Increasing vaccine uptake in low- and middle-income countries

Opportunities for behavioural insights research

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THE
BEHAVIOURAL
INSIGHTS
TEAM

Contents

Glossary

Term	Definition
BMGF	Bill and Melinda Gates Foundation
BeSD working group	Measuring Behavioural and Social Drivers of Vaccination working group
CCT	Conditional cash transfer
CHW	Community health worker
CFIR	Consolidated Framework for Implementation Research
DiD	Difference-in-differences
DTP (DTP3)	Diphtheria, tetanus and pertussis vaccination. DTP1, DTP2 and DTP3 respectively refer to the first, second and third doses of the DTP vaccine schedule.
EPI	Expanded Programme on Immunisation
Gavi	The Gavi Vaccine Alliance
GVAP	Global Vaccines Action Plan
HIC	High-income country
HPV	Human papillomavirus vaccination
J-PAL	The Abdul Latif Jameel Poverty Action Lab
KES	Kenyan Shilling
LMIC	Low- or middle- income country
LMIS	Logistics management information system
mHealth	Mobile health
MMR	Measles, mumps and rubella vaccination
NITAG	National immunisation technical advisory group
NFC	Near field communication
OPV	Oral polio vaccination
OR	Odds ratio

PHC	Primary healthcare centre
RCT	Randomised controlled trial
RD	Risk difference
RR	Relative risk
SAGE	Strategic Advisory Group of Experts on Immunisation
SIV	Seasonal influenza vaccination
SMS	Short message service (text messages)
UCT	Unconditional cash transfer
WHO	World Health Organisation

Executive summary

Introduction

Vaccination is a key component of delivering universal health coverage. Not only does vaccination prevent an estimated 2-3 million deaths each year but it can contribute to the achievement of multiple Sustainable Development Goals and efforts to tackle antimicrobial resistance[1,2]. Though substantial progress has been made towards global vaccine coverage, 19.4 million infants did not receive basic vaccines in 2018, and the majority of these live in low- and middle income countries (LMICs)[3].

The determinants of undervaccination are multiple and varied, ranging from inadequate supply of vaccines to lack of awareness and education about vaccination[4]. Though some of the barriers to vaccine uptake are structural, others are related to individual behaviour and decision-making. There has been increasing recognition in the global health community of the role that behavioural science can play in encouraging vaccine uptake, most recently in a background paper for the Global Vaccination Summit 2019[5]. However, despite this recent attention, the available evidence from behavioural science for 'what works' to encourage vaccination in LMICs is limited.

'Behavioural insights' is an approach that brings together evidence from a range of academic disciplines, most notably psychology and economics, and applies it to solve real-world problems. The approach is underpinned by a 'dual-process' model of thinking that recognises the biases inherent in the way that we behave and make decisions[6]. Informed by this realistic understanding of human behaviour, behavioural insights practitioners then set out to design more effective policies and systems. The Wellcome Trust supported the Behavioural Insights Team to produce a landscape analysis of opportunities for behavioural insights research to increase vaccine uptake in LMICs. This report details the findings from that review.

Vaccination behaviour

Several of the attributes of vaccination make people vulnerable to bias in making vaccination decisions[7]. Specifically, the outcomes of vaccination are uncertain (for example, people aren't sure they will contract the disease if they are not immunised, but vaccination might cause side-effects), the benefits and costs of vaccination occur at different points in time and may accrue to people other than the decision maker (particularly in the case of childhood vaccination). Though vaccination seems like an obvious decision at the population level, at the individual level the cost-benefit analysis is much more uncertain.

Brewer et al. have proposed the 'Increasing Vaccination Model' to help structure thinking about the behavioural barriers to vaccination (see Figure 1 below)[8]. The model suggests that people's attitudes (what they think and feel) and wider social processes jointly influence

people's motivations and intentions towards vaccination. Practical barriers then mediate the relationship between favourable intentions to vaccinate and ultimate vaccination behaviour. The model highlights the existence of what is known as the 'intention-behaviour gap' in vaccination behaviour: the finding that people's ultimate behaviours do not always correspond to their stated motivations or intentions[9]. We shouldn't assume that because an intervention successfully changed attitudes and intentions towards vaccination that it will translate into behaviour change.

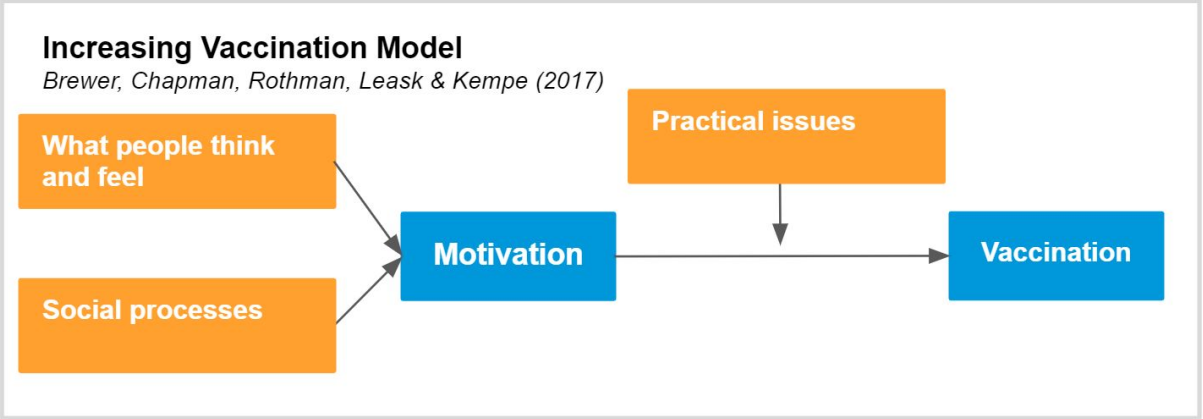


Figure 1: Increasing Vaccination Model[8]

Part A: Landscape Analysis

Part A of this report sets out a review of existing evidence from behavioural insights research on vaccine uptake. Section 1 describes in detail the existing evidence from LMIC settings. Section 2 then summarises the outputs of comparable research conducted in high-income countries (HICs).

Section 1: Evidence from low- and middle-income countries

For vaccination programmes to be successful there needs to be both reliable and sufficient supply of vaccines (and capacity to deliver them), and demand from within the population that is due to be vaccinated. Research into behavioural interventions to improve vaccine uptake in LMIC settings has predominantly focused on encouraging demand for vaccinations (as opposed to boosting vaccine supply). Only a limited number of studies have used behavioural approaches to improve the availability of vaccines and vaccine services in LMICs. These approaches have been components of broader initiatives to implement better supply chain technology. For this reason the review of evidence from LMIC settings falls into two parts:

1. A review of the evidence for behavioural interventions to encourage vaccine demand in LMIC settings
2. A summary of existing research into initiatives that have drawn on behavioural techniques to improve vaccine supply in LMIC settings

Encouraging 'vaccine demand' describes both promoting favourable intentions towards vaccination among potential recipients, and breaking down practical barriers that might prevent or discourage people from receiving vaccinations. We identified 28 studies published in the past 10 years evaluating the effect of behavioural interventions intended to increase demand for vaccinations in LMIC settings. The characteristics of these studies are summarised in Figure 2 below. The evidence in this area was generally assessed to be low or very low quality according to the widely used GRADE framework[10].

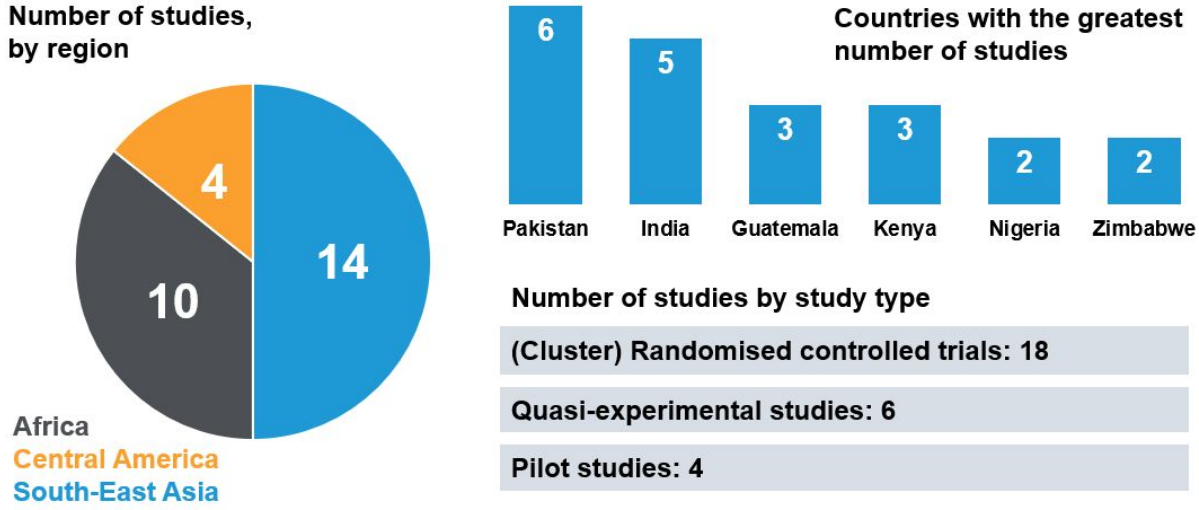


Figure 2: Characteristics of studies investigating the effect of behavioural interventions to encourage vaccine uptake in LMIC settings

Our landscape analysis found that most studies from LMICs published in the past 10 years have evaluated the use of either incentives, reminder and recall messages (in particular taking advantage of the proliferation of mobile phone ownership in LMICs), or improvements to delivery of vaccine education and information to encourage vaccine uptake. A limited number of studies have tested solutions that highlight social norms in favour of vaccination and create social pressure to have infants vaccinated. The findings from existing behavioural insights research on vaccine uptake in LMICs is summarised below under these four headings:

Education and information about vaccines

- There is some limited evidence that centre-based education, in-home education with visual aids and redesigned immunization cards are effective in increasing childhood vaccination uptake in Asia.
- There is no evidence that a loss- or gain-frame is more effective in encouraging vaccine uptake in LMIC settings, but this was only tested in one study.
- There is insufficient evidence about planning and implementation intentions to draw any conclusion about the effectiveness of these strategies in a LMIC context.

Incentives for vaccination

- The limited available evidence is inconclusive as to whether cash transfer programmes are effective at increasing vaccine uptake in LMIC settings.

- There is some evidence that small, compliance-linked incentives increase infant vaccine uptake.
- One study found that a pay-for-performance scheme for primary healthcare providers was no more effective in encouraging vaccine uptake than traditional input-based financing.

Reminders and recalls for vaccination appointments

- Reminder and recall messages sent to mobile phones are generally effective at encouraging infant vaccine uptake and on-time infant vaccine uptake.
- We found no studies from the past 10 years that tried varying reminder message content to investigate which messages are most effective at encouraging parents to bring their children to vaccination appointments.
- Reminder and recall messages are an effective component of systems to track vaccine doses within the population.

Using social networks to encourage vaccination

- Using social signaling to highlight social norms in favour of vaccination is promising, but there has only been one high quality trial in this area.
- One study found vaccination discussion groups with influential members of the community in Pakistan increased childhood vaccine uptake.

Our landscape review did not identify any standalone interventions focused on changing individual behaviour to improve the supply of vaccines and vaccine services in LMICs. We did identify three studies that evaluated vaccine stock-tracking technology systems that drew on behavioural techniques to influence behaviour. These interventions were generally less rigorously evaluated than the demand-side interventions described above, likely because of the greater challenge of assessing changes implemented at the system level. All three studies found that the new technology increased vaccine availability or quality of vaccine tracking data.

Section 2: Evidence from high-income countries

Much of the research investigating behaviourally-informed interventions to increase vaccine uptake has been conducted in HICs. In Section 2 we summarise the evidence from intervention research in HICs structured according to the 'Increasing Vaccination Model' proposed by Brewer et al. The key conclusions from this summary are as follows:

Changing what people think and feel about vaccination

- Substantial evidence suggests that neither 'loss-' or 'gain-' framed messages are more effective in encouraging vaccination behaviour.
- Most studies that have successfully changed the way people perceive the risks of vaccine preventable diseases have not demonstrated any subsequent impact on vaccination behaviour.
- Evidence suggests that educational interventions to increase childhood vaccine uptake are more effective in LMICs than in HICs. In general, educational interventions have not been effective at increasing vaccine uptake in HICs.

- There is some evidence to suggest that motivational interviewing has a moderate positive impact on vaccine uptake.

Using social processes to encourage vaccination

- Correlational studies suggest that interventions that highlight social norms in favour of vaccination could increase vaccine uptake, but we are not aware of any studies that have tested such interventions.
- Available evidence suggests that providing performance feedback to primary healthcare providers has a modest positive effect on vaccine uptake.
- Limited evidence suggests that emphasising the pro-social nature of vaccination behaviour has little if any impact on vaccine uptake.
- There is considerable evidence that healthcare provider recommendations increase vaccine uptake.

Bridging the gap between motivation and behaviour

- Available evidence suggests that interventions which set vaccination as the default, such as automatic appointment scheduling, presumptive announcements, and vaccine requirements are effective at increasing vaccine uptake.
- Limited evidence indicates that requiring people to make an active choice about vaccination is moderately effective at increasing uptake.
- There is good evidence that reducing friction costs increases uptake of vaccinations.
- Timely interventions that prompt people to plan when they will get vaccinated or remind them of upcoming appointments increase vaccination.
- Strong evidence suggests that incentives, structured as either rewards or sanctions are effective at encouraging vaccination.

Part B: Opportunities for future research

Part B of this report sets out future opportunities for behavioural insights research to encourage vaccine uptake in LMICs in light of the evidence gaps identified in Part A. Our recommendations are structured around a four part framework that categorises options for funding research in this area (see Figure 3 below).

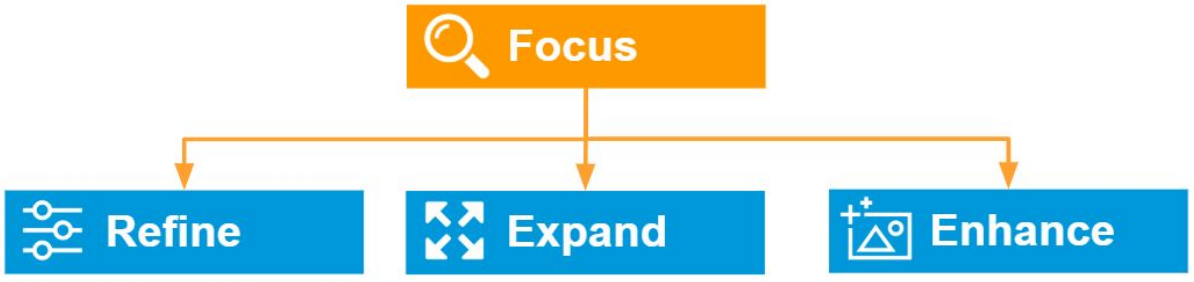


Figure 3: Approaches to funding options

'Focus' provides an initial lens for deciding which undervaccinated populations to focus on, with the objective of maximising impact. The inclusion of 'Focus' recognises that behavioural barriers and solutions are to some extent context specific, and that research outputs will not necessarily be generalisable across geographies. Following on from the 'Focus' stage, we

have identified three broad approaches to behavioural insights research on encouraging vaccine uptake in LMICs: 'Refine', 'Expand' or 'Enhance'. Which approach is most appropriate for a given context will be informed by the barriers to vaccination in the target population, the state of existing evidence for encouraging vaccine uptake in the target population, and whether behavioural insights is the central component of the intervention approach:

- **Refine**. Develop behaviourally-informed solutions where there is existing evidence of effectiveness in encouraging vaccine uptake. This would involve refining promising solutions by testing different variants of interventions in similar contexts, or testing interventions (based on those) that have worked in HICs, in LMIC settings.

- **Expand**. Expand the evidence base by funding research into behaviourally-informed solutions that haven't yet been applied to vaccination behaviour in LMIC settings. Interventions that have been effective at encouraging other health behaviours could be newly applied to undervaccinated populations in LMICs. Solutions based on encouraging results from correlational research could be developed and tested.

- **Enhance**. The 'Enhance' approach is suggested where behaviourally-informed interventions are not the central component of a given solution but where there is a role for behavioural insights to play in maximising impact and effectiveness. Options under this approach include applying behavioural insights to improve the effectiveness of new technology, support evidence dissemination, or scale-up impactful solutions.

Table 1 below summarises the funding opportunities under each of the four headings in the Framework.

Table 1: Summary of funding opportunities

Approach	Opportunity
Focus	Fund research into **describing and quantifying the prevalence of local behavioural barriers to vaccination** using World Health Organisation (WHO) tools.
Refine	Fund research to **refine and build evidence for promising behavioural interventions** to encourage vaccine uptake.
Expand	Expand the evidence base by funding research to **evaluate behaviourally-informed strategies that have not yet been applied to encourage vaccine uptake**.
Enhance	**Scaling effective interventions:** Fund evaluation of the scale-up of interventions for which there is evidence that they encourage vaccine uptake.
	Addressing barriers to implementation: Fund collaborative behavioural insights and implementation science research to improve the effectiveness of implementation programmes.
	Spreading evidence-based practice: Fund the creation of easy-to-use resources summarising available evidence about interventions to encourage vaccine uptake and facilitate effective knowledge networks.
	Improving supply chain technology: Fund behavioural insights support to design of vaccine supply chain technology.
	Enhancing vaccine communications: Fund behavioural insights support to national vaccination campaigns and communications.

