Capability, Opportunity, Motivation – Behaviour (COM-B) model of behaviours underpinned the study. The TDF considers a broad range of influences Knowledge, Skills, Social role and Identity, Beliefs about consequences, Reinforcement, Goals, Environmental context and resources, Social influences and Behavioural Regulation.[18] The TDF has previously been used to explore behavioural interventions in a range of contexts.[1,18–22] An existing BCI (taken from Hallsworth, Chadborn, Sallis, Sanders, Berry, Greaves, Clements, Davies,[6] see Supplementary Material 1) was adapted to include information relating to climate change as well as information which was identified as relevant to participants. It included information to motivate the recipient, by comparing the liquid to solid amoxicillin prescribing ratio of the recipient's practice with the median liquid to solid amoxicillin prescribing ratio (data obtained from OpenPrescribing).[23–25] Information was also provided to demonstrate the opportunity to change, by informing the recipient about the level of greenhouse gas emissions linked to liquid amoxicillin prescribing in comparison to solid amoxicillin prescribing.[26] The intervention included signposting to resources to build the capability of the recipient to switch patients from liquid to pill formulations by using the KidzMed programme to help children and young people to swallow solid oral dosage forms, instead of prescribing liquid formulations, was also included.[13,14] Participants were shown the intervention prior to being interviewed.

2.3. Data collection

Rapid, semi-structured, one-to-one, online interviews were conducted by one author (JP) using a topic guide. The topic guide was developed using information from the literature and the TDF. During interviews, participants were shown the draft version of the BCI and asked to provide a 'think aloud' commentary describing their initial thoughts, feelings, and responses to aspects of the intervention. Participants were also asked to describe how to improve the clarity of the intervention and the value they ascribe to different information within the intervention (i.e. relating to climate change, antimicrobial resistance, liquid versus solid prescribing data). Interviews were recorded, transcribed automatically using Microsoft Teams and quality checked by a second author (APR). Rapid qualitative interviews are a recognised method providing research teams with the means to obtain qualitative insights quickly in response to urgent and developing circumstances.[27,28] Whilst there is some contention as the trustworthiness of rapid interviews versus conventional interviewing techniques,[29] this approach was considered suitable for this research as it draws on existing paradigms and well-established practices of behaviour change. Data collection continued until theoretical data saturation, the point at which new findings can reasonably be understood not to be identified, was reached.[30]

2.4. Data analyses

Data were coded in NVivo Version 12.6 and thematically analysed by two authors (JP, APR), with data presentation to other others (LG, AM, NV, EL) to increase objectivity. Data analyses used a constant comparison approach where words, phrases and sentences were identified and coded.[30] Codes were grouped into clusters and clusters into themes which were mapped to the TDF. All authors reviewed the findings alongside the intervention to identify how the findings be used to develop the intervention using track changes in Microsoft Word. Comments from all authors were reviewed by two authors (JP, APR) who made final amendments to the intervention (See Supplementary Material 1).

3. Findings

Interviews lasted on average 10 min and 55 s, with a range of 5 min 35 s to 16 min 12 s. A summary of participant demographics are shown in Table 1. Most participants where White British and female (82 %, n = 9, respectively). Participants had varying levels of education and worked in general practice for a range of time from 3 months to 25 years, in a range of roles, including administrators, practice managers, healthcare assistants, general practitioners (GP) (both salaried and partner), foundation doctors, pharmacists and paramedics. Thirty-six percent (n = 4) of participants were prescribers, 36 % were non-prescribers and 27 % (n = 3) were making prescribing decisions which were later authorised under the supervision of a GP. The main message identified in the intervention by the participants was 'high level of liquid prescribing', 'climate change' and 'children swallowing pills' for equal numbers of participants (27 %, n = 3, respectively), with 'cost and waste' identified by two participants (18 %). There were no obvious associations to role, sex, level of education or prescriber status or main message identified in the intervention.

Themes were identified and are described below. Data extracts are used to describe the themes in participants' own words, with additional data extracts provided in Table 2.