Introduction

Vaccine uptake in low- and middle-income countries

It is estimated 2-3 million deaths from preventable diseases are averted each year because of vaccines, but an additional 1.5 million deaths could be avoided with improvements in vaccination coverage[1]. Despite substantial progress in recent years, 19.4 million infants did not receive basic vaccines in 2018[3]. The burden of under-vaccination is overwhelmingly concentrated in LMICs. Ten LMICs[1] account for 60% of the 19.4 million unprotected children[3]. About 1 in 5 un- and under-vaccinated children live in fragile or humanitarian settings[11]. In 2011 the 'Decade of Vaccines' was declared by the global health community and the Global Vaccines Action Plan (GVAP) was launched, setting out a framework to achieve 90% coverage for all vaccines in national immunisation programmes[12]. In the final assessment report before the close of the decade, it was estimated that an additional 20 million children have received vaccinations since 2010, but uptake of the DTP (Diphtheria, Tetanus and Pertussis vaccination) and the first dose of measles-containing vaccine has plateaued at 85%[2].

The drivers of under-vaccination in LMICs are multiple. Following a systematic review Philipps et al. identified both structural and behavioural determinants of effective vaccine coverage in LMICs[4]. Structural factors include political commitment to vaccination, adequate funding, vaccine supply and storage capacity, and health facility access. Among the behavioural determinants were awareness and education about vaccines, perceived vaccine safety and effectiveness, available free time for vaccination and facility wait time. The recent Wellcome Global Monitor report found that while the overwhelming majority of people living in LMICs are in favour of vaccination, anti-vaccine sentiment is rising in the Global South, as it is in the Global North[7].

Though structural barriers to vaccination will predominantly require structural solutions, individual and collective decisions are an important driver of whether people get vaccinated, and can be amenable to interventions informed by behavioural science to encourage vaccine uptake. For example, we know that people tend to judge actions that cause harm more harshly than inactions which result in equivalent negative consequences[13]. This can explain why some parents might be more concerned about subjecting their child to negative side-effects as a result of vaccination, than the symptoms of disease that might arise after failing to vaccinate. Interventions that frame non-vaccination as an active choice rather than an omission can increase vaccine uptake[14] (see section below on 'omission bias and active choice' for more detail).

There has been increasing recognition of the role that behavioural science can play in achieving universal vaccination coverage goals. One of the background papers for The

[1] Nigeria, India, Pakistan, Indonesia, Ethiopia, Philippines, Democratic Republic of Congo, Brazil, Angola, Vietnam

Global Vaccination Summit in 2019 highlighted the need to apply insights from behavioural science research to vaccination policies and programmes[5]. In 2013 the WHO Regional Office for Europe released advice for 'Tailoring Immunisation Programmes' based on behavioural insights theory[15]. More recently, UNICEF published the 'Demand for Health Services Field Guide', which offers health professionals advice on taking a human-centred design approach (similar to behavioural insights) to increasing demand for health services including vaccination[16]. Finally, in 2018, the WHO launched the 'Measuring Behavioural and Social Drivers of Vaccination' (BeSD) Working Group with the aim of developing tools and guidance "to enable immunization programmes and partners to measure and address local reasons of under-vaccination, and to track consistent and comparable data over time"[111].

Despite recent attention, the field of behavioural insights research on 'what works' to encourage vaccination in LMICs is relatively underdeveloped. Much work has been published that describes the range of barriers to vaccination in LMICs though little has been done to describe the prevalence of these factors in specific contexts[4]. There has been extensive research in HIC settings to evaluate behaviourally-informed strategies to increase vaccine uptake but to date there has been relatively little high-quality intervention research in LMICs. This report is intended to describe the existing research landscape with a view to informing investment into future behavioural insights research to help address the issue of under-vaccination in LMICs.

An introduction to behavioural insights

'Behavioural insights' is an approach that uses evidence of the conscious and non-conscious drivers of human behaviour to address practical issues. The term was coined in 2010 by a team within the Cabinet Office of the UK government, established to apply evidence from behavioural science to inform policy and improve public services. We (the authors of this report) are now known as the Behavioural Insights Team and in 2014 we spun out of government to form a social purpose company. There are now over 200 government bodies around the world that have dedicated resource for applied behavioural science. Wellcome supported the Behavioural Insights Team to complete a landscape analysis of opportunities for behavioural insights research on vaccine uptake in LMICs.

Why a behavioural insights approach?

Policy makers have always sought to influence behaviour, whether by encouraging more people to save for a pension or to eat healthier food. Historically, policy design has been informed by ideas from traditional economics which assume that people are 'rational actors' and make logical and coherent choices for themselves based on available information. Since the 1970s, evidence produced by various academic disciplines, most notably psychology and behavioural economics, has challenged these assumptions and demonstrated that the preferences and subsequent behaviour of individuals can be influenced by their context and the way choices are presented.

Work across these disciplines is united by the 'dual-process' model of thinking, popularised by Kahneman's book 'Thinking, Fast and Slow'[18]. The dual-process model describes two concurrent processes that give rise to thought: the automatic, intuitive and unconscious

"System One" and the reflective, deliberate and conscious "System Two". The unconscious System One is fundamental to our ability to engage with the world in a productive and sustainable way, but at times it can give rise to biased and incoherent decision making. The behavioural insights approach recognises these biases, and aims to design better policies, systems and services informed by a realistic model of human behaviour.

'Behavioural insights' encompasses three core components. It brings together evidence about human behaviour from a range of disciplines and applies it to solve real world problems. The method is underpinned, where possible, by rigorous evaluation, promoting a culture of evidence-based policy-making which recognises that not all interventions will work as intended. As behavioural insights is an approach to solving real world problems rather than a totalising framework, it is difficult to describe everything that might fit under the umbrella of a 'behaviourally-informed approach'.

Cappelen et al. argue that several of the attributes of vaccination put people at risk of bias in making vaccination decisions[7]. Specifically, they argue that the outcomes of vaccination are uncertain (for example people aren't sure they will contract the disease if they are not immunised, but vaccination might cause side-effects), the benefits and costs of vaccination occur at different points in time and may accrue to people other than the decision maker (particularly in the case of childhood vaccination). Though vaccination seems like an obvious decision at the population level, at the individual level the cost-benefit analysis is much more uncertain. In Table 2 below we describe key behavioural biases that are particularly relevant to vaccination behaviour. In Appendix 1 we describe common behavioural solutions that are used to address these biases. An understanding of both biases and solutions will provide useful context to the subsequent landscape analysis.

Table 2: Key behavioural biases relevant to vaccination behaviour

Behavioural bias	Description
Status quo bias	Most decisions include an option that involves doing nothing or continuing with a previous decision. When presented with such a decision, people disproportionately stick with the status quo, particularly when they don't have a strong preference for any alternative options[19]. Additionally, people tend to be biased towards doing nothing over doing something because of the relative effort involved in making a choice, particularly when presented with a complex decision.
Omission bias	'Omission bias' describes the tendency for people to judge harmful actions more harshly than inaction, even when both might cause equivalent harm[13]. In the context of vaccination, omission bias can explain why some parents may hesitate to have their child vaccinated, because they are more concerned about directly causing harm (i.e. bringing about negative side-effects) than they are about failing to prevent the disease[13].

Loss aversion	We know that people are generally loss-averse, meaning that we will make greater efforts to avoid a potential loss than we will to try to benefit from an equivalent gain[6] If individuals consider vaccination to be a risky choice for themselves or their families they may be sensitive to a message stressing the potential losses associated with not being vaccinated (e.g. "If your child is not vaccinated they will be vulnerable to killer diseases"). Alternatively, if a parent considers the risk of vaccination to be low, a 'gain-framed' message focusing on potential benefits of behaviour may be effective (e.g. "Vaccination can protect your child against killer diseases").
Present bias	Present bias describes the tendency for people to overvalue immediate rewards at the expense of their long-term intentions. If benefits are in the present and costs are in the future, people tend to ignore the costs[20]. This is true of vaccination behaviour: for a given individual, getting vaccinated entails costs today (such as the time lost, or experiencing the potential side-effects), a part of which will be compensated in the long-term (reduced likelihood of infection by the virus).
Intention-behaviour gap	The 'intention-behaviour gap' describes people's failure to follow through on favourable intentions. Even when people intend to get vaccinated and we provide timely prompts to help them achieve this, people may still fail to follow through due to forgetfulness, a lapse in willpower, or other difficulties or distractions[9]. Though intentions are predictive of behavioural outcomes, a meta-analysis of 47 experimental studies found that interventions that successfully produced a medium-to-large change in intentions resulted in only a small-to-medium sized effect on behaviour[21]. There is evidence of such an intention-behaviour gap in the literature on vaccination: one study found that over 70% of UK parents intended to vaccinate their children against seasonal flu but only 52.8% reported doing so[22].
Friction costs	We are more likely to complete tasks that we find easy. The behavioural literature has shown that even seemingly irrelevant details which make a task marginally more effortful, known as 'friction costs', have a disproportionate effect on whether we end up doing something[23].
Conformity and social influence	Social norms are the values, actions and expectations of a particular society or group. We tend to imitate what others around us do, as the behaviour of the majority is perceived to indicate the 'desirable' or 'correct' course of action[24]. In places where vaccination uptake is high, vaccination is the social norm. Reciprocity refers to the specific social norm of obliging repayment of favours and the shunning of those who freeload off others. Vaccination could induce reciprocal behaviour as the benefits of an individual person getting vaccinated are shared by the broader community (by achieving herd immunity and thereby helping to protect others).
Confirmation bias and cognitive dissonance	Confirmation bias describes the tendency for people to seek out or evaluate information in a way that fits with their existing thinking and preconceptions[25]. People with unfavourable views towards vaccination are more likely to seek out content with a negative stance on vaccination, and those in favour of vaccines are more likely to seek out content that supports vaccination[26]. This phenomenon can be explained by the theory of 'cognitive dissonance' which posits that people strive to achieve consistency in their cognitions and beliefs, and in turn in their actions[27].
Availability heuristic	The availability heuristic describes the tendency to judge the frequency of an event or outcome by how easily it comes to mind[17]. Rare events, such as a negative reaction to a vaccination, stand out because they are more special. There is a

	greater likelihood that they will be reported in the media or discussed within social groups. In turn, these rare events are more easily retrieved from memory and people tend to overestimate the probability of them happening[7].

Vaccination attitudes, intentions and behaviours

As part of a recent review of evidence from behavioural science for 'what works' to encourage vaccination, Brewer et al. proposed the 'Increasing Vaccination Model'[8] (see Figure 4 below). The model suggests that people's attitudes (what they think and feel) and wider social processes jointly influence people's motivations and intentions towards vaccination. Practical barriers then mediate the relationship between favourable intentions to vaccinate and ultimate vaccination behaviour. It is important to consider the intention-behaviour gap when interpreting evidence for interventions that aim to increase vaccination. Many studies use vaccination intentions as an outcome measure though it is not a reliable proxy for behaviour. We shouldn't assume that because an intervention successfully changed attitudes and intentions that it will translate into behaviour change.

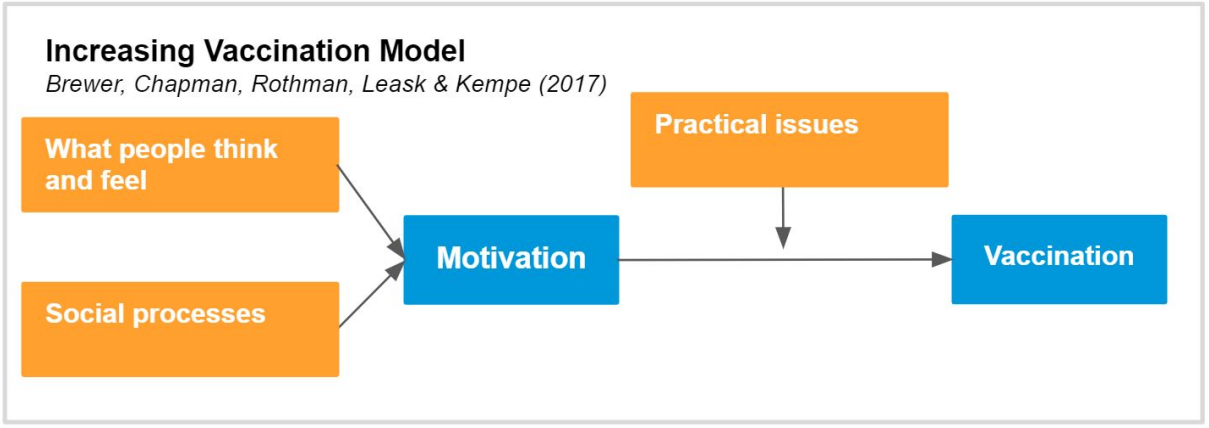


Figure 4: Increasing Vaccination Model[8]

In an earlier report in 2014 the WHO Strategic Advisory Group of Experts on Immunisation (SAGE) working group explored the determinants of 'vaccine hesitancy' defined as both delay in the acceptance of vaccines as well as outright refusal of vaccination despite the availability of vaccine services[28]. Importantly the report noted that vaccine hesitancy can vary across vaccines, with some people accepting some vaccines and refusing others (see Figure 5 below).

The SAGE working group proposed the '3Cs' model of vaccine hesitancy determinants, advancing that complacency, convenience and vaccine confidence explain many of the factors that contribute to vaccine hesitancy[28]. Vaccine **confidence** refers to people not having trust in vaccines and/ or the health system that delivers them. **Complacency** describes situations where people do not consider vaccines to be important. This is likely driven by the fact that the diseases they prevent are not prevalent in many places so people are naive to their potentially devastating effects. Lastly, vaccines might theoretically be available but are not necessarily **convenient** to access. In a separate paper Betsch et al.

proposed an additional fourth 'C': **calculation**, to describe individuals who do not receive vaccination because they consider the costs to outweigh the benefits[29].

It is helpful to reflect on how the older '4Cs' model maps onto the more recent Increasing Vaccination Model from Brewer et al.. We consider that 'confidence' and 'complacency' describe 'what people think and feel' about vaccination. Similarly, 'convenience' describes the 'practical barriers' that get in the way of people acting on their intentions. The fourth 'C', 'calculation' encompasses people weighing-up attitudinal, social and practical factors to inform their ultimate vaccination decision.

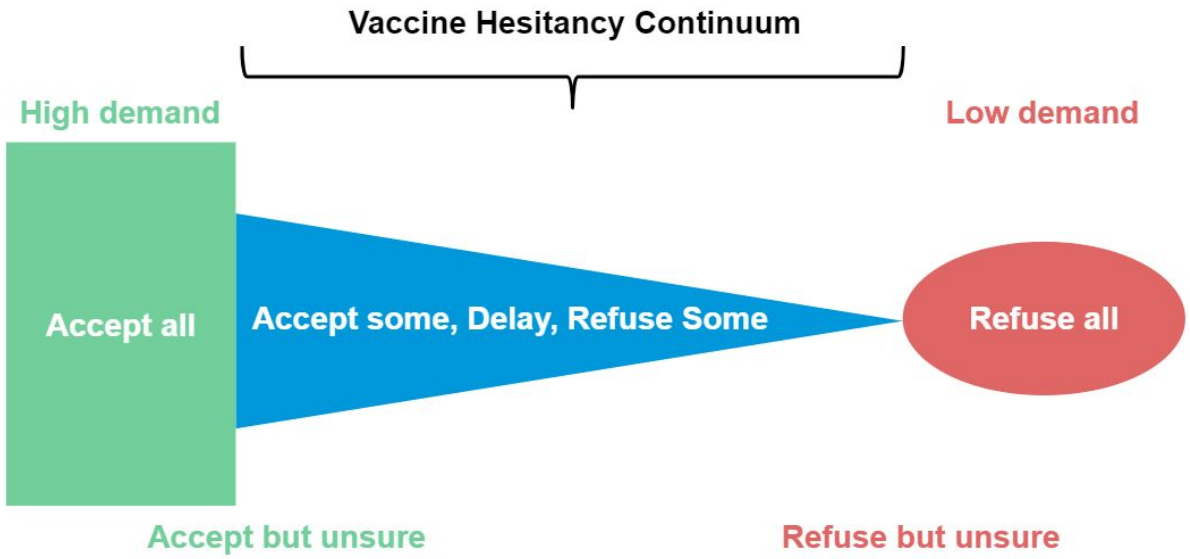


Figure 5: Continuum of vaccine hesitancy between full acceptance and outright refusal of vaccines[28]

This report

Part A of this report sets out a review of existing evidence from behavioural insights research on vaccine uptake. Section 1 describes in detail the existing evidence from LMIC settings. Section 2 then summarises the outputs of comparable research conducted in HICs. In light of the evidence gaps identified in Part A, Part B sets out future opportunities for behavioural insights research on vaccines in LMICs.

Part A: Landscape Analysis

Section 1: Evidence from low- and middle-income countries

For vaccination programmes to be successful there needs to be both reliable and sufficient supply of vaccines (and capacity to deliver them), and demand from within the population that is due to be vaccinated. Research into behavioural interventions to improve vaccine uptake in LMIC settings has predominantly focused on encouraging demand for vaccinations (as opposed to boosting vaccine supply). Only a limited number of studies have used behavioural approaches to improve the availability of vaccines and vaccine services in LMICs. These approaches have been components of broader initiatives to implement better supply chain technology. For this reason the review of evidence from LMIC settings falls into two parts:

1. A review of the evidence for behavioural interventions to encourage vaccine demand in LMIC settings
2. A summary of existing research into initiatives that have drawn on behavioural techniques to improve vaccine supply in LMIC settings

Methodology

It is worth briefly noting that this landscape analysis is neither a systematic review nor a meta-analysis. We did not use a systematic or replicable search strategy in identifying existing evidence. We started by identifying key review papers on interventions to encourage vaccine uptake in LMICs[8,30–37], and then searched reference lists, forward citations, and grey literature for relevant studies. Studies were included that were published in the past 10 years (2009 or later) and included a quantitative evaluation of the impact of a behaviourally-informed intervention to encourage vaccine uptake. Feasibility studies or qualitative studies without a quantitative evaluation of impact were excluded. Though studies of adult or adolescent vaccinations were not excluded, almost all of the research on vaccine uptake in LMIC settings concerns childhood vaccinations. We identified only one study from Thailand that investigated uptake of adult seasonal influenza vaccination (SIV).

In conducting this landscape analysis we were interested in both assessing the quality of existing evidence and describing the breadth of behavioural interventions that have been tested to encourage vaccine uptake in LMIC settings. For this reason we included all studies that evaluated interventions using quantitative methods, regardless of their methodological quality. The GRADE (Grading of Recommendations, Assessment, Development and Evaluations) framework was used to assess the quality of evidence in each study, based on the likelihood that the effect estimated by the study is similar to the true effect of the intervention[10] (see Appendix 2 for GRADE methodology and definitions). The evidence in

this area was generally assessed to be low or very low quality according to the GRADE framework.

Twelve studies were considered to be at high risk of bias due to their study design ('very low' quality of evidence rating against the GRADE Framework). Half of the studies reviewed were conducted using sample sizes smaller than 1000 and only four of the RCTs we reviewed had sample sizes greater than 2000 people. We also observed substantial variability in the effect sizes for similar interventions. This could be driven by variability in implementation, or due to the fact that the effect of behavioural interventions is highly context specific. Based on existing evidence, it is difficult to be confident about the true effect of the interventions that have been tested and there is ample scope to improve the quality of evidence in this area. That being said, the GRADE framework used in this report presents a tough standard. While there is uncertainty about the magnitude of effects, that doesn't mean there aren't promising behavioural interventions to tackle undervaccination in LMICs.

Due to the fact that very few studies evaluated interventions that drew on behavioral techniques to improve vaccine supply in LMIC settings these studies are described separately. In Section 2 of Part A, the evidence from HICs is summarised, though less comprehensively than evidence from LMICs.

Behavioural interventions to encourage vaccine demand in low- and middle-income settings

Encouraging 'vaccine demand' describes both promoting favourable intentions towards vaccination among potential recipients, and breaking down practical barriers that might prevent or discourage people from receiving vaccinations. These strategies relate to components of the 'Increasing Vaccination Model' offered by Brewer et al.[8]. Interventions that manipulate social processes, and change the way people think and feel about vaccination, act on people's motivations and intentions to vaccinate. Breaking down logistical barriers to vaccination (however small), can increase ultimate vaccine-seeking behaviour.

We identified 28 studies published in the past 10 years evaluating the effect of behavioural interventions intended to increase demand for vaccinations in LMIC settings. Of these studies, half were conducted in South-East Asia (and of these 11 were based in either Pakistan or India), 10 in Africa and 4 in Central America (of which three were in Guatemala). 18 studies were either RCTs or cluster RCTs; 6 studies used quasi-experimental evaluation methods and 4 were pilot studies. Table 3 provides a summary of each study.

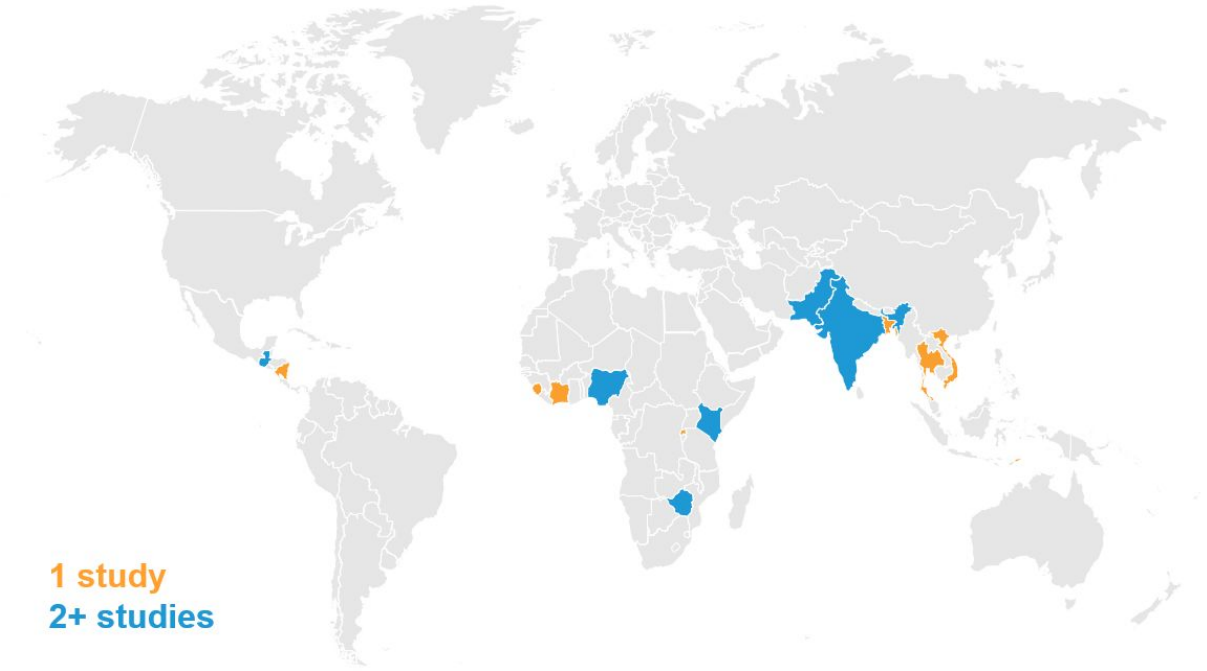


Figure 6: Location of studies investigating the effect of behavioural interventions to encourage vaccine uptake in LMIC settings

Our landscape analysis found that most studies from LMICs published in the past 10 years have evaluated the use of either incentives, reminder and recall messages (in particular taking advantage of the proliferation of mobile phone ownership in LMICs), or improvements to delivery of vaccine education and information to encourage vaccine uptake. A limited number of studies have tested solutions that highlight social norms in favour of vaccination and create social pressure to have infants vaccinated. It is also interesting to note how the focus of research in LMICs has transitioned in the past decade. It is possible to see from Table 3 (which is structured chronologically) that studies published earlier in the decade primarily investigated education and incentive-based interventions, and more recently there has been a cluster of publications evaluating reminder-recall strategies.

Below we describe the existing evidence under four headings:

1. Education and information about vaccines
2. Incentives for vaccination
3. Reminders and recalls for vaccination appointments
4. Using social networks to encourage vaccination

We then give an overview of ongoing research in this area.

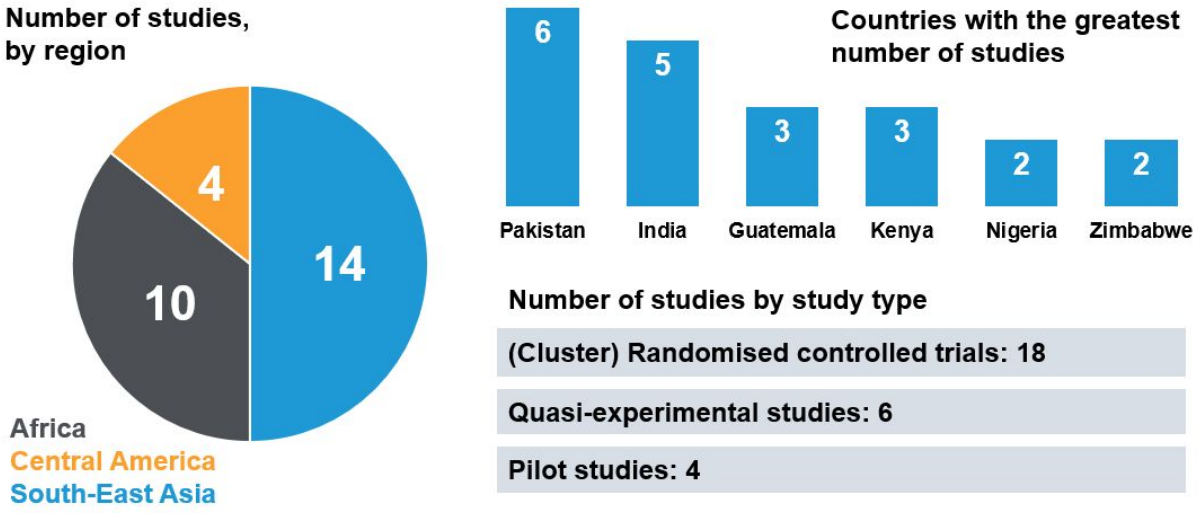


Figure 7: Characteristics of studies investigating the effect of behavioural interventions to encourage vaccine uptake in LMIC settings

Table 1: Studies providing evidence for behavioural interventions to increase demand for vaccinations in LMIC settings (2009-2019)

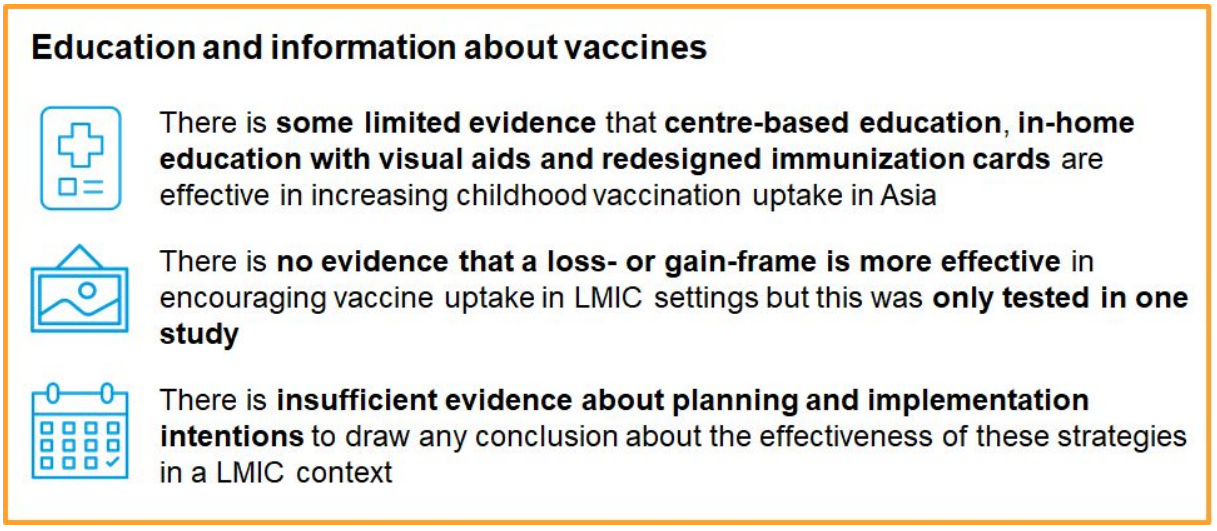
			Reminders and recalls							Incentives			Education and information				Other						
Year	Author	Location	SMS reminders	Reminder phone calls	In-person reminders	Sticker reminders	Recall phone calls	Planning prompts	Redesigned immunisation card	Incentives	Unconditional cash transfers	Conditional cash transfers	Education: visual aids	Education: in person	Education: leaflet	Gain/loss frame	Immunisation provider training	Reliable vaccine clinics	Evidence-based discussion	Social signalling	Study type (sample size, no. clusters where applicable)	Results (primary outcome)	Quality of evidence (GRADE framework)
2019	Domek et al.	Guatemala	Yes																		**RCT** (720)	●	●
2019	Ekhaguere et al.	Nigeria	Yes	Yes																	**RCT** (501)	●	●
2019	Dissieka et al.	Cote d'Ivoire	Yes	Yes			Yes														**RCT** (1596)	●	●
2018	Kazi et al.	Pakistan	Yes																		**RCT** (300)	●	●
2018	Nagar et al.	India		Yes																Yes	**Pilot** (203)	●	●
2018	Karing	Sierra Leone																		Yes	**Cluster RCT** (7482, 119)	●	●
2018	Powell-Jackson et al.	India											Yes	Yes	Yes	Yes					**RCT** (722)	●	●
2018	Seth et al.	India	Yes							Yes											**RCT** (608)	●	●
2017	Nguyen et al.	Vietnam	Yes																		**Pre-post study** (c. 67,000)	●	●
2017	Gibson et al.	Kenya	Yes							Yes											**Cluster RCT** (1600, 152)	●	●
2016	Haji et al.	Kenya	Yes			Yes															**RCT** (980)	●	●
2016	Domek et al.	Guatemala	Yes																		**Pilot** (321)	●	●
2016	Brown et al.	Nigeria		Yes			Yes										Yes				**Cluster RCT** (595, 4)	●	●
2016	Uddin et al.	Bangladesh	Yes																		**Difference-in-differences** (2078, 4)	●	●
2015	Jain et al.	India and Timor-Leste																		Yes	**Pilot** (1411)	●	●
2015	Bangure et al.	Zimbabwe	Yes																		**RCT** (304)	●	●
2015	Busso et al.	Guatemala			Yes																**Cluster RCT** (c.13000, 130)	●	●
2013	Robertson et al.	Zimbabwe									Yes	Yes									**Cluster RCT** (4043, 30)	●	●
2012	Briere et al.	Kenya								Yes											**Pilot** (5894)	●	●
2011	Basinga et al.	Rwanda								Yes											**Difference-in-differences** (2158, 166)	●	●
2011	Usman et al.	Pakistan							Yes					Yes							**RCT** (1506)	●	●
2011	Payaprom et al.	Thailand						Yes							Yes						**Controlled before and after study** (201)	●	●
2011	Owais et al.	Pakistan											Yes	Yes							**RCT** (366)	●	●
2010	Banerjee et al.	India								Yes								Yes			**Cluster RCT** (1621, 134)	●	●
2010	Chandir et al.	Pakistan								Yes											**Longitudinal intervention study** (1500)	●	●
2009	Usman et al.	Pakistan							Yes					Yes							**RCT** (1500)	●	●
2009	Barham and Maluccio	Nicaragua										Yes									**Difference-in-differences** (9986, 42)	●	●
2009	Andersson et al.	Pakistan																	Yes		**Cluster RCT** (5641, 32)	●	●

Results ● = Positive effect (p<0.05) ● = Negative effect (p<0.05) or no significant effect

Quality of evidence (GRADE Framework) ● = Very Low ● = Low ● = Moderate ● = High

Education and information about vaccines

Five studies we identified investigated the effect of behavioural interventions to improve the delivery of key messages about vaccinations in LMIC settings. The interventions focused on making information about vaccines and vaccination appointments more salient and simple to understand. All of the studies testing educational interventions were conducted in South-East Asia, three of them in Pakistan.



Usman et al. tested the separate and combined impact of centre-based education and a re-designed immunisation card on DTP3 completion in Pakistan, first in an urban setting[38] and subsequently in a rural setting[39]. On attendance at an Expanded Programme on Immunisation (EPI) centre for their child's DTP1 vaccination, caregivers in one treatment group received 2-3 minutes of face-to-face education emphasising the importance of immunisation schedule completion and potential adverse health impacts for the child if the schedule was not completed. A second group received a new version of the standard immunisation card, redesigned to provide a more prominent and salient reminder of subsequent immunisation appointments. A third group received face-to-face education and the redesigned card. Both interventions were found to be effective at increasing DTP3 completion at 90 days post-DTP1 in urban and rural settings. The effect size of the interventions was greater in the rural setting (centre-based education relative risk (RR):1.5, 95% CI: 1.3-1.8; redesigned card RR: 1.7, 95% CI: 1.5-2.0[39]) than in the urban setting (centre-based education RR: 1.18, 95% CI: 1.05-1.33; redesigned card RR: 1.25, 95% CI: 1.11-1.40[38]). The combined effect of the interventions was not significantly greater than their individual effects.