3.1. Theme 1) Motivation – the main message from the intervention

> "*to* ***reduce liquid prescribing of antibiotics*** *for children,* ***to be better for the environment and cost wise*** *[…]" – Participant 7, Pharmacist*

> "***prescribing in the practice is high,*** *so we need to empower professionals to* ***prescribe tablets or capsules instead of liquids*** *[because] last winter, there were shortages and more broadly, climate change,* ***if there is something we should do, we should do it***" *– Participant 5, General Practitioner*

This theme captures how information to motivate behaviour change in the intervention was reported by participants. Most participants were

Table 1
Summary of participant demographics.

	n	%
Total	*11*	100 %
Sex		
Male	*2*	18 %
Female	*9*	82 %
Ethnicity		
White British	*9*	82 %
Arab	*1*	9 %
British Asian	*1*	9 %
Role		
Management and Administration	*2*	18 %
Non-GP Clinical Staff[a]	*6*	55 %
Salaried GP or GP Partner	*3*	27 %
Length of practice		
<2 years	*2*	18 %
2–10 years	*4*	36 %
>11 years	*5*	45 %
Highest Qualification		
GCSE	*2*	18 %
A Level	*1*	9 %
Undergraduate Degree	*4*	36 %
Postgraduate Degree	*4*	36 %
Prescriber Status		
Yes	*4*	36 %
No	*4*	36 %
Prescribing under supervision	*3*	27 %
Main message identified in BCI		
Children swallowing pills	*3*	27 %
High liquid prescribing	*3*	27 %
Climate change	*3*	27 %
Cost and waste	*2*	18 %

[a] Included pharmacists (n = 3), a paramedic (n = 1), a healthcare assistant (n = 1) and a junior doctor (n = 1).

able to identify the information relating to high rates of liquid prescribing for their practice, that children over 4 years old could swallow pills and climate change linked to liquid amoxicillin use. Participants also identified costs, waste and their previous experiences of shortages of amoxicillin during the Group A Streptococcus epidemic in 2022/23 (and the threat of repeated shortages in 2023/24) resonated with information in the intervention. Participants reported their surprise at information in the intervention, which challenged their existing beliefs and motivated them to act. These factors typically overlapped, reinforcing a rationale for changes to prescribing practice. This meant although information about climate change (greenhouse gas emissions) was a motivating factor, this was considered equally as motivating as information about high rates of liquid prescribing and that children over 4 years old could swallow pills. This appeared to be because these latter constructs were more surprising and had a more personal and professional connections to the participants, than the information about greenhouse gas emissions linked to liquid amoxicillin.

3.2. Theme 2) Opportunity – the broader context of practice

"part of you is already trying to be more cost effective for the NHS, erm, thinking about how many times you go on a home visit and there are load of inhalers there, its 50 quid inhalers, waste for me personally is, like 'that's not great'" – Participant 11, General Practitioner

> "I think **there is a bit of a drive in the NHS to be greener**, but beyond that and the teaching, I don't really know anything about [the environments and tablets], which I think it's good, [but] I think that would be the least impactful because as a junior I'm quite removed from it - Participant 6, Junior Doctor

Table 2
Data extracts mapped to clusters, themes and COM-B Domains.

COM-B Domain	Theme	Cluster	Data Extract
Motivation	Main message in the intervention	Children swallowing pills	"we find a lot of children **don't like the taste of liquid, so if they learn to swallow**" Participant 2, Management and Administration
			it talks about the positives about pills, **try to remember it tastes better and doesn't go in the fridge** and […], it does talk about an age over 4 and give some websites you could give to a parent to encourage them to use pills." – Participant 11, General Practitioner
			"I **think from where I sit as a parent, as well as a prescriber**, […] the parents might be pushed towards doing it by the taste and by the don't have to put it in the fridge, people have to take it to nursery or the school and it's something that's three times a day, it has to be this person or that person, quite often as a prescriber if somebody is at school, I'll say it doesn't have to go to school, just do it morning and bedtime. If somebody has to flog a new idea, there has to be something for them that floats there boat" - Participant 11, General Practitioner
			"**giving a pill for children over 4, which I was quite surprised at**, it was quite [a] low [age], […] I thought it would be higher, maybe 6 or 7 years old, but I know sometimes people who are 11 or 12." - Participant 10, Pharmacist
			"we often get the mum's ringing saying […] **my child […] they don't like the liquid** and they want a strawberry flavour instead, but there is no such as thing as strawberry flavour so I sometimes give them an alternative drug, after discussing it with the GP, but p**robably for the future, after reading this letter, it is giving them an alternative of a tablet, which can be swallowed and then they don't need to worry about the taste** – Participant, 9, Pharmacist
		Drug shortages	"what you have to remember is [liquids] might get wasted, someone might not take it, it might get spilled or **it might be difficult to get hold of'** – Participant 11, General Practitioner
			"something else that actually stood out [in addition to climate change] w**as the**

(*continued on next page*)

Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			running out of amoxicillin and penicillin, and I think if we can get children to take pills earlier, rather than have to try when they're unwell, it would benefit them […] so I think [all three are priorities to highlight]. – Participant 6, Junior Doctor
		High Liquid Prescribing	"**if we're an outlier, we could use it as a quality improvement activity**, it's talking about ease for the patient, cost and climate stuff, so quality improvement activities are useful for safer and best practice, there are some people in the practice who will be more motivated by the green bit, there will be some people motivated by the cash" – Participant 11, General Practitioner
			"it **showed some practices are high prescribing, prescribing a lot of liquid antibiotics** – Participant 6, Junior Doctor
			"I think [being in the top centile of prescribing] for me, personally **it would encourage me to try and prescribe liquids less**. It's not really naming and shaming, but being highlighted it's a kick up the backside isn't it? I think that would be the same for everyone, [it is something they would want to change], not an insult" – Participant 7, Pharmacist
			"it's trying to target people that they perceive or have been shown from the data **they've got the higher prescribers**, it's tried to use an example of **when medicines run out**, Group A Strep, so that might rely on your memory, and some people might recall that issue last year," – Participant 11, General Practitioner
		Climate Change	"I wasn't massively aware, until my colleagues presentation recently, I wasn't **aware that the liquids did greenhouse gases,** because it comes as a powder in a bottle you add the water and shake it and then use it or stick it in the fridge" – Participant 11, General Practitioner
			'Climate [stood out the most] as **climate will end up impacting on costs and shortages anyone in the long run,** so if you tackle the original problem you can solve lots of things – Participant 7, Pharmacist
			"**the impact on the climate, is quite concerning** […]

Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			there has been a bit of a crisis at the moment, so reading that and realising how much it takes to turn them into a liquid is a concern **especially when they can get it prescribed, kind of, very often so** – Participant 4, Non-Medical Practitioner
			"the climate one was quite interesting, **and we've just had teaching on the sustainability of medicines, so that it did resonate with that,** - Participant 6, Junior Doctor
			"**I didn't realise the number of tonnes of liquid formulations**, **I had no knowledge or understanding about that whatsoever, so that was quite interesting** […] And inhalers are really well known, but I've never read anything about sort of the impact of liquids having some sort of impact, so it was quite interesting as well" - Participant 10, Pharmacist
		Cost	"occasionally, it comes up **when you're prescribing liquids it comes up with a cost warning** when you're doing it on system one and **that would make you think twice**," – Participant 11, General Practitioner
			"I think **cost changes are most relevant for me**, people might think [liquids] are a little bit more expensive but I know some of the antibiotic ones are incredibly more expensive, so you know, not even double or triple but much more expensive, **[…] I think prescribers would be surprised by the difference**, **they know it's more expensive but not how much** – Participant 10, Pharmacist
			"[I would be most influenced by the information about] **by the cost, as a pharmacist we do look at the cost** and try and prescribe the most cost effective, and saving money on the NHS as well." – Participant 9, Pharmacist
Opportunity	Broader context	Cost saving in initiatives	"**part of you is already trying to be more cost effective for the NHS**, erm, thinking about how many times you go on a home visit and there are load of inhalers there, its 50 quid inhalers, waste for me personally is, like 'that's not great'" – Participant 11, General Practitioner
			"I was aware **that pills were cheaper**, but I think having the number, that the

(*continued on next page*)

Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			Children's Hospital saved £50,000 really helped illustrate [how much cheaper pills are] better […] and **putting it in the context of the Strep A epidemic**, and we're coming to winter again, the bugs are going to go round again, s**o the context of it made a lot of sense**, at the moment we're getting a lot of parents with typical cough and cold symptoms coming in, so it would stand out to a lot of GPs." – Participant 6, Junior Doctor
			"It would be good to get the pharmacies involved **to save the waste for that second prescription** without getting the GP involved, if they could just present with their tablets and say you know, she my four year old, can't take them please convert it, without getting the GP involved, making the GP prescribe twice, I mean that seems a bit pie in the sky, but I don't know if that can happen" – Participant 8, General Practitioner
		Climate change action	"the climate change [is the biggest message], **it's on the tv a lot**, **my husband has recently become vegan, he wants to save the world**, so it's on our minds at the moment, and to be honest, in healthcare, its not really but it's to save the world isn't it, the flooding, the fires, we've all got to pull together on this one haven't we" – Participant 3, Management and Administration
			"I think **there is a bit of a drive in the NHS to be greener**, but beyond that and the teaching, I don't really know anything about [the environments and tablets], which I think it's good, [but] I think that would be the least impactful because as a junior I'm quite removed from it - Participant 6, Junior Doctor
			"there was a pharmacy **update about six months ago about inhalers, and recycling inhalers**, one our GPs **has also done a sustainable healthcare conference to improve the practice generally**, so of all the points, just, encouraging children to take tablets, including adults who say they can't swallow, to try and take tablets" – Participant 5, General practitioner
			"I wasn't aware it would make a huge difference to the environment, but I am very environment focused [sic], so if it's going to make a difference, then sounds good to me, mainly in **my personal life, I try to be environmentally friendly but I would like to increase that in my working life** […] One of the GPs did a presentation the other week, which was quite interesting about the little changes we could make, pledges that we could make as a practice, and for me, **I quite like to hear other people being motivated about it, because sometimes it feels like you're the only one, and when you hear other people speaking about it to, it gets you going a bit,** [it's definitely a good thing to focus on in the letter as] medicines are a big area for this" – Participant 7, Pharmacist
			"**in general healthcare obviously it's been a big drive**, inhalers in there as well, **so it makes sense if this is causing emissions to kind of see and get a resolution for to and change the ways** […] **I wasn't aware of medicines created a massive emission, so that's a surprise**" - Participant 4, Non-Medical Practitioner
		Previous drug Shortages	Well, I think both of them are the most important but probably more the climate change as well, **but of course the shortages was a problem a few months back,** so we were prescribing the tablets or capsules to kids and they were able to take it as well, […] and sometimes if they can't swallow, the tablets can be crushed – Participant 9, Pharmacist
			another point to back that the pills can be beneficial. […] At the moment, the thing that would influence me the most, because **we're getting lots of children in at the moment, the shortages as that stays closer to home,** […] if I had to be honest, I think the least impactful one would be the sustainability just because, as an F2 junior doctor I feel quite removed from the grander scheme of things" – Participant 6, Junior Doctor
		E-prescribing	"it talks about delayed prescriptions and from where I sit, those things don't work that well, because you end up signing it now and they go and get it anyhow, and then they've still got to ring up and pester for it to get switched because we have electronic

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Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			prescribing, so those things are less easy, **whereas, if it was a printed script, that would sort that out"** – Participant 11, General Practitioner
Capability	Structure and layout	Length	"It's quite long, but I think it's fine […] but **nothing to really get rid** of, you need as much information as possible" – Participant 2, Management and Administration "it's a very long letter […], **it's quite bulky**, I think it's a **good letter in terms of the information** it's giving but I wondered if it could be shorter […] having the three points is good, three simple actions. **Information in the footer isn't really needed** I don't think […] short paragraphs were good […] The things in bold are good, as are the links, **I think removing the footer, I don't think people will look at that**" – Participant 8, General Practitioner "**it looks quite wordy**, so some of the doctors without a lot of time would probably skim over things" – Participant 6, Junior Doctor "it's **three clear reasons,** and it's good to have more than one reason to do it" – Participant 7, Pharmacist "**It's easy to read and understandable**, it's not too much information, each point is mentioned appropriately," – Participant 9, Pharmacist
		Content	I would say, because it's a letter to a GP all three points, keep them all, just I think **it's more information for the prescriber, it gives the rationale and three reasons** why you're focusing in on this, that's as much as you can give, and they're quite short points, they're not long things, **it's virtually one side of A4**, the footnotes could go on the next page" – Participant 10, Pharmacist As written the letter is fine, **quite clear** and does point out that the majority of practices prescribe fewer liquid antibiotics than yours, […] that **explains the rationale** for why they're getting the letter and if most practices are doing that then they need to think about how they can get into that area don't they – Participant 10, Pharmacist "I think **it's quite positive at the end** where it's sort of [acknowledges it's] not a

Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			simple issue and there are small changes you can make, so **it's trying to encourage you to get on board**. The fact it goes on to two pages isn't good, one page is always good, but **it does say who the people are who are doing the study which is good to know"** – Participant 11, General Practitioner "I think they're all relevant and appropriate, **they're all equally important** […] **make it bolder**, those points there [prescribing rates, climate change and swallowing pills,] if they were bolder, it does read well though" – Participant 4, Non-medical Practitioner
	Impact	Individual	"**it will definitely be in my mind**, you know challenging parents and recommending a back up when I am prescribing and recommending those medications and the information for them to read at home in the background is useful" – Participant 4, Non-Medical Practitioner "**the resources are good professionally, and personally**, because I have young children too. **I think if you said to a parent now, can I give you tablets because they're cheaper they would just say no, but if you gave them the resources to try it, then, erm I think it would be helpful,** it might not be a massive uptake, but it might get better a bit" – Participant 5, General practitioner.
		Sharing with team	"**I have very little influence on how the practice runs**, I just do what I'm told a lot, although I have kind of taken away from the sustainability teaching the importance of turning off the computer at the end of the day, and **I will obviously bare this in mind as well going ahead**. [So if I received this as an F2] it **would still influence me because there are resources to help children to swallow pills and to cut down on liquids**" Participant 6, Junior Doctors 'they are all important, but **remember there are many other people prescribing**, **there are physicians associates or paramedics**, lots of AGPs, usually AGPs will be responsible for signing those prescriptions, so getting the message out, you could tell an AGP who prescribes very little themselves, it the

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Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			allied health care professionals that are doing it, so it's getting information out to all the right people. – Participant 8, General Practitioner
			"we would definitely put the links on our website, […] **we would put it in the patient newsletter** and definitely get it up on the website […] **we could have posters in our waiting room too**, little pre-set text that we could text to parents as we give them the antibiotic prescription" – Participant 8, General Practitioner
		Using Resources	**[it] signposted to resources** that would help children to swallow pills, it gave quite good examples of problems from the past and how we can try to avoid them […] **I think it would make me think about things**, I think some people underestimate that children can and will swallow tablets, one told me the other week they didn't want the banana medicine they wanted tablets." - Participant 6, Junior Doctor
			"the points to consider are clear enough, there wouldn't be any problem, **the hyperlinks [to resources] are good**" - Participant 5, General Practitioner
			"it's well written, and **has simple actions to take**, I wasn't aware of KidzMed so I wanted to click on that, **but it's quite easy to share that with patients too** […] **we can put them on the shared intranet** to share in the practice as well […] which could be useful for people later in life as well" – Participant 10, Pharmacist
			"I think **something we could text to their number would be helpful, a poster for the waiting room** would probably help too" – Participant 6, Junior Doctor
	Signatories	Local clinicians	"**coming from local area leads in pharmacy and paediatrics is fine** […] it's a consultant paediatrician and lead paediatrician pharmacist, so yeah very relevant. To be fair, when I read the letter, I knew it was going to be from the children's hospital but for me, that it's from a doctor, and **the contents of the letter is what is important, not who it is from**" – Participant 2, Management and Administration
			"**people pay attention when things come from specialists or the hospital** […] what would influence me more is **the consultant paediatrician**, I don't think patients would be aware of other places, and especially it's for kids as well, they [at the Children's Hospital] would know more" – Participant 9, Pharmacist
			"parents often think they know what they want for their children but it's about challenging that and seeing if we can make a difference at all [it was a surprise it was children over 4 years old] but I mean if they can swallow sweeties and things like that then there is no reason they can't swallow tablets, so **yeah over four, I was expecting it to be a bit older, but if that's coming from a consultant paediatrician then yeah**" – Participant 4, Non-medical Practitioner
			"It's nice to have a name on it, **it makes it more personable**, **and lets you know there are people behind it,** and people [working] in the appropriate area for what they're asking, **it's not some higher up NHS-thing, its people who actually do work with children** kind of thing and I think clinicians will respond to [it being from clinicians], perhaps. [In addition it would be good] to say it's supported by a climate organisation, or have their logo or something." – Participant 7, Pharmacist
			"well, **[a paediatrician and pharmacist] they're important people aren't they, a pharmacist in the hospital, they know what they're talking about it**" – Participant 3, Management and Administration
			"I think **having the clinical backing, would give [prescribers] more confidence** in what is in the letter. These people seem quite accessible, there is contact info for them, an email address, so I think that's more personable" – Participant 6, Junior Doctor
		Regional or national leaders	"I think **it would be good to have someone from the ICB** on there as well, **someone from the Meds Optimisation Team** perhaps, just so it's got some **sort of agreement and rubber stamping** by the ICB, so that could be the third name, The specialities is really good, but having a

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Table 2 (*continued*)