Both Owais et al.[40] in Pakistan and Powell-Jackson et al.[41] in India evaluated the effectiveness of in-home education with the support of visual aids. In the Pakistan study, vaccination uptake in infants of mothers who received messages about vaccination from easy-to-understand pictorial cards was compared to uptake in infants of mothers receiving general health promotion messages. Infants of mothers in the visual aids group were 39%

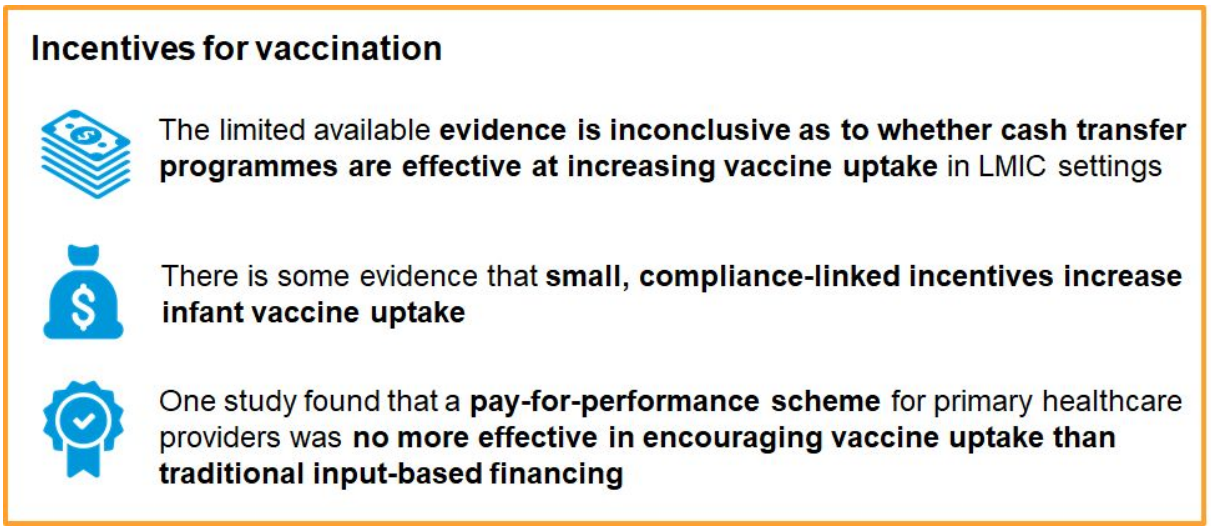
more likely to have completed DTP3 and Hepatitis B vaccinations 4 months after trial enrollment (adjusted RR: 1.39, 95% CI: 1.06-1.81[40]), though this study had high risk of bias.

In India, Powell-Jackson et al.[41] evaluated the effect of providing information about the tetanus vaccine to mothers in their own home. Visual aids were used to help convey messages to illiterate women and mothers were left with an information leaflet at the end of the visit. This is the only study that investigated how message framing impacted vaccine uptake in an LMIC setting. In one treatment group the field workers used a script that framed tetanus vaccination as a 'gain', emphasising that children are less likely to get tetanus and more likely to be healthy if they are vaccinated. In a second treatment group tetanus vaccination was framed as a 'loss' and field workers highlighted that children would be more likely to get ill without the vaccination. Pooled together the treatment groups achieved a substantial increase in the proportion of children that had completed DTP3 after 7 months of follow up (RD: 15pp from a baseline uptake of 28% in the control group, 95% CI: 7pp-22pp[41]). The study found no evidence that either the gain or loss framed message was more effective than the other.

The only study we found that focused on adult vaccine uptake was conducted in Thailand. Payaprom et al.[7] ran a controlled before and after study to investigate the impact of a behaviourally-informed leaflet on the uptake of SIV among adults in clinical risk groups in Thailand. The leaflet was designed to influence perceptions of disease risk by highlighting high risk individuals' susceptibility to influenza and its complications. The leaflet also asked participants to develop a specific plan of where and when they would obtain the vaccination and how they would get to the clinic. 89.9% of individuals in the intervention group received the vaccination vs. 84.3% in the comparison group, but the study was underpowered to find evidence for small effects and the difference was not statistically significant.

Incentives for vaccination

Eight studies evaluated the use of incentives in encouraging parents in LMIC countries to vaccinate their children. Two of these studies evaluated cash transfer programmes that rewarded a range of health behaviours. Five studies investigated the effectiveness of small monetary or non-monetary compliance-linked incentives and one study evaluated the use of a pay-for-performance scheme for primary healthcare providers where childhood vaccination coverage was one of the reward criteria.



Conditional and Unconditional cash transfer programmes

Two studies investigated the effect of conditional and unconditional cash transfer (CCT/UCT) programmes on childhood vaccine uptake with differing results. In Nicaragua Barham et al. used a difference-in-differences (DiD) approach to evaluate the 'Red de Proteccion Social' CCT programme on vaccine uptake in 42 localities[42]. Cash transfers worth approximately $37 were made bi-monthly to households meeting several conditions. Vaccination was not an explicit condition for receipt of the cash transfers but providers were paid to deliver vaccinations during scheduled health visits. DiD estimates indicate that the programme led to a 23pp increase in full, on-time vaccination coverage in children aged 12-23 months in the first year and 15pp in the second year (DiD estimates 1st year: 0.23, 2nd year: 0.15, both $p<0.01$[42]).

Conversely, Robertson et al. found no evidence that CCTs and UCTs increase vaccination uptake based on a matched cluster RCT in Zimbabwe[43]. Clusters of households were randomly allocated to one of two treatment groups or control. Households in the first treatment group were eligible for UCTs and could collect $18 every 2 months plus $4 per child up to 3 children. Households in the second treatment group could receive the same amounts but were monitored for compliance with several conditions including that children in the household younger than 5 must be up-to-date with vaccinations. If conditions were not met the amount of the transfer was reduced by 10%, but this was poorly enforced. Both treatment groups had a small directional increase in vaccination uptake (adjusted risk difference (RD) 3.1pp for UCT, 95% CI: -3.8pp-9.9pp; 1.8pp for CCT, 95% CI: -5.0pp-8.7pp[43]) but the study found no evidence that uptake in these groups was different from the control group.

Small monetary and non-monetary incentives for vaccination

Banerjee et al. ran a large, three-arm cluster RCT in rural Rajasthan, India[44]. Both intervention groups received reliable immunisation services from a mobile immunisation team that conducted monthly immunisation camps in villages at a fixed time. In each village a social worker was also responsible for identifying eligible children, informing mothers about the camps and educating them about the benefits of vaccination. Additionally, parents in one of the intervention groups were offered 1kg of raw lentils per vaccination administered, plus a

set of metal plates on completion of a child's full vaccination schedule. The control group received no intervention, but in all villages the government nurse continued to provide immunisation services for the duration of the study. Both interventions were found to be effective compared to control but the group that were offered the incentives had double the increase in full vaccination uptake (EPI schedule) than was observed in the group that received only reliable vaccination services. (Reliable immunisation RR: 3.09, 95% CI: 1.96-4.21; reliable immunisation plus incentives RR: 6.66, 95% CI: 4.53-8.80[44]).

Two low quality studies conducted in Pakistan and Kenya contribute little to the evidence base on using incentives to encourage vaccine uptake, but provide further examples of how incentive schemes might be implemented. Chandir et al. conducted a longitudinal intervention study in 6 EPI centres in Pakistan[45]. Vaccination uptake in an intervention cohort that received food or medicine coupons worth $2 at each follow-up vaccination visit until DTP3 was compared to a subsequent cohort that did not receive incentives for vaccination. Complete DTP immunisation coverage at 18 weeks of age was twice as high in the intervention cohort compared to the control cohort, but the study design was subject to bias (adjusted RR: 2.20, 95% CI: 1.95-2.48[45]). Briere et al. ran a pilot programme in Kenya where caregivers attending routine immunisation visits for pentavalent vaccine, oral polio vaccine (OPV) and measles vaccine were offered free hygiene kits and education about water treatment and hand hygiene[46]. However, limitations in the study design meant it was not possible to isolate the effect of the intervention on vaccine coverage.

Two further studies found that small compliance-linked incentives sent to participants using mobile phones were effective in increasing infant vaccine uptake. As part of a 4-arm RCT in Kenya, Gibson et al. sent short message service (SMS) reminders to caregivers allocated to all 3 intervention arms prior to scheduled infant immunisation visits for pentavalent vaccine and measles vaccine at 9 months[47]. For each timely dose of vaccination (within 2 weeks of the EPI scheduled date) caregivers in two of the intervention arms additionally received either a small incentive of 75 Kenyan Shilling (KES, 85KES = $1 USD at the time of the study) or a larger incentive of 200 KES, via their mobile phone. The authors found no evidence that vaccine uptake in arms that received SMS reminders only or SMS reminders plus small incentives was different from uptake in the control group. An increase in vaccination uptake was observed in the group that received SMS reminders plus 200 KES (RR: 1.09, 95% CI 1.02-1.16[47]). The effect was driven by an increase in the uptake of measles vaccination at 9 months.

Similarly, Seth et al. ran an RCT in Haryana, India, allocating caregivers to either a no intervention control group, automated phone reminders for vaccination appointments or automated phone reminders plus 30 Indian Rupees of phone talk time per completed vaccination[48]. As in the Gibson study, the trial found no evidence that reminders alone increased vaccine uptake. Some evidence was found that automated reminders with small compliance-linked incentives were effective at increasing immunisation coverage (adjusted RR: 1.09, 95% CI: 1.002-1.19[48]).

Vaccination provider incentives

Finally, Basinga et al. evaluated the use of incentives for primary healthcare providers in encouraging vaccine uptake using a DiD methodology[49]. Endline immunisation coverage at 80 Rwandan health facilities randomly assigned to a pay-for-performance scheme was compared to coverage in 86 facilities that continued to receive input-based financing. Pay-for-performance payments were awarded based on 14 key maternal and child health output indicators, one of which was the number of children that had completed their vaccination schedule. Payments were reduced based on the outcome of a quarterly quality audit. The study results suggest that the pay-for-performance scheme was no more effective than input-based financing at increasing vaccine uptake (DiD estimate: -0.055, 95% CI: -0.184-0.074[49]).

Reminders and recalls for vaccination appointments

Of all the behaviourally-informed interventions to increase uptake of vaccinations in LMICs, most research has been done to evaluate the effectiveness of reminder and recall messages to encourage attendance at vaccination appointments. These solutions have taken advantage of the now widespread use of mobile phones and digital technologies in LMICs. The use of such technology to improve healthcare is called ‘mHealth’ (short for mobile health).

Of 14 studies overall where reminders were a component of the intervention, 6 were in Africa, 5 in South-East Asia and 3 in Guatemala. 13 of these studies tested SMS or voice call reminders using mHealth technology; only one study evaluated in-person reminders. Studies additionally tested sticker reminders, recall messages after missed appointments and primary healthcare provider refresher training. Nine studies found evidence to suggest that reminders are effective at encouraging childhood vaccination uptake in LMIC settings where mobile phone ownership is widespread and vaccine dose monitoring technology is available. The remaining 5 studies did not find evidence for the effectiveness of reminders, though 3 of these studies were underpowered.

Reminders and recalls for vaccination appointments

Reminder and recall messages sent to mobile phones are generally effective at encouraging infant vaccine uptake and on-time infant vaccine uptake

We found no studies from the past 10 years that tried varying reminder message content to investigate which messages are most effective at encouraging parents to bring their children to vaccination appointments.

Reminder and recall messages are an effective component of systems to track vaccine doses within the population

Details of the content and timing of reminder messages tested to encourage vaccine uptake are set out in Appendix 3. Several studies have found SMS reminder messages to be effective in encouraging vaccine uptake. An RCT in Zimbabwe run by Bangure et al. found that SMS reminder messages increased uptake of infant vaccines at 6, 10 and 14 week appointments (RD for receiving third dose of OPV, pneumococcal and pentavalent vaccine at 14 weeks 16.3pp; 95% CI, 12.5pp-28.0pp)[50]. Uddin et al. also found that SMS reminders increased uptake of infant vaccination in Bangladesh, though the study design was subject to bias. The study found that the odds of complete infant vaccination were 3.5 times higher in the two intervention areas compared to the two control areas (95% CI: 1.2-6.1)[51]. In Kenya, Haji et al. evaluated the impact of both SMS and sticker reminders on dropout from the first to the third dose of pentavalent vaccine. The odds of dropout from Penta1 to Penta3 were much lower in the SMS reminder group compared to a control group that did not receive SMS reminders but could look up the scheduled vaccination date in the child's health booklet (adjusted odds ratio (OR): 0.20, 95% CI: 0.09-0.43)[52]. The study found no evidence that giving caregivers reminder stickers to place prominently in their home decreased dropout rates compared to the control group.

In Nigeria, Ekhaguere et al. evaluated the impact of reminders on uptake of all three doses of Pentavalent vaccine and the measles vaccine[53]. The authors did not find evidence that the intervention improved the primary outcome of uptake of all three Pentavalent vaccines at 18 weeks (RR: 1.05, 95% CI: 0.98-1.13) though the estimate was directionally positive. They did, however, observe improvements in secondary outcomes, including the proportion of infants completing measles vaccination at 12 months (RR: 1.12, 95% CI: 1.01-1.25) and completing all scheduled vaccinations within 1 week of recommended date (RR: 1.13, 95% CI: 1.02-1.26). Similarly, a large RCT in Guatemala found mixed results. Domek et al. did not find evidence for a rise in attendance at infant vaccination visits at 4 and 6 months, but an increase in on-time attendance at vaccination appointments was observed in the group that received SMS reminders[54]. More infants presented on the scheduled visit date for both visit 2 at four months (42.2% vs. 30.7%, p = .001) and visit 3 at six months (34.0% vs. 27.0%, p = .05).

An earlier pilot study by Domek et al., also in Guatemala, was underpowered to detect a moderate increase in vaccine uptake. However, the results did show a non-statistically significant rise in the percentage of infants completing both vaccination visit 2 at four months (95.0% vs. 90.1%, p = .12) and visit 3 at six months (84.4% vs. 80.7%, p = .69) in the group that received SMS reminders compared to control[55]. An RCT run by Kazi et al. in Pakistan also observed a directional increase in infant vaccine uptake of 5.3pp in the group that received SMS reminder messages compared to control, but the study was only powered to detect an effect of 20pp or more[56]. Studies by Gibson et al.[47] and Seth at al.[48] (described above in the section on incentives) found no evidence that SMS reminders alone increase infant vaccine uptake compared to no intervention.

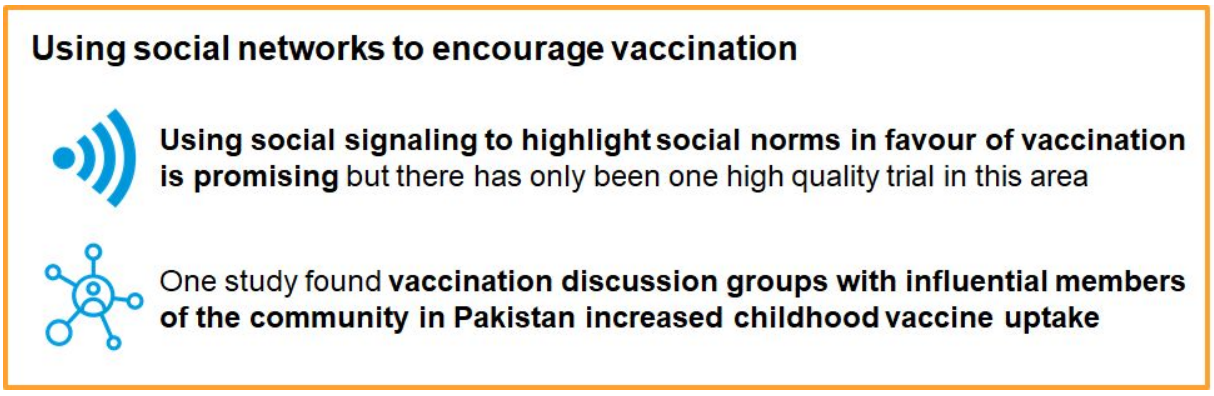
Two studies evaluated both reminder and recall messages. A large RCT by Dissieka et al. in Côte D'Ivoire found that infants of caregivers who received reminder and recall messages by SMS or voice call had a greater odds of receiving all required vaccinations in the first year of life[57]. More than half of infants in the intervention group (60.7%) completed measles, mumps

and rubella (MMR) and yellow fever vaccinations at 9 months compared to 37.8% in the control group (adjusted OR: 4.52, 95% CI 2.84-7.20). In Nigeria, Brown et al. evaluated the effect of voice call reminder and recall messages on completion of routine infant vaccinations alongside refresher training for primary healthcare providers. Both treatment groups that received the phone call intervention had a 70% relative increase in completion of all required vaccinations at 12 months compared to the control group, though the study had a high likelihood of bias (voice call reminders and recall only RR: 1.72, 95 % CI 1.50–1.98; voice call reminders and recall plus healthcare provider training RR: 1.70, 95 % CI 1.47–1.95)[58]. In the group where only healthcare provider training was offered, a smaller increase in uptake was observed compared to control (RR 1.22, 95 % CI 1.03–1.45).

Nguyen et al., Busso et al. and Nagar evaluated the impact of reminder messages as part of a broader solution to encourage vaccine uptake. Nguyen et al. evaluated the introduction of a vaccination tracking system in BenTre province in Vietnam. The web-based application 'ImmReg' allows for the easy registration of pregnant women and children to track vaccination doses, generate lists of those due for vaccination, and send SMS reminders to clients when they need their next dose. Full vaccination coverage for children under 1 year increased substantially from 75.4% pre-intervention to 99.2% one year post-intervention though the results of this uncontrolled pre-post study should be interpreted with caution[59]. In Guatemala, Busso et al. evaluated a similar paper-based vaccine tracking and reminder system. Administrative records were used to generate lists of patients due for preventive health services, including vaccinations. These lists were provided to community healthcare workers (CHWs) on a monthly basis, enabling them to give specific and timely individual reminders to families alongside details of upcoming clinic visits. A large cluster RCT in 130 communities found evidence of a small but significant increase in full infant vaccination coverage among communities that received the intervention (adjusted RD 2.2pp, $p<0.05$)[60]. Reminder messages were also a component of a social signalling intervention evaluated by Nagar. The study is described in further detail in the section on social norms interventions below, but voice call reminders were not found to improve the effectiveness of a wearable pendant in encouraging DTP3 completion[61].

Using social networks to encourage vaccination

Few studies in LMIC settings have explored solutions that take advantage of social processes to encourage vaccination uptake. Three studies conducted in India, Sierra Leone and Timor-Leste have evaluated interventions aimed at making social norms in favour of vaccination more salient. Finally, researchers in Pakistan facilitated discussion groups with trusted members of communities in the hope that they would act as influential messengers to encourage vaccination in their local area.



Karing implemented a large, 4-arm cluster RCT in Sierra Leone to investigate the impact of giving children coloured bracelets at vaccination appointments. In the 'uninformative bracelet' treatment group, parents chose either a yellow or green bracelet for their child at their first vaccination visit which they then retained for all subsequent vaccinations. In a second treatment group, children received a yellow bracelet at their first vaccine appointment which was exchanged for a green bracelet following completion of their fourth required vaccine. In the third treatment arm, the initial yellow bracelet was exchanged for a green one following receipt of the fifth and final vaccine. The study found evidence that all three interventions increased the average number of vaccinations a child received by age 1 compared to a no-intervention control group. Only the intervention where the different coloured bracelet signalled receipt of the fifth and final vaccination resulted in an increase in the proportion of children receiving all required vaccines (RD: 13.7pp, 95% CI: 5.3pp-22.1pp)[62].

Nagar also evaluated the effectiveness of a wearable item signalling receipt of vaccination in encouraging childhood vaccine uptake. In this pilot RCT, vaccination history of infants was recorded digitally on a near field communication (NFC) chip which could be read and updated by a smartphone application. In the control group the chip was stuck on the infant's immunisation card. In the two treatment arms the NFC chip was embedded in a pendant on black thread worn around the child's neck. The black thread had cultural significance to the intervention community indicating protection from evil, and the pendant served as a visible reminder to the community that the child had been vaccinated. One of the treatment arms also included additional voice call reminders when the child was due for vaccination. The pilot was underpowered and did not find evidence that DTP3 completion was higher in either treatment group compared to control (pendant only adjusted RR: 1.57, 95% CI: 0.59-4.20; pendant plus voice reminder adjusted RR: 1.48, 95% CI: 0.5-4.37)[61].

In India and Timor-Leste an intervention called 'My Village My Home' used large posters displayed prominently within communities to record the vaccination status of each child in that community. As above, the intervention was designed to make norms for vaccination visible and create social pressure on parents, community leaders and healthcare providers to ensure all children are up-to-date with vaccinations. Evaluation was only decided upon post-hoc and there was no reliable comparative data so it is difficult to draw conclusions about the effectiveness of this intervention on the basis of this study. However, pilot communities in India had higher uptake of all required childhood vaccinations (80% or above) compared to overall coverage in the intervention districts of between 49%-69%. In

Timor-Leste the number of infants identified rose to 236 from 155 the previous year; the number of infants vaccinated with the third dose of Pentavalent vaccine rose to 185 from 146 the previous year[63].

Lastly, Andersson et al. tested an intervention in Pakistan that encouraged influential messengers within communities to discuss vaccination and create action plans to improve vaccine uptake. In each of the 94 intervention villages a male and a female discussion group was created, with participants selected because they were trusted members of the community. Trained staff facilitated three structured discussions concerning existing vaccine uptake rates, the costs and benefits of childhood vaccinations, and the challenges and barriers to childhood vaccination. The groups were also encouraged to develop action plans to address identified barriers. Children in intervention communities aged 12-23 months had increased odds of being vaccinated against measles (OR 2.20, 95% CI 1.24-3.88) and with all three doses of DTP vaccine (OR 3.36, 95% CI 2.03-5.56)[64]. No difference was observed in polio vaccine uptake between intervention and control communities, but this was almost 100% at baseline.

Using behavioural approaches to improve vaccine supply in low- and middle-income settings

'Vaccine supply' describes establishing sufficient and consistent stock of vaccine doses at point of delivery, as well as accessible and reliable primary healthcare services to administer vaccines. Our landscape review did not identify any standalone interventions focused on changing individual behaviour to improve the supply of vaccines and vaccine services in LMICs. We did, however, find research evaluating vaccine stock-tracking technology systems that drew on behavioural techniques to influence behaviour. These interventions were generally less rigorously evaluated than the demand-side interventions described above, likely because of the greater challenge of assessing changes implemented at the system level.

Three studies evaluated the implementation of digital systems to improve the collection and communication of stock updates at primary healthcare facilities with the aim of reducing stockout incidents. All three studies found that the new technology increased vaccine availability or quality of vaccine tracking data. Ramanujapuram and Akkihal reviewed the implementation of an improved logistics management information system (LMIS) at 29 primary healthcare centres (PHCs) in Karnataka, India[65]. The system involved installing an application on the mobile phones of pharmacists or health workers, allowing simple reporting of transaction data such as stock depletion and replenishment. Cloud-based logistics software consolidated the transaction data for reporting and created alerts for abnormalities in the system, such as stockouts. Alerts were sent to system users by SMS or email and displayed on a digital bulletin board in the area supervisor's office in a post-it note style.

Aside from the technological solution which improved quality of vaccine stock data, the intervention was designed to influence supervisor behaviour. The bulletin board made system abnormalities more salient than they had previously been when supervisors were

required to go into a system to track stock, and the public display was designed to create social pressure for supervisors to act. Alerts included the mobile phone number of the local contact to make it easier for supervisors to take action. The study collected stock transaction data for 9 vaccines for 5 months prior to implementation and 9 months afterwards. Vaccine availability (number of vaccination session days when stock was available), increased to near 99% for all 9 vaccines compared to between 85% - 98% prior to the intervention (no statistical tests were conducted). The researchers also observed an improvement in the time taken to replenish stock following a stockout.

Funded by the Bill and Melinda Gates Foundation (BMGF), Gilbert et al. ran a pilot study in two districts of Uttar Pradesh, India to evaluate the implementation of the same LMIS studied by Ramanujapuram and Akkihal (described above)[66]. In the Uttar Pradesh study, staff at primary healthcare centres additionally received a basic mobile phone for reporting, paper forms to collect data at each vaccination session, and one day of training on how to report data through the mobile-phone application. The study tracked vaccine supply at 39 vaccine delivery centres supplied by two district vaccine stores for 18 months. Stability of vaccine supply remained high during the pilot, but the three lowest performing facilities improved vaccine availability from 91.05% ‘pre-stability’ to 98.70% ‘post-stability’. The average replenishment time post-stockout decreased 52.3% from 4.93 days to 2.35 days.

More recently, a pilot in Zambia tested an mHealth solution that enabled workers at rural health centres to report vaccine stock levels directly to an online platform via SMS messages[67]. Small incentives of mobile phone credit were offered to workers to encourage them to report through the system, and reminder messages were sent either daily or weekly requesting stock updates. Responses were received from users based at 10 of the 21 rural health centres involved in the pilot (48%, 13 unique users). Among the users who sent at least one message to the platform, the percentage-of-doses-tracked was high at 93.8%.

Before going on to discuss continuing research it is worth commenting briefly on the possibility of reporting bias in the behavioural insights literature on vaccine uptake. We have not assessed the evidence for publication bias as part of this landscape analysis. In the most recently published meta-analysis of interventions for increasing vaccine coverage in LMICs Oyo-Ita (2016) concluded that assessment of reporting bias was not feasible as too few studies were included in the meta-analysis[32]. Authors of a subsequent systematic review and meta-analysis of mobile phone intervention to increase vaccine uptake in LMICs concluded the same[30].

Ongoing research in low- and middle-income settings

This landscape review covers studies published in the 10 years to 2019, but research is ongoing to improve and build the evidence base for behaviourally-informed solutions to encourage vaccine uptake in LMICs. Promisingly, several large scale trials are ongoing that should improve the quality of evidence for some of the interventions highlighted in our landscape analysis.

The NGO Interactive Research and Development is currently running two RCTs to evaluate the effect of small compliance-linked incentives and vaccine reminder bracelets on childhood vaccine uptake in Pakistan. The first study is an individually randomised, twelve-arm RCT that has recruited over 11,000 participants and is scheduled to finish in 2020[68]. The study is investigating the effectiveness of small CCTs sent to mobile phones alongside SMS reminders to encourage infant vaccination. The different treatment arms will test variations on the payment amount (up to $15.00 per vaccination), likelihood of reward (certain payment vs. lottery with 20% chance of reward) and payment format (mobile phone credit vs. cash sent via mobile money transfer). The outcome measure is full immunisation with recommended vaccines at 2 years of age. The second study is a 3-arm RCT to evaluate the use of silicon bracelets given to infants as an alternative to traditional immunisation cards[69]. The bracelets are imprinted with numbers and symbols which indicate to parents when their child is due for vaccination. Each time the child comes to a vaccination appointment, vaccination staff perforate a hole in the relevant symbol and the bracelet thereby serves as a vaccination record. Two bracelet designs will be compared against control. This study was due to finish in 2018 but the results have not yet been published.

Separately The Abdul Latif Jameel Poverty Action Lab (J-PAL) has two ongoing studies investigating interventions to increase vaccination. Firstly Banerjee et al. are running a large cluster RCT across 140 PHCs covering 154,000 children under one year in Haryana, India[70]. The trial will evaluate the separate and combined impact of three programs on infant vaccination uptake. Firstly, in a randomly selected half of PHCs, parents will receive small non-monetary incentives worth $0.80 each time their child gets vaccinated and a larger incentive worth $1.60 for their final vaccination. A randomly selected sample of households will receive text message or voice call reminders when their child is due for vaccination with details of when and where they need to go for the appointment. Finally, in randomly assigned villages, trusted members of the community will be asked to disseminate information about the benefits of vaccination and details of upcoming vaccination sessions. The study was due to finish data collection in March 2019.

Secondly, Crowley et al., also affiliated with J-PAL, are running a cluster RCT to evaluate the impact of a mHealth intervention in 151 rural health facilities in Mozambique[71]. The phone application called ‘mVacciNation’ is designed to address issues with both vaccine supply and demand. The application provides a way for health facilities to digitise information about vaccine demand and stock levels. Facilities also receive a warning text when DTP3 stock is running low. Secondly expectant mothers who visit health facilities will be automatically enrolled to receive SMS reminders on upcoming infant vaccination events. The researchers will additionally evaluate the effect of varying the content and channel of messages sent to caregivers on vaccine uptake. As above, the study was due to finish data collection in March 2019.

Four further published trial protocols describe ongoing studies to evaluate mobile phone reminders and small financial incentives to encourage infant vaccination. Ostermann et al. are running a quasi-RCT to evaluate the impact of SMS messages and small conditional incentives in the form of phone credit on infant vaccination in Tanzania[72]. In Western Kenya, Gibson et al. are evaluating the effectiveness of SMS reminders and small, unconditional

financial incentives in improving childhood measles vaccination rates[73]. Kazi et al. are running a cluster RCT to evaluate the effect of both interactive and one-way SMS and voice call reminders for infant vaccination appointments in Pakistan[74]. According to the trial registries all three of these studies were due to finish by the end of 2018 but we were not able to find published results. Finally, in Northern Ghana Innovations for Poverty Action are implementing a small RCT to evaluate the impact of phone reminders and small incentives on vaccine uptake[75].

Research conducted in LMICs represents only a subset of the behavioural insights literature focused on increasing vaccine uptake. To give full context to the landscape analysis of existing evidence from LMIC settings, Section 2 provides a summary of the available evidence from studies in HICs. This summary is less comprehensive than the analysis included in Section 1 but gives an overview of the broad themes and findings from evaluation of behaviourally-informed interventions designed to increase vaccination.

Section 2: Evidence from high-income countries

Much of the research investigating behaviourally-informed interventions to increase vaccine uptake has been conducted in HICs, and in particular the USA and Europe[8]. Vaccine supply is a less prevalent barrier to vaccination in HIC settings compared to LMIC settings: on average between 2011 and 2015 only 14% of national level vaccine stock-outs occurred in HICs though they represent 28% of all countries[76]. For this reason we have focused on summarising evidence for behavioural solutions to encourage vaccine demand. A 2017 paper by Brewer et al., 'Increasing Vaccination: Putting Psychological Science Into Action' provides a comprehensive overview of the existing evidence base for interventions informed by psychology in increasing demand for vaccination[8]. In this section we summarise the key evidence from intervention research in HICs structured according to the 'Increasing Vaccination Model' proposed by Brewer et al. (see Figure 8 below).

Context is key when considering the generalisability of behavioural insights research, and therefore the extent to which evidence gathered in HIC settings might be applicable to LMIC settings. Different populations can respond to behavioural interventions in different ways and the relative importance of behavioural barriers will vary between and within countries. We should also remember that countries do not only vary by income: it is necessary to question (and test) whether interventions that work in one LMIC setting can be effective in other LMICs. That being said, some behavioural interventions have been shown to work across geographies, despite structural and cultural differences. For example, techniques that were effective in encouraging UK citizens to pay their tax on time were also effective at increasing tax payments in Guatemala[23,77].

Important when considering the generalisability of vaccine uptake research is that anti-vaccine sentiment is generally greater in HICs compared to LMICs[78]. Conversely, practical barriers to vaccination and lack of knowledge about vaccination are a greater problem in LMICs. As vaccine-preventable diseases are also more prevalent in LMICs, populations in these countries might respond differently to interventions intended to work by changing perceptions of the risk these diseases pose. Finally, where the majority of research conducted in LMICs focused on childhood vaccination, much recent research in HICs has been trying to encourage uptake of SIV in adults and human papillomavirus vaccination (HPV) in adolescents.

The effectiveness of behavioural interventions to encourage vaccination doesn't only vary geographically. Different strategies are more or less successful depending on the existing knowledge of vaccines and attitudes towards vaccination in the target population. Generally speaking, interventions which seek to bridge the intention-behaviour gap are more effective when people already have favourable intentions towards vaccination[8]. In some cases, interventions that have been designed to prompt people to get vaccinated, or provide information on vaccination, have backfired among individuals that have existing unfavourable views on vaccines[79]. This effect could be explained by the existence of a bias known as 'motivated reasoning', where people will more readily accept information that is consistent with their existing beliefs[80].

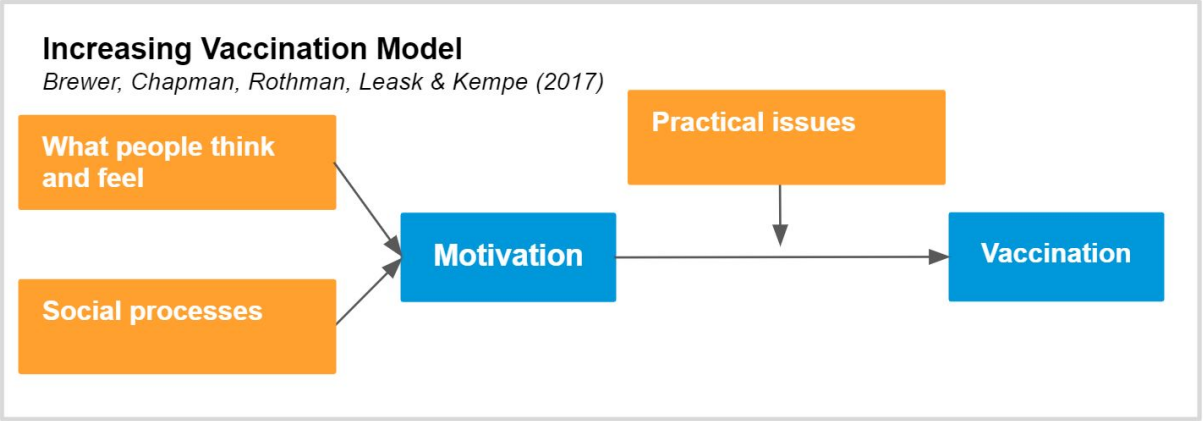


Figure 8: Increasing Vaccination Model[8]

Changing what people think and feel about vaccination

Undervaccination can be both 'active' and 'passive'. Active undervaccination describes people choosing not to receive vaccinations because they are opposed to or concerned about vaccinations and/or the systems that deliver them. Passive undervaccination arises when people fail to receive vaccinations because of ambivalence, uncertainty or logistical issues. Many interventions have been designed to change how people think and feel about vaccines in order to encourage vaccine uptake (the first component in Brewer's model)[8]. Research from HIC settings has shown such interventions to be successful at increasing confidence in vaccines and intentions to vaccinate, but ineffective in influencing ultimate vaccination behaviour[8].