COM-B Domain	Theme	Cluster	Data Extract
			rubber stamp for the area would be good, the ICB" – Participant 10, Pharmacist "**Sometimes [coming from national leaders] makes it so big that you just don't care**, like the equivalent of the Prime Minister saying we're going to do this for the health service, and it just gets lost" – Participant 11, General Practitioner "it would make **more of an impact if it was from a higher level from the NHS**" – Participant 3, Management and Administration "I was thinking **if there was someone more locally, prescribing advice** […], **it would be useful to have that on there as well as a signatory. I think the RCGP or RCPCH and someone I think certainly, from our local prescribing guidance**, **like who tells us what we can and can't prescribe**, **that would be more impactful than specialists.** – Participant 5, General Practitioner "what would also be helpful is **someone from the ICB or NHS England** who is also onboard with this, putting their name to this as well, because then people will think, well why are they [the paediatrician and pharmacist] writing to us and not the ICB, **who we are sort of accountable** […] from medicines management, probably ICB or Royal College, I think alongside the [local clinicians] cause they've done all the work" – Participant 8, General Practitioner "that could be **something that the ICB or public health England or whoever send out to practices** anyway, or text this number to all parents of children who are over 4 years old, so then to start getting the word into pharmacies as well" – Participant 8, General Practitioner

Motivating factors were contextualised to knowledge and awareness of other interventions, initiatives and opportunities in the National Health Service (NHS) and more widely in society generally. For example, participants reported repeated initiatives to reduce costs and waste in the NHS and reduce greenhouse gas emissions by making 'environmentally friendly' changes to everyday life. The zeitgeist in society about climate change, being environmentally friendly and greenhouse gases emissions reduction meant participants already had access to information about the relationship between health services and the environment through education and training, and their personal and professional relationship (spouses and colleagues, respectively) prior to this intervention. They therefore appeared receptive to additional information about climate change and reducing cost. However, one participant who was a junior doctor, reported they felt more influenced to change their prescribing behaviour by information to support children swallowing pills and drug shortages, as they had closer proximity to this, in comparison to the broader, strategic initiatives, such as reducing cost and greenhouse gas emissions more broadly. Other initiatives, such as e-prescribing, reduced opportunities to implement the changes recommended, such as delayed antimicrobial prescriptions.

3.3. Theme 3) Capability - how the intervention could impact behaviour

> "*the resources are good professionally, and personally, because I have young children too. I think if you said to a parent now, can I give you tablets because they're cheaper they would just say no, but if you gave them the resources to try it, then, erm I think it would be helpful, it might not be a massive uptake, but it might get better a bit" – Participant 5, General practitioner.*

> "*the resources are good professionally, and personally, because I have young children too. I think if you said to a parent now, can I give you tablets because they're cheaper they would just say no, but if you gave them the resources to try it, then, erm I think it would be helpful, it might not be a massive uptake, but it might get better a bit" – Participant 5, General practitioner*

This theme captures findings relating to capability to communicate information to participants, through form, structure and layout, and proposed or planned actions participants reported. The layout and structure of the intervention was reported as appropriate, particularly being (almost) a single side of A4, presenting three distinct points and providing local, named and contactable signatories. Although some participants did report the BCI contained a lot of information, was too long and wordy, this was balanced with other participants reporting the information included was necessary, clear and appropriate. Data related to capabilities to change behaviour at an individual and team level. At an individual level, the majority of participants reported that the information would 'stay in the back of their mind' and 'make them think twice' or 'challenge parents' to use pills, in preference to liquids. At a team level, participants reported they would share resources with parents and professional colleagues, through newsletters, websites, and practice intranet – suggesting the intervention could trigger changes to whole teams as well as individuals. One participant reported they would did not feel able to make such broad, team-based changes, due to their junior role in the practice (relative to others).

4. Discussion

4.1. Summary of findings

The findings demonstrated information about high rates of liquid prescribing and the impact this has on climate change and cost, which can be mitigated through substituting prescriptions for liquids with solid oral dosage forms, may be suitable as a behaviour change intervention. Data demonstrated the inclusion of multiple, overlapping pieces of information to reduce liquid prescribing, could motivate behaviour change. The existing zeitgeist related to reducing greenhouse gas emissions and costs provides an opportunity to influence prescribing practices of participants, who were receptive to receiving this information. Finally, the intervention demonstrated participants had the capability to change their behaviours by using, and sharing, resources included in the intervention. Data suggesting the involvement of regional prescribing leadership may further improve the capability of participants to change their behaviours.