Changing what people think and feel about vaccination

Substantial evidence suggests that **neither 'loss-' or 'gain-' framed are more effective in encouraging vaccination behaviour**

Most studies that have successfully changed the way people perceive the risks of vaccine preventable diseases have not demonstrated any subsequent impact on vaccination behaviour

Evidence suggests that educational interventions to increase childhood vaccine uptake are more effective in LMICs than in HICs. **In general, educational interventions have not been effective at increasing vaccine uptake in HICs**

There is some evidence to suggest that **motivational interviewing has a moderate positive impact on vaccine uptake**

Framing vaccination and anticipated regret

Various researchers have explored the application of 'loss-' and 'gain-' frames to messages promoting vaccination, comparing the impact of emphasising the desirable benefits of being

vaccinated ("gain-framed") to emphasising the undesirable consequences of not taking up vaccination ("loss-frame"). One reason that parents might be more persuaded by loss-framed messages when deciding whether to vaccinate their children is that they feel responsible for protecting their children, and therefore act in order to avoid the anticipated guilt and regret from not doing so. Studies have found evidence that anticipating regret for a decision not to be vaccinated was both associated with receiving vaccination in a meta-analysis of 18 studies ($r=0.27$, $p<0.001$)[81], and greater intention among caregivers to choose HPV vaccination for teenage girls[82].

Despite substantial research on loss- and gain-framed messages to encourage vaccination, the evidence suggests no effect of this framing. A meta-analysis of 32 studies in this area found no difference in the effectiveness of gain and loss framed messages in promoting intentions to vaccinate or vaccination behaviour itself[83]. The same meta-analysis did indicate that loss-framing may be more effective than gain-framing in encouraging people to choose vaccination for others (for example parents on behalf of children). However, only 3 of the 32 studies explored vaccination decisions on behalf of others and there was not sufficient statistical power to provide good evidence for this effect.

Anticipated regret and vaccine risk appraisals

Some interventions have been designed to change risk appraisals, including changing perceived likelihood and severity of disease, or changing negative affect such as worry and fear of disease. A meta-analysis of 5 intervention studies that successfully changed self-reported risk appraisals of tetanus and influenza vaccination had a moderate positive effect on related behavioural outcomes including vaccination uptake ($d = .33$, 95% CI = .21 - .46)[84]. However, these studies represent the minority. Most studies that have successfully changed vaccine risk appraisals have not demonstrated any subsequent impact on vaccination behaviour[8].

Education and information about vaccination

The evidence for the effectiveness of providing education and information about vaccines to encourage vaccine uptake differs between HICs and LMICs. As described above, there is some evidence from LMICs in South-East Asia that in-home or centre-based education, and education using visual aids, is effective at increasing childhood vaccine uptake. A systematic review and meta-analysis from 2015 found that educational interventions to increase childhood vaccine uptake were more effective in LMICs (RD: 0.13, 95% CI: 0.05-0.22)[33]. The same study found that overall educational interventions have not been effective at increasing vaccine uptake in HICs (RD: 0.027, 95% CI: -0.028-0.082)[33]. One possible explanation could be variation in the baseline level of knowledge across these settings; interventions that communicate the importance of vaccines might be expected to have a greater impact in places where existing knowledge of vaccines is lower.

The evidence as to which educational interventions are most effective is inconclusive. A systematic review of 7 studies in both HICs and LMICs concluded that face-to-face education interventions have little or no impact on vaccine uptake, though the available evidence was assessed to be low quality[85]. The same random-effects meta-analysis described in the previous paragraph found that where educational interventions have been successful, they

have generally been delivered through discussion rather than one-way information provision (RD: 0.12, 95% CI: 0.02-0.21)[33]. On the latter point, Brewer et al. argue that the lack of evidence for the effect of providing information about vaccination is not necessarily the result of the communication method, but the messaging itself. They suggest that those designing information interventions have mistakenly assumed that facts are persuasive and that different results might be achieved with messages that appeal to people's emotions[8].

Research in HICs has focused in particular on using education to change the attitudes of vaccine hesitant parents - those who contribute to 'active' undervaccination. A systematic review focusing on interventions to reduce parental vaccine refusal and hesitancy identified 23 studies that evaluated educational interventions, of which 17 tested the impact of written information (the vast majority were conducted in the USA)[86]. About half of the studies that measured parents' attitudes and intentions concerning vaccination reported statistically significant improvements from educational interventions, however the authors of the study reported that they had little confidence in the reported intervention effects. Further, only two studies investigated vaccination behaviour as an outcome and both had a high likelihood of bias.

Beyond just being ineffective, there is some evidence that providing information on vaccines could have a backfire effect among vaccine hesitant parents. An RCT in the USA compared the effect of a range of affective and fact-based messages sent to parents about measles vaccination[79]. None of the four message interventions tested increased intent to vaccinate among a sample of 1759 parents. Worryingly, though a message refuting the claim between MMR vaccine and autism was successful in reducing the mistaken belief that MMR causes autism, it also decreased intentions to vaccinate among parents with the least favourable attitudes towards vaccination (adjusted OR: 0.36, 95% CI: 0.20-0.64). Further, messages containing images of children with vaccine preventable disease were found to increase belief in the link between vaccines and autism, and a message containing a dramatic narrative about a child with vaccine preventable disease was found to increase perceptions of the likelihood of serious side effects from vaccination.

Motivational interviewing to encourage vaccination

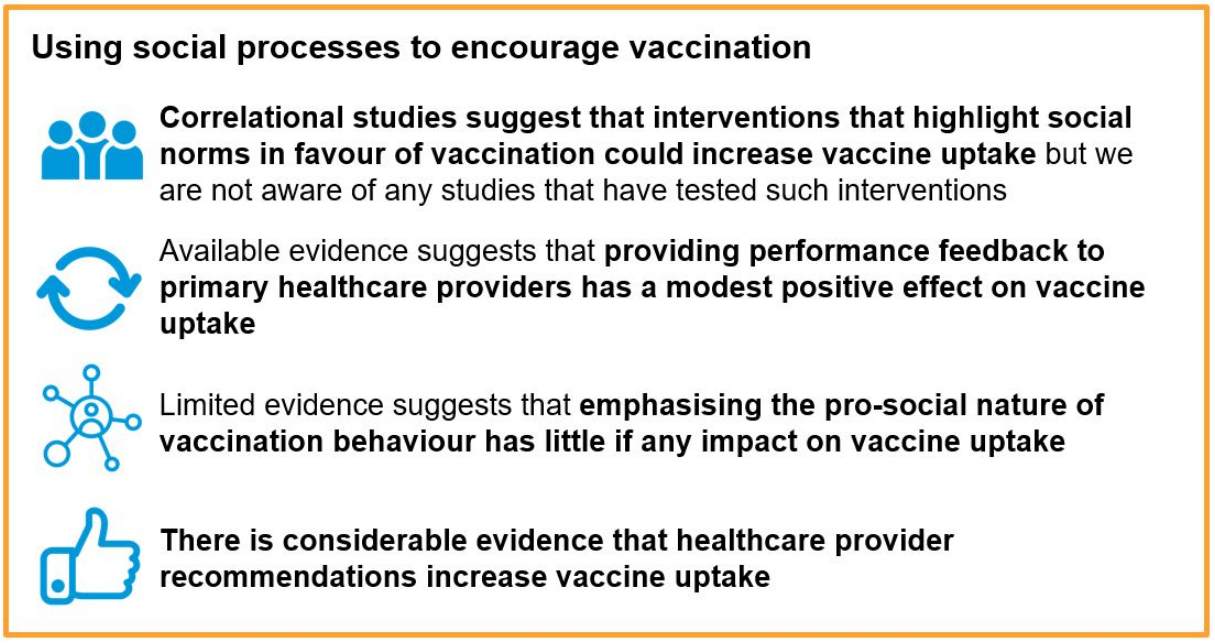
One intervention that builds on the idea of using discussion techniques to change parental attitudes to vaccination is motivational interviewing. This is a resource-intensive strategy designed to strengthen personal motivation to perform a particular behaviour (in this case vaccination) by exploring a person's reasons for change in a collaborative and goal-oriented conversation[87]. A small pilot study in the US tested the use of motivational interviewing techniques to encourage mothers to choose HPV vaccination for their daughters. The results showed a directional increase in HPV vaccine uptake in the treatment group compared to control (56% vs. 51%) but the result was not statistically significant[88].

More recently the 'PromoVac' intervention has been developed in Canada, using motivational interviewing techniques as part of a short, postpartum education session delivered on the maternity ward. A quasi-experimental cohort study in one hospital in Quebec found a small but significant increase in vaccination coverage at 7 months among infants of women who received the intervention compared to a control group (RR: 1.07, 95% CI: 1.02-1.12)[89]. The

intervention has now been scaled up across Canada and is being evaluated in a large-scale RCT[90].

Using social processes to encourage vaccination

The least studied component of the Increasing Vaccination Model considers how social processes influence vaccination behaviour[8]. Beyond inducing immunity in individuals, vaccination works by reducing the spread of disease within a population, thereby protecting those who are unable to be vaccinated, or those for whom vaccination did not trigger an immune response. In this sense, vaccination can be considered a pro-social behaviour which might be encouraged by highlighting the altruistic nature of vaccination. However, lab-based studies have shown that some people might choose to 'free-ride', relying on others being vaccinated to protect themselves[91].



Highlighting social norms to encourage vaccination

Strategies that raise the visibility of social norms in favour of vaccination could be an effective way to encourage vaccine uptake. Correlational studies have demonstrated that individuals who believe vaccination is the prevailing social norm are more likely to be vaccinated, but we are not aware of any intervention studies to date that have evaluated the manipulation of social norms to influence individual vaccination behaviour in HIC settings[8]. In this instance, researchers working in LMIC settings have made more progress in building an evidence base for intervention studies that employ social processes to encourage vaccine uptake. In particular, recent and ongoing research is exploring the use of social signalling interventions that use wearable symbols that highlight social norms in favour of vaccination (see previous section on evidence from LMIC settings for more detail). It is however important to note that such strategies will only be effective where there is a majority favourable opinion towards vaccination; highlighting weak social norms could have a backfire effect.

Healthcare provider performance feedback

Audit and feedback interventions that involve collecting data on clinical performance and presenting that data back to relevant clinicians, have been successfully deployed to improve vaccination rates in primary healthcare facilities. A systematic review of 15 studies (only 5 used randomised, controlled study designs) suggested that audit and feedback may be effective at increasing vaccination rates but any effect is likely to be modest[92]. Based on this early review plus 20 further studies between 1997-2012 the Community Preventive Services Task Force in the US recommends the implementation of provider assessment and feedback programs[93]. More recently a cross-sectional study identified strategies associated with uptake of SIV among 795 general practices (GPs) in England. Identifying a lead staff member to plan the flu campaign and producing a written report of practice performance was associated with 8% higher vaccination rates among individuals aged <65 in clinical-risk groups (OR 1.37, 95% CI: 1.10-1.71)[94].

Emphasising the pro-social nature of vaccination behaviour

Studies have shown limited benefits of emphasising the altruistic nature of vaccination in increasing people's intention to get vaccinated, but with no demonstrated impact on actual vaccination behaviour. One online scenario-based experiment found that among previous non-vaccinators, messages about people who suffered from the flu because their contacts had not been vaccinated increased vaccination intentions (subsequent vaccination behaviour was not measured)[95]. Another study found that adolescent boys were more willing to receive the HPV vaccine if they found it important that the vaccine would protect their future partners[96]. However, compared to control, messaging emphasising the benefits to society of a child receiving the MMR vaccine did not impact on parents' intention to vaccinate[97]. Similarly, an intervention study comparing the effectiveness of a message that vaccination of healthcare workers benefits patients against a no message control found no difference in vaccination uptake between the two groups (though it should be noted that the message was delivered in an optional information session)[98].

Research into the broader influences on vaccination decisions demonstrates that prosocial motives are relatively unimportant compared to other factors in driving vaccination uptake. A systematic review found that between 1% and 6% of parents spontaneously offer 'benefit to others' as the primary reason to vaccinate their children; between 30% and 60% of parents considered this an important factor influencing their decision when prompted[99]. Shim et. al. found that both benefits-to-self and benefits-to-others were associated with the decision to receive a flu vaccination but that self-interest motives were a more important predictor than prosocial motives at a ratio of 3:1[100].

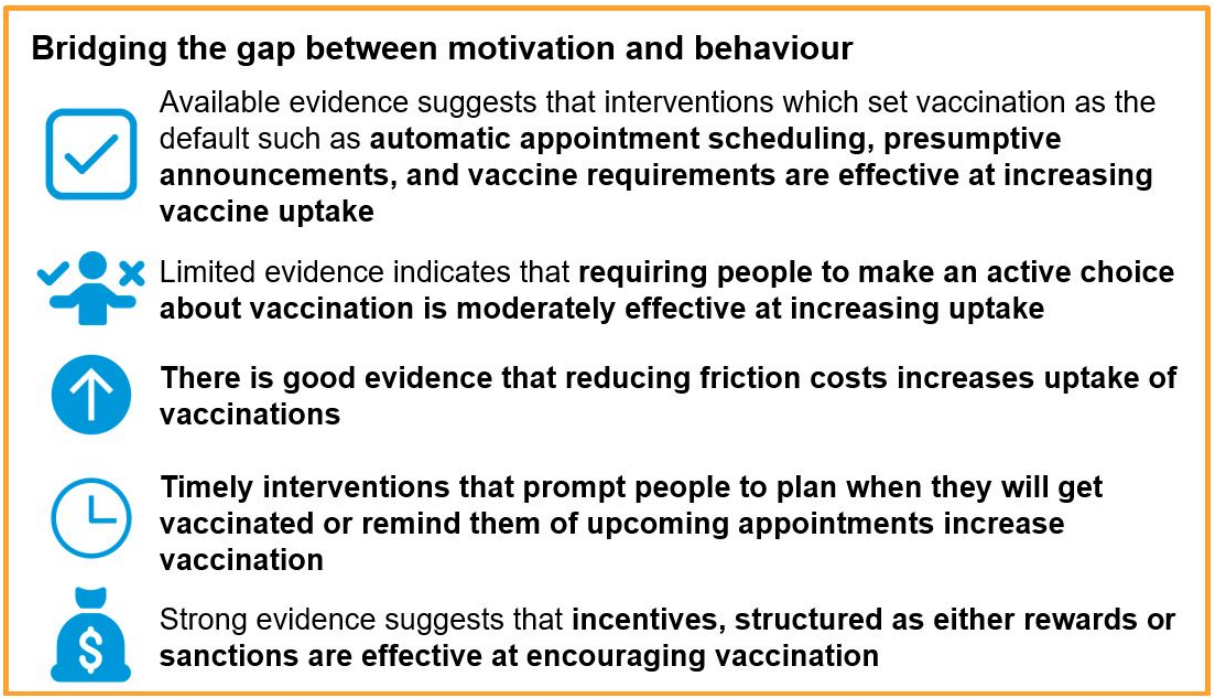
Healthcare provider recommendations

There is considerable evidence that healthcare provider recommendations increase vaccine uptake[8]. In a systematic review of the barriers to SIV uptake Schmid et al. found that individuals who did not receive a direct recommendation from medical personnel were frequently reported to be less likely to vaccinate[101]. Two cross-sectional studies in the US found that among parents who reported having considered delaying or refusing vaccines, the recommendation of a health provider was the most frequently cited reason for getting vaccines as recommended[102,103].

Despite strong evidence in favour of provider recommendations it is not clear why they are so effective. One possible explanation is that the intention-behaviour gap is quite small when the patient is already in the consulting room and the vaccine is readily available (see further discussion of the intention-behaviour gap below). We might also expect that clinicians are trusted messengers that people are happy to rely on for advice about vaccination. However, patients who report feeling less trust in health-care providers are no less likely to get vaccinated following a provider recommendation[8].

Bridging the gap between motivation and behaviour

The most promising evidence for what works to encourage vaccine uptake in HICs relates to interventions that do not attempt to influence people's motivations for vaccination but instead try to bridge the 'intention-behaviour gap'. Such interventions tend to address passive undervaccination among individuals who have existing favourable or ambivalent attitudes to vaccination but ultimately fail to get vaccinated for reasons such as (lack of) convenience and complacency. Strategies that fit into this category include presenting vaccination as the default option, sending reminders and helping people plan how they will get their vaccinations, and providing incentives for vaccination.



Default scheduling of vaccination appointments

One way to set vaccination as the default option is to schedule eligible individuals for vaccination appointments rather than relying on people to arrange appointments themselves. Such an approach has been shown to be effective in increasing vaccine uptake. One RCT randomised people to receive either an email telling them they had been scheduled for a flu vaccination appointment with details of the date, time and location of the appointment and hyperlinks allowing them to change or cancel the appointment, or an email telling them that free flu vaccinations were available with links to a webpage where they could schedule an

appointment. People in the opt-out condition were more likely to be vaccinated than those in the opt-in condition (45% vs. 33%, p=0.0008)[104]. A second RCT replicated this effect and demonstrated that the increase in uptake was not a result of vaccinations being displaced from one setting to another; however this intervention did result in a substantial number of no-shows among patients in the opt-out condition[105].

Presumptive announcements about vaccination

Healthcare providers can use presumptive announcements to create an implicit default that patients will be vaccinated. By using presumptive language such as “We need to do your flu vaccine today” rather than the less definitive “Would you like to get your flu vaccine today?”, providers create a situation where patients must take action and opt-out if they do not want to get their shot. There is evidence from the USA that such an approach is effective at encouraging vaccination. A cluster RCT found that uptake of HPV vaccination in 11 and 12 year olds six months post-intervention was higher in clinics that received training on presumptive announcements compared to a no-training control (5.4% increase in coverage relative to control, p=0.02)[106]. Clinics that received training in open-ended conversations about vaccine uptake showed no difference in vaccine uptake compared to control. Two observational studies found that when doctors used a participatory conversation style to recommend vaccination, patients had higher odds of resisting vaccination and lower odds of accepting all vaccines by the end of the visit compared to when a presumptive announcement style was used[107,108]. Beyond framing vaccination as the default option, presumptive announcements might also be a more effective way of indicating clinical endorsement of vaccines than other styles of recommendation (see the section above on provider recommendations).

Requiring people to make an active choice about vaccination

Studies have shown the effect of omission versus commission bias in the context of childhood vaccinations: omission bias tends to make parents reluctant to vaccinate their child, when the vaccine can cause adverse effects, even if the consequences of not vaccinating the child can be even worse[109]. Two lab-based studies investigated the impact of presenting vaccination as an active choice on individuals’ intention to get a flu shot and their desire to receive a flu shot reminder. Participants in all treatment conditions were told that they could save $50 on their regular health insurance contribution if they received the flu shot. People who were prompted to actively choose were significantly more likely to opt for a reminder to get a flu shot, compared to the group simply offered an opportunity to opt in (72% compared to 45%)[110]. This effect was even stronger when people were prompted with an ‘enhanced active choice’ which highlighted the advantages of getting a flu shot, and the disadvantages of not doing so: “I will get a Flu Shot this Fall to reduce my risk of getting the flu and I want to save $50” (in this context, the saving was because the employer would pay) or, “I will not get a Flu Shot this Fall even if it means I may increase my risk of getting the flu and I don't want to save $50”.

Separately, a DiD study in the US evaluated the impact of incorporating an enforced active choice into the Electronic Health Record (EHR) on the uptake of flu vaccine. During clinic visits with eligible patients, physicians were prompted to actively choose to ‘accept’ or ‘cancel’ an order for the flu vaccine on behalf of the patient. Flu vaccine order rates in one

intervention practice were compared to two control practices that had similar trends in flu vaccination rates in the two years prior to the intervention. The practice where doctors were prompted to make an active choice saw a significantly bigger increase in flu vaccination rates than the control practices in the year post-intervention. (adjusted DiD: 6.6pp, 95% CI: 5.1pp-8.1pp)[14].

Reducing friction costs encourages vaccination

As discussed in the introduction, we are more likely to complete tasks that we find easy. Strategies that reduce the friction costs of getting vaccinated, such as weekend and evening vaccination sessions and walk-in clinics have been shown to increase vaccine uptake[111]. This is reflected in the guidance from the UK-based National Institute for Health and Care Excellence which recommends that access to immunisation services is subject to limited friction costs, for example "by extending clinic times, ensuring children and young people are seen promptly and by making sure clinics are child- and family-friendly"[112]. A study in the UK found that offering people over the age of 75 the flu vaccination as part of a home health check increased uptake by 6.4 percentage points (from 67.9% to 74.3 %), compared to sending out invitation letters for a flu vaccine appointment[113].

The reverse is also true: increasing friction in a process can discourage undesirable behaviours. For example, in the US, (public) schools often require children to be vaccinated before they can enrol, but parents can seek exemptions on medical and sometimes religious and philosophical grounds. In 2011 Washington State implemented a law that required parents to provide evidence that they had participated in counselling on the benefits and risks of vaccinations with a licensed healthcare provider before they could obtain an exemption for their child. Following the introduction of the new law there was a significant absolute reduction in exemptions of 2.9 percentage points (95% CI: -4.2 to 1.7)[114].

Prompting people to plan vaccination

There is some evidence that prompting people to plan when, where and how they will get vaccinated is effective at encouraging vaccine uptake. Prompting people to plan in greater detail is more effective at increasing vaccination. An RCT was used to evaluate the effect of asking employees in a US firm to plan when they would get vaccinated on the take up of SIV in a free onsite clinic[115]. There was no evidence that employees who were prompted to write down the date they would get vaccinated were any more likely to receive a vaccination than the no prompt control group. However employees asked to write down the date and time that they would receive the SIV had a 4.2 percentage point higher vaccination rate than the control group ($p<0.05$).

A further trial evaluated the effect of a prompt to form implementation intentions on rates of hepatitis B vaccination among men who have sex with men (MSM) in the Netherlands[116]. Men who were prompted to form implementation intentions were more likely to receive the hepatitis B vaccination than men who received no prompt (OR: 2.52, $p=0.01$). Further, men with more complete implementation intention plans (with details of when, where and how they would book the appointment) were more likely to receive the vaccination than those with incomplete implementation intentions ($p<0.001$) though it should be noted that men with a stronger initial intention to receive the vaccination were more likely to form complete plans.

We are not aware of any intervention studies in HIC settings that have investigated the effect of an 'implementation intentions' approach to planning. This would involve prompting eligible individuals to make 'if... then...' plans for how they would overcome likely obstacles to being vaccinated.

Reminders to get vaccinated

As in LMICs, reminding people to get vaccinated and sending recall messages to those who have missed vaccination appointments is probably the most studied of all behavioural interventions aiming to increase vaccination in HIC settings. There is good evidence that this strategy works. A Cochrane review of patient reminder and recall interventions to improve vaccination rates included a meta-analysis on 55 studies with 138,000 participants that estimated the pooled risk ratio of 1.28 for this intervention (95% CI: 1.23-1.35, RD: 8%)[117].

The evidence suggests that interventions combining communication methods and enabling easy appointment booking are the most effective. The systematic review mentioned above found that telephone systems that allow patients to schedule an appointment when they receive the reminder are the most effective method of delivering a reminder[117]. A meta-analysis of specifically parental reminder and recall messages to increase childhood vaccination uptake found that a letter reminder is more effective than a telephone call (RD 9.9pp and 4.1pp respectively) but that combined postal and telephone reminders were most effective of all (RD: 11.3pp, 95% CI: 3.3pp-19.3pp)[33].

Priming vaccination

One group of researchers has explored the effectiveness of 'priming' SIV by getting people to complete surveys about vaccination. In one RCT healthcare workers at hospitals in Canada were randomly assigned to receive a questionnaire asking about their attitudes and intentions towards SIV or a no intervention control group. Those in the intervention group were more likely to subsequently receive SIV than those in the control group (adjusted OR: 1.29, 95% CI: 1.01-1.66) but the effect was only observed among those individuals that actually completed the questionnaire[118]. The effect among those that merely received the questionnaire was no different from control. Further, exploratory analysis suggested that the effect was stronger among people with positive attitudes and intentions towards SIV. In a subsequent, 8-arm RCT the researchers investigated the effect of the same intervention on uptake of SIV among adults aged over 65 registered at GP practices in England. Results showed a small increase in uptake of SIV among patients that received a questionnaire compared to those that didn't (OR: 1.13, 95% CI 1.01-1.25)[119].

Incentives for vaccination

Incentives for vaccination can be structured as either rewards for receiving vaccines or sanctions for not receiving vaccines, though the majority of research in HICs has focused on the former.

Studies in the US have evaluated small financial incentives for receiving SIV. In one large study weak evidence was found that offering a $5 gift card to employees alongside a choice of vaccination types increased uptake of workplace SIV (RD: 94.00, p=0.059)[120]. Another

large RCT across 6 US colleges found that a $30 financial incentive was associated with higher rates of SIV uptake among college students (10.7pp, p<0.01)[121]. In the UK researchers found that offering £45 worth of vouchers increased uptake of 3 doses of HPV vaccination among adolescent girls who had not responded to previous invitations to vaccination (OR: 4.3, 95% CI: 1.9-9.6) or had been invited for the first time (OR: 2.14, 95% CI 1.3-3.5)[122].

Several systematic reviews have been conducted to consolidate evidence for the effect of incentives on vaccination uptake. The Community Preventive Services Task Force in the US makes an overall recommendation for the use of individual and family incentives for vaccination based on 7 studies, though only two of these used a randomised and controlled study design[93]. Incentives studied included food vouchers, gift cards and lottery tickets. A separate review specifically searched for studies that evaluated parental financial incentives for increasing preschool vaccination uptake[123]. It found four studies, all based in the USA, that tested the effectiveness of incentives, including sanctions and quasi-mandatory schemes that make access to daycare contingent upon vaccination. The reviewers concluded that there was some evidence in favour of incentives but that it was insufficient to make a recommendation.

Primary healthcare providers could also be motivated using effective financial incentives. A recent UK review of GP practices has found that those entitled to financial reward (via the Quality and Outcomes Framework, a programme of annual financial rewards for GP surgeries) for having reached the target of vaccinating 75% of people aged 65 years against flu were more active in contacting patients and tended to achieve higher uptake rates[94]. For instance, patients received 42% more reminders to attend their vaccination if their GP was to be rewarded via the QOF for completing the vaccination.

Vaccine requirements

Some jurisdictions set ‘vaccine requirements’, mandating that children must have received certain vaccinations in order to access state education or childcare, or for parents to access childcare benefits. Though often referred to as ‘mandatory vaccination’, exemptions are allowed on medical grounds and sometimes it is possible to apply for religious or philosophical exemptions. Without an exemption, parents can still choose not to vaccinate their children but they will be sanctioned for doing so, losing out on key benefits or services. Aside from the threat of sanctions acting as an incentive to vaccination, vaccine requirements also act as a powerful default indicating a strong recommendation from the authorities in favour of vaccination.

The fact that vaccine requirements are implemented at national or state level makes it difficult to conduct rigorous, controlled evaluations. However based on evidence from 32, primarily observational, studies (mostly from the US) the Community Preventive Services Task Force recommends the use of vaccine requirements to increase vaccine uptake[93]. Of the 17 reviewed studies that investigated the impact of requirements on vaccination rates the median change in uptake was an increase of 18 percentage points (IQR: 10pp - 35pp). Studies in the US that have investigated the effect of exemptions on vaccination rates have found that coverage is consistently lower when religious and philosophical exemptions are

allowed compared to when they are not[8]. Increasing the 'friction' involved in obtaining exemptions reduces their use[114].

Table 4: Summary of causal evidence for the effect of behaviourally-informed interventions on vaccine uptake in HIC and LMIC settings

	HICs		LMICs	
Intervention	**Strength of evidence**	**Likely magnitude of effect**	**Strength of evidence**	**Likely magnitude of effect**
Changing what people think and feel about vaccination				
Messages that use gain/ loss framing	●●●	0	○○○	?
Messages that induce anticipated regret/ change disease risk appraisals	●●○	1	○○○	?
Education and information provision about vaccination (incl. visual aids)	●●●	0	●●○	2
Motivational interviewing	●●○	1	○○○	?
Using social processes to encourage vaccination				
Messages including descriptive social norms	○○○	?	○○○	?
Social signalling	○○○	?	●●○	2
Healthcare provider audit and feedback	●●○	1	○○○	?
Messages emphasising the prosocial nature of vaccination	●●○	0 / 1	○○○	?
Messenger effects (incl. provider recommendations)	●●●	2	●●○	1 / 2
Bridging the gap between motivation and behaviour				
Default vaccination appointments	●●○	2	○○○	?
Presumptive announcements	●●○	2	○○○	?
Enforced active choice	●●○	1	○○○	?
Reducing friction costs to vaccination	●●●	2	●●●	2
Planning prompts and implementation intentions	●●○	1	○○○	?
Reminder and recall messages	●●●	2	●●●	2
Priming vaccination (mere measurement)	●●○	0 / 1	○○○	?
Incentives	●●●	2	●●●	2
Requirements	●●○	2	○○○	?

Strength of evidence		Likely magnitude of effect	
	Evidence is substantial/ high quality	2	Likely to have a substantial effect of vaccine uptake
	There is some evidence/ evidence if of moderate quality	1	Likely to have a small/ moderate effect on vaccine uptake
	There is little or no evidence/ evidence is very low quality	0	Likely to have marginal or no effect on vaccine uptake
		?	Evidence is insufficient to estimate the likely effect of the intervention

Part B: Opportunities for future research

Part B of this report outlines opportunities for funding research into behaviourally-informed solutions to encourage vaccine uptake in LMICs. The opportunities outlined are informed by the evidence gaps identified in the landscape analysis set out in Part A. We structure our discussion of funding opportunities around a four part framework (see Figure 9 below). The framework not only categorises funding options, but is designed to support funders to weigh-up different research opportunities in this area.

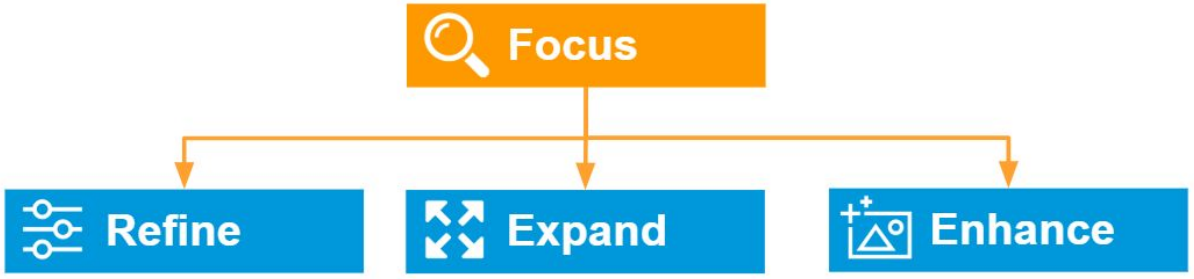


Figure 9: Approaches to funding options

Research funding can be directed towards populations where there is the greatest potential for impact. 'Focus' provides an initial lens for deciding which undervaccinated populations to focus on, with the objective of maximising impact. This could mean people in a particular country, but also populations defined by their existing level of vaccine uptake (e.g. unvaccinated, or undervaccinated), or specific actors, such as primary healthcare workers or those monitoring vaccine supply chains. The inclusion of 'Focus' recognises that behavioural barriers and solutions are to some extent context specific, and that research outputs will not necessarily be generalisable across geographies.

The three remaining parts of the framework describe different approaches to investing in behavioural insights to encourage vaccine uptake:

- **Refine**. Develop behaviourally-informed solutions where there is existing evidence of effectiveness in encouraging vaccine uptake. This would involve refining promising solutions by testing different variants of interventions in similar contexts, or testing interventions (based on those) that have worked in HICs, in LMIC settings.

- **Expand**. Expand the evidence base by funding research into behaviourally-informed solutions that haven't yet been applied to vaccination behaviour in LMIC settings. Interventions that have been effective at encouraging other health behaviours could be newly applied to undervaccinated populations in LMICs. Solutions based on encouraging results from correlational research could be developed and tested.

- **Enhance**. The 'Enhance' approach is suggested where behaviourally-informed interventions are not the central component of a given solution but where there is a role for behavioural insights to play in maximising impact and effectiveness. Options under this approach include applying behavioural insights to improve the effectiveness of new technology, support evidence dissemination, or scale up impactful solutions.

Focus

Focus

Identify target populations where vaccine uptake research can achieve the greatest impact e.g. zero-dose populations, migrant populations, countries with high levels of undervaccination. Invest in research to **describe the relative prevalence of behavioural barriers to vaccination** in target populations.

Funders looking to maximise the impact of their investments should invest in projects where there is the greatest potential to increase vaccine uptake in LMICs. One key dimension that influences the potential for impact is the population being targeted. In some populations vaccine uptake might be particularly low, meaning there is considerable scope to increase vaccination; in certain populations the specific barriers to vaccination might be easier to overcome with behavioural interventions.

The fact that behavioural interventions can be context specific makes 'Focusing' particularly important. A key consideration of the behavioural insights approach is that barriers to desired behaviours, and therefore effective solutions, differ across populations. This is one reason for the emphasis of behavioural insights practitioners on robust evaluation: what works in one population might not work somewhere else. Similarly, what works to solve one problem might not work to solve another, though the underlying behaviours seem similar. An important initial lens to consider when weighing-up research funding options is: 'What populations should we focus on to maximise impact?'. In Table 5 below we set out criteria to consider in defining target populations with the overall aim of increasing vaccine uptake. We also include some key questions that would be valuable to answer (either through desk-based or primary research) to inform where funding is focused.