4.2. Comparison to existing literature

Existing evidence has demonstrated social influence can change behaviours of healthcare professionals,[3–6] particularly in relation to antimicrobial prescribing.[6] The findings of this study adds to the literature by demonstrating that information about greenhouse gas emissions linked to a medicine has similar value to prescribers as information about cost, drug shortages and waste reduction. This is important, as many governments, health systems and policy organisations are working towards reducing greenhouse gas emissions to Net Zero,[9] so evidence this information can influence prescribing behaviours represents an additional tool in the work to avert the climate crisis. Although care must be taken not to over-exaggerate the influence of information about greenhouse gas emissions on prescribing behaviours, due to the limited sample size of this study as well as existing work, which has shown behaviours are multifactorial and subject to extraneous and compound variables which can influence behaviour in different contexts.[17] Furthermore, this study related to the development of the intervention, rather than an evaluation of the efficacy of the intervention, therefore further work is needed to test if the intervention successfully influenced prescribing behaviours.

4.3. Implications for policy and practice

The findings have implications for policy and practice as they showcase the potential to reduce greenhouse gas emissions linked to liquid prescribing. Existing preliminary work has shown prescribing liquid amoxicillin, compared to solid oral dosage forms like tablets and capsules, leads to increased greenhouse gas emissions.[11] Other work has shown cognitive pill aversion in adults without dysphagia is high,[12] and that BCIs aimed at children and young people can support switching patients from liquid to solid oral dosage forms, thereby reducing liquid prescribing and greenhouse gas emissions.[13–16] This study adds to the existing evidence, as it demonstrates the feasibility of a BCI which combines information about greenhouse gas emissions linked to prescribing liquid antibiotics with resources to combat pill aversion and support pill swallowing. For practitioners and policy makers, the findings indicate more work is needed to explore how information about greenhouse gas emissions linked to prescribing can be utilised with existing prescribing data and health education resources.

4.4. Strengths and limitations

Although participants came from a range of professional and educational backgrounds, a limitation of the study is the very small sample size and that the majority of participants were recruited from one geographical area (North East England). This can weaken the transferability of the findings to other settings and contexts.[31] However, the data collection was completed until theoretical data saturation was reached, which strengthens the trustworthiness of the findings.[31] Interviews were conducted by one author (JP) under supervision of another (APR), with data extracts and study materials made available, which increases the dependability of the findings.[31] Further work is needed to evaluate the impact of the behaviour change intervention in practice.

5. Conclusion

The aim of this study was to develop a behaviour change intervention using information about greenhouse gas emissions to reduce antibiotic prescribing. This study showed empirical data from the target population demonstrated information about greenhouse gas emissions, when presented alongside information about practice liquid prescribing rates, drug shortages, costs and how to support children to swallow pills, may motivate primary care teams to prescriber less liquid amoxicillin. Further work should focus on the application of behaviour change techniques utilising information about greenhouse gas emissions linked to the prescribing of liquid medications in comparison to solid oral dosage forms.

CRediT authorship contribution statement

Joseph Pickles: Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Laura Griffiths:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alice Patricia McCloskey:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nicola Vasey:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Emma Lim:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Adam Pattison Rathbone:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

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References

1. Talkhan H, Stewart D, McIntosh T, et al. Investigating clinicians' determinants of antimicrobial prescribing behaviour using the Theoretical Domains Framework. *J Hosp Infect.* 2022;122:72–83.
2. Friedkin NE, Johnsen EC. *Social Influence Network Theory: A Sociological Examination of Small Group Dynamics*. Cambridge University Press; 2011.
3. Davis BP, Knowles ES. A disrupt-then-reframe technique of social influence. *J Pers Soc Psychol.* 1999;76:192.
4. Webb T, Joseph J, Yardley L, et al. Using the internet to promote health behavior change: a systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. *J Med Internet Res.* 2010;12, e1376.
5. Michie S, Wood CE, Johnston M, et al. Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). *Health Technol Assess.* 2015;19.
6. Hallsworth M, Chadborn T, Sallis A, et al. Provision of social norm feedback to high prescribers of antibiotics in general practice: a pragmatic national randomised controlled trial. *Lancet.* 2016;387:1743–1752.
7. Magnano San Lio R, Favara G, Maugeri A, et al. How antimicrobial resistance is linked to climate change: an overview of two intertwined global challenges. *Int J Environ Res Publ Health.* 2023;20:1681.
8. Meinen A, Tomczyk S, Wiegand FN, et al. Antimicrobial resistance in Germany and Europe–A systematic review on the increasing threat accelerated by climate change. *J Health Monit.* 2023;8:93.

9. Fankhauser S, Smith SM, Allen M, et al. The meaning of net zero and how to get it right. *Nat Clim Change*. 2022;12:15–21.
10. Danielsson R, Lucas J, Dahlberg J, et al. Compound-and context-dependent effects of antibiotics on greenhouse gas emissions from livestock. *R Soc Open Sci*. 2019;6, 182049.
11. Parker E, Sawyer M, McCloskey A, et al. *729 EcoKidzMed: Measuring the Carbon Emissions of Packaging, Distribution and Waste Disposal of Liquid and Capsule Amoxicillin*. BMJ Publishing Group Ltd; 2023.
12. McCloskey AP, Penson PE, Tse Y, et al. Identifying and addressing pill aversion in adults without physiological-related dysphagia: a narrative review. *Br J Clin Pharmacol*. 2022;88:5128–5148.
13. McCloskey AP, Lunn A, Traynor MJ, et al. KidzMed e-learning to upskill student pharmacists to teach pill swallowing to children. *PLoS One*. 2023;18, e0282070.
14. Tse Y, Vasey N, Dua D, et al. The KidzMed project: teaching children to swallow tablet medication. *Arch Dis Child*. 2020;105:1105–1107.
15. Mistry R, Leung M, Varma N, et al. *1100 Young person's peer-to-peer 'pill swallowing'training via video-link. A Kidzmed Pilot Study*. BMJ Publishing Group Ltd; 2021.
16. Vasey N, Tse Y, Pickering A, et al. SP9 the KidzMed project part 1: pill popping heroes. *Arch Dis Child*. 2020;105:e5–e6.
17. Michie S, Johnston M. *Theories and Techniques of Behaviour Change: Developing a Cumulative Science of Behaviour Change*. vol. 6. Taylor & Francis; 2012:1–6.
18. Coffey T, Duncan E, Morgan H, et al. Developing strategies to address disparities in retention communication during the consent discussion: development of a behavioural intervention. *Trials*. 2023;24:296.
19. Chen D, Zhang H, Cui N, et al. Development of a behavior change intervention to improve physical activity adherence in individuals with metabolic syndrome using the behavior change wheel. *BMC Publ Health*. 2022;22:1740.
20. Courtenay M, Rowbotham S, Lim R, et al. Examining influences on antibiotic prescribing by nurse and pharmacist prescribers: a qualitative study using the Theoretical Domains Framework and COM-B. *BMJ Open*. 2019;9, e029177.
21. Sargent L, McCullough A, Del Mar C, et al. Using theory to explore facilitators and barriers to delayed prescribing in Australia: a qualitative study using the theoretical domains framework and the behaviour change wheel. *BMC Fam Pract*. 2017;18:1–14.
22. Porcheret M, Main C, Croft P, et al. Development of a behaviour change intervention: a case study on the practical application of theory. *Implement Sci*. 2014;9:42.
23. Curtis HJ, Goldacre B. OpenPrescribing: normalised data and software tool to research trends in English NHS primary care prescribing 1998–2016. *BMJ Open*. 2018;8, e019921.
24. Curtis HJ, MacKenna B, Reddy B, et al. Educational interventions delivered to prescribing advisers to influence primary care prescribing: a very low-cost pragmatic randomised trial using routine data from OpenPrescribing.net. *medRxiv*; 2024. https://www.medrxiv.org/content/10.1101/2024.01.05.24300907v1.full.pdf+html.
25. OpenPrescribing.net. *Bennett Institute for Applied Data Science*. University of Oxford; 2024. https://openprescribing.net/, 7th January 2025.
26. Lim E, Parker E, Vasey N. Why learning how to swallow pills is good for patients, parents, and the planet. *bmj*. 2024;384.
27. Vindrola-Padros C, Johnson GA. Rapid techniques in qualitative research: a critical review of the literature. *Qual Health Res*. 2020;30:1596–1604.
28. Vindrola-Padros C, Chisnall G, Cooper S, et al. Carrying out rapid qualitative research during a pandemic: emerging lessons from COVID-19. *Qual Health Res*. 2020;30:2192–2204.
29. Wanat M, Borek AJ, Pilbeam C, et al. Conducting rapid qualitative interview research during the COVID-19 pandemic—reflections on methodological choices. *Front Soc*. 2022;7, 953872.
30. Crotty MJ. The foundations of social research: meaning and perspective in the research process. *Foundations Soc Res*. 1998:1–256.
31. Shenton AK. Strategies for ensuring trustworthiness in qualitative research projects. *Educ Inf*. 2004;22:63–75.