Table 5: Possible parameters for defining target populations for vaccine uptake research

Parameter	Details
Existing vaccine uptake	Previous vaccination is a strong predictor of subsequent vaccination uptake[124]. The barriers to vaccination among children that have received at least one vaccination can be different from those among children who haven't received any vaccines at all ('zero-dose')[125]. In 2009 the WHO commissioned reviews of both the grey and academic literature to identify barriers to vaccination among both unvaccinated and undervaccinated children[125,126]. It was found that a greater proportion of barriers related to under-vaccination were to do with 'immunisation system' factors (45%), whereas a greater proportion of the factors related to having no vaccinations were linked to 'parental attitudes and knowledge' (42%)[125]. A key limitation of this analysis is that it did not explore the relative prevalence of barriers to vaccination, but it does highlight the

	relevance, at times, of exploring solutions to increasing uptake in these populations separately. Zero-dose children also make up the largest proportion (70%) of the 19.4 million undervaccinated children globally[3]. The WHO is leading the co-creation of the 'Immunisation Agenda 2030'[127]. The current draft is subtitled 'A Global Strategy to Leave No One Behind', clearly emphasising the focus on equitable vaccine coverage. One specific goal of the agenda is to reduce the number of 'zero-dose' children not reached by immunisation programmes. It might make sense to align any investment with global priorities, but it is worth also considering the potential impact of behavioural interventions in these two populations. Our landscape analysis highlighted that changing the way people think and feel about vaccination is more difficult than addressing logistical barriers. If attitudinal barriers to vaccination are indeed more prevalent among parents of unvaccinated children it might be harder to increase vaccination rates among this group. **Key questions:** ● What is the relative prevalence of unvaccinated and under-vaccinated children? ● How do the barriers to vaccination differ between unvaccinated and under-vaccinated children? ● To what extent are barriers to vaccination among unvaccinated and under-vaccinated children amenable to behaviourally-informed solutions?
Reasons for low vaccine uptake	As behaviourally-informed solutions are designed to address specific barriers, it might make sense to define target populations according to the barriers they face to vaccine uptake, for example targeting parents with low vaccine confidence. Such an approach is dependent on having a clear understanding of the barriers to uptake and their relative prevalence. Identifying the prevalence of barriers to uptake is a research opportunity in itself, which is discussed in greater detail below. **Key questions:** ● Which barriers to vaccination are the most prevalent? ● Which barriers to vaccination are amenable to behaviourally-informed solutions? ● Which barriers to vaccination are common across countries/ regions?
Geography	It makes sense to define population units as those that share vaccine delivery systems and policies, for example countries or states. One approach could be to focus on countries where there is the greatest potential for impact: the WHO and UNICEF estimate that just 10 countries account for 60% of the 19.4 un- and under-vaccinated children in the world; a particular focus could be on pockets of low uptake within these countries[3]. Almost half of the studies identified in our landscape analysis were based in India and Pakistan, yet undervaccination is a substantial problem across other parts of South-East Asia and the rest of the world. Funding could also be directed to countries that have seen little research to date, though it should first be considered if there are any barriers, such as lack of political stability, that would make conducting research unfeasible in these settings. It would make sense to build on the strength of existing research centres and strong relationships with governments and vaccination programmes. Funders can help by partnering researchers with organisations that have implementation capacity, making it easier to test interventions and increasing the likelihood that successful solutions are then implemented at a wider scale. **Key questions:**

	• In which countries is there greatest potential for impact by increasing vaccination? • Are there any factors such as humanitarian crises, conflict or lack of political will that might obstruct research being carried out? • Where could funders build upon existing presence or relationships to maximise research impact?
Actor	Different actors influence vaccine uptake in LMICs. The majority of research to date in LMICs has evaluated interventions aimed at parents of children eligible for vaccination. We think there is scope to explore behaviourally-informed interventions that target other actors involved in increasing demand for, and supply of, vaccinations, for example primary healthcare workers, community health workers and supply chain managers. **Key questions:** • Who are the stakeholders involved in delivering successful vaccination programmes in primary healthcare facilities? • How do these stakeholders contribute to the problem of undervaccination? • What behaviours do we want to encourage from these stakeholders?
Vaccine type	The target population will vary depending on the specific vaccines being targeted. In the crudest example, HPV vaccine is targeted at adolescents who might make vaccination decisions for themselves, whereas most other Gavi (Vaccine Alliance) funded vaccines are administered to infants or young children, following a parental decision. The myths and misconceptions associated with vaccination might also vary from vaccine to vaccine. For example, there have been specific concerns in some countries around the introduction of the HPV vaccine as it is given to young girls and prevents a sexually transmitted infection[128]. **Key questions:** • Which specific vaccines are being targeted? • What is the target population for specific vaccines? • What are the barriers associated with uptake of specific vaccines?

When weighing-up which populations should be the focus of research funding, it is useful to identify opportunities that maximise impact and feasibility:

Impact. Investing funds where there is the greatest scope for impact, for example by focusing on countries with the greatest number of undervaccinated children or by funding research in areas that have been neglected by other funders.

Feasibility. Focusing on populations where it is likely easier to improve vaccine uptake. Existing research suggests that it is easier to improve uptake among populations that experience practical barriers to vaccination compared to those who have unfavourable attitudes towards vaccines[8].

'Focusing' should not be understood as merely making decisions about where to invest. There are opportunities to improve the availability of evidence to inform decisions regarding funding of behavioural insights research on vaccines. Much research has been done in recent years to describe the range of barriers to vaccine uptake, including in LMICs[4,129]. However, information on the existence, and importantly the relative prevalence, of barriers to

vaccination in a given context is not easily available.

The recent Wellcome Global Monitor report was useful in quantifying attitudes towards vaccines at country-level across the globe[78]. Ongoing funding to turn this into a longitudinal dataset will be valuable to track (and in turn target) low vaccine confidence where it arises. The WHO BeSD working group is currently developing tools and guidance to identify and track local barriers to vaccination. The tools are expected to be finalised in late 2020 and a valuable contribution would be to fund their implementation to assess barriers to vaccination where required. The outputs of that research will help guide judgements about where to focus subsequent research into behaviourally-informed solutions to address under-vaccination.

Assessment of the global prevalence of barriers to vaccination will help to guide investment, but any individual funded project should also involve exploratory work to clarify the barriers to vaccination in the specific research population. This report necessarily discusses evidence for promising behavioural solutions to vaccine uptake in a relatively abstract way. However, a key principle of the behavioural insights approach is that any solution should be designed to address specific barriers to the target behaviour (in this case vaccination) in a given population. This is also the methodology recommended by the WHO 'Tailoring Immunisation Programmes' approach, which was built on behavioural insights theory[15].

Following on from the 'Focus' stage, we have identified three broad research approaches that funders might consider: 'Refine', 'Expand' or 'Enhance'. Our view is that a funding portfolio might combine elements of all three. Which approach is most appropriate for a given context will be informed by the barriers to vaccination in the target population, the state of existing evidence for encouraging vaccine uptake in the target population, and whether behavioural insights is the central component of the intervention approach.

Refine

Refine

Invest in research to **refine promising behavioural interventions** to improve vaccine uptake and build evidence to support the scaling of these solutions in LMIC settings.

The 'Refine' approach is best where promising solutions exist that work to increase vaccine uptake. Further research can help to refine these solutions and provide sufficient evidence so that they can be incorporated into vaccine policy in LMIC settings. In practice this strategy involves funding large-scale RCTs (or other robust evaluation methods) to test:

- Interventions where there is **causal evidence in HIC settings** but which have not been tried in LMIC settings
- Interventions where there is **some evidence that they work in LMIC settings** but they could be:
    - Further tested in other LMICs to show that they are replicable in different

LMIC contexts

- Refined by testing different variants to identify the optimal solution design

Examples of research that might be funded under the 'Refine' heading include:

- Testing the effectiveness of planning prompts to encourage vaccine uptake in LMICs. Planning prompts have been shown to be effective in HICs but have not been tested in LMICs.
- Studies to refine the message content of reminder and recall interventions. Possible options include testing messaging that draws on social norms or invokes anticipated regret. Research could also investigate the most effective message frequency and communication channel.
- Social signalling interventions are promising, but have undergone only limited testing. There is an opportunity to further test and develop this approach.

Expand

Expand

Expand the range of effective behavioural interventions to increase vaccine uptake by **investing in research into solutions that haven't yet been tried** in the vaccines space.

Our landscape analysis of behavioural insights research on vaccine uptake in LMICs suggests that research coalesces around interventions that appear to be effective, testing different variants of the same broad solution in different populations. For example, since 2015 the majority of research published on vaccine uptake in LMICs has focused on evaluating vaccine reminders using mHealth technologies. This strategy is akin to the 'Refine' approach we described above.

There are however a range of behavioural insights techniques that are commonly used to encourage desired behaviours, but for which there is limited or no causal evidence relating to vaccine uptake. 'Expand' sets out to extend the range of evidence-based, behaviourally-informed interventions to increase vaccine uptake. This approach would consist of investing in research into solutions that haven't yet been tried in the vaccines space and might involve funding small-scale pilot studies prior to larger RCTs.

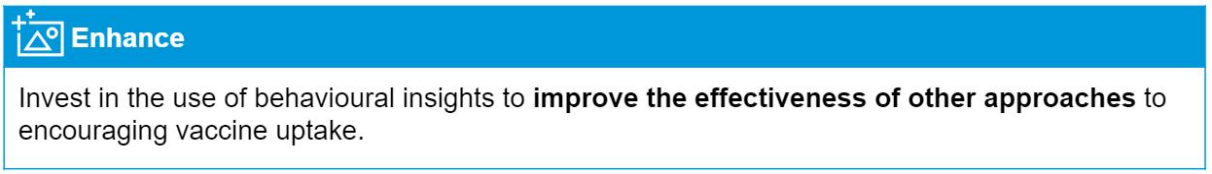
Potential areas of focus under the 'Expand' strategy include the following:

- Our review found very few studies that aimed to increase vaccination in LMICs by changing the behaviour of primary healthcare workers. We think there is opportunity to use behaviourally-informed solutions to increase the performance and reliability of healthcare workers in providing vaccinations for example by providing workers with 'rules-of-thumb' for how to identify and address misconceptions about vaccination within the population.

- There is correlational evidence from HICs to suggest that messages describing social norms in favour of vaccination could be effective at encouraging uptake, but no causal evidence in HIC or LMIC settings. Future research could evaluate interventions using social norm messaging to encourage vaccine uptake.

- Behavioural insights researchers are in the initial stages of exploring ways to tackle the spread of disinfomation online[130,131]. Research could be funded to test behaviourally-informed interventions designed to undermine online disinformation concerning vaccines in LMICs.

Enhance



Finally, 'Enhance' involves investing in the use of behavioural insights to improve the effectiveness of other strategies to encourage vaccine uptake. Behavioural insights is just one of many possible approaches to tackling vaccine hesitancy. Other stakeholders, disciplines and industries are involved in the development of solutions to address the global challenge of undervaccination, notably technology, logistics, communications, policy and implementation science. These approaches all involve elements that seek to influence behaviour. Behavioural insights can be used to inform and enhance the development of solutions to maximise their impact on vaccine uptake.

In contrast to 'Refine' and 'Expand', the 'Enhance' strategy would likely involve support to other research programmes and initiatives rather than investing in primary behavioural insights research. Below we explore areas where we think behavioural insights could add value.

Scaling effective interventions

It is important to consider how much of a role the efforts of a motivated research or implementation team have played in finding a positive impact for a given intervention. What proves efficacious at a small scale might not turn out to be effective at district or national level, particularly when a given solution is heavily reliant on people to implement it successfully. Evaluating the scale-up of interventions that have been found effective in small trials is a key part of the transition from pilot to policy, providing evidence that the administrative burden on an immunisation programme is manageable, and that the impact is sustained beyond a research context[132]. Funding for the evaluation of interventions that are being scaled up could help country vaccination programmes avoid spending valuable resources on initiatives that don't work outside a research context, or speed up the spread of interventions that are impactful at scale. One way to do this is by funding stepped-wedge trials that compare outcomes across e.g. clinics or local districts as an intervention is gradually rolled-out over time.

To maximise the impact of this research, partnerships could be facilitated between researchers and organisations with implementation capacity. In this way, interventions can be evaluated as they are integrated into national or state level vaccination programmes rather than as an adjunct to existing systems. Such an approach will give a realistic estimate of the impact of a given solution. Commitment could be sought prior to the research that if an intervention is evaluated to be successful at scale, it will be funded and sustained.

Addressing barriers to implementation

Related to the above recommendation, behavioural insights research could help to diagnose and offer solutions to bottlenecks or inefficiencies in regional and national implementation programmes. This is traditionally the realm of implementation science, a discipline that aims to facilitate the effective implementation of evidence-based health interventions. The approaches taken by implementation science and behavioural insights are complementary: the two disciplines respectively aim to identify and address barriers to optimal intervention delivery and desired behaviours. We identified a few published studies that use an implementation science approach to improve the effectiveness of vaccination programmes. Bazos et al. ran a proof-of-concept study in Uganda that aimed to develop problem-solving capacity among frontline workers to improve routine immunisation systems[133]. Prinja et al. evaluated planning and management interventions for improving vaccination coverage in rural India though the study was not explicitly informed by implementation theory[134].

Many different theoretical approaches to implementation science exist, but the Consolidated Framework for Implementation Research (CFIR) was created to offer an overarching typology of implementation theories[135]. The CFIR proposes five domains across which barriers to successful implementation might be identified, including 'intervention characteristics', 'characteristics of the individuals involved' and 'process of implementation'. Implementation science does not however set out to understand the underlying psychology of stakeholders involved in implementation, nor does it explicitly seek to describe the behavioural barriers to successful implementation. A behavioural dimension could enhance the implementation science approach. By providing a psychological explanation of the barriers and enablers to successful implementation, behavioural insights could inform the design of more effective and comprehensive solutions within implementation science research.

Spreading evidence-based practice

Behavioural insights can also inform strategies to spread evidence-based interventions. There are behavioural barriers to accessing, interpreting and acting on new evidence. The same strategies that we might use to encourage people to get vaccinated can also be employed to encourage adoption of evidence-based practice. It is not possible here to elaborate all the ways that behaviourally-informed interventions might encourage adoption of new interventions, but we explore a couple of examples below.

Before an intervention can be adopted, there needs to be awareness and acceptance that it is a useful idea. Consideration should be given to how information can be conveyed in the most influential way. One way to do this is by keeping it concise and making it easy for people to understand the impact of the practice. A good example of this is the Education

Endowment Foundation's Teaching and Learning Toolkit[136]. The Toolkit compares interventions to improve teaching outcomes across three simple metrics: cost effectiveness, strength of evidence and magnitude of impact, quantified in terms of months of progress gained. Decision-makers can easily see 'what works' and weigh up key considerations before deciding what to implement. A similar 'one-stop-shop' could detail what works to encourage vaccine uptake. Other useful resources might include a short guide, aimed at those who run vaccination programmes, summarising effective interventions. A good example of such a guide is the one published by the UK Government Equalities Office setting-out evidence-based actions that employers can take to reduce the gender pay gap and improve gender equality[137].

The spread of ideas and behaviours is heavily influenced by social connections[138]. Who you encounter shapes what you come to know, with relationships being critical for obtaining information[139,140]. The importance of networks holds true for the spread of new practices[141]. One famous study showed that uptake of prescribing a new drug occurred most quickly among doctors most integrated into a medical social network[142]. Evidence also suggests that greater intimacy between the source of change (the early adopter or champion) and the recipient increases adoption rates[143], as does greater ease of communication[144].

Funders could invest in creating and facilitating networks to enable sharing of evidence and best-practice in the vaccine community. Remembering the importance of trusted messengers in encouraging behaviour change, it would be valuable for such networks to include researchers from LMICs, country-decision makers and managers of vaccination programmes. Participants can learn about best-practice but also attend as co-creators and advocates of successful interventions. We know that people are more likely to listen to others who are similar to them, both in terms of demographics and behaviours[145]. Those involved in implementing immunisation programmes might be more persuaded by the experiences and recommendations of others in the same position. Other ideas include holding meetings in locations where the research is applicable and focusing on one specific issue at a time.

Improving supply chain technology

The website of TechNet-21 (a global network of immunisation professionals) sets out the Gavi strategy for strengthening the immunisation supply chain[146]. One of the five core pillars of this strategy is 'Data for Management': ensuring that relevant and reliable data is available to decision-makers so that they can take action in a timely manner to improve the performance of the supply chain. The success of Data for Management relies on frontline workers consistently inputting data accurately and on-time, something TechNet-21 identifies as a common challenge. Often primary healthcare workers don't see the value of data collection, considering it to be a chore on top of already high workloads[146]. Reducing the friction to data input, for example by funding technology that does not require consistent access to a mobile network, or that sends reminders to data collectors, could improve the vaccine supply chain.

As described in Part A, designers of technology to track and improve the vaccine supply chain are already incorporating techniques to influence the behaviour of users. Further involving behavioural insights practitioners in the design of supply chain technology could

help improve the collection and communication of data to facilitate supply chain management.

Enhancing vaccine communications

Behavioural insights is concerned with simplifying information and making it easier for people to take action. The same behaviourally-informed techniques that are effective in individually targeted interventions could be used to improve communications around vaccination. For example national or sub-national public health campaigns could use social norms messaging, affect-inducing vignettes or make the negative consequences of non-vaccination more salient to encourage uptake.

In a more specific example, behavioural insights could inform how governments communicate stockouts to make sure that citizens aren't discouraged from accessing vaccination in the future. Each year, one in three WHO member states experience at least one vaccine stockout lasting at least one month[76]. National level vaccine stockouts are experienced by countries of all income groups, but middle income countries are most affected[76]. 86% of national level stockouts lead to district level stockouts, and of these 96% will lead to an interruption in vaccine services. Unreliable vaccination supply could in turn lead to reduced confidence in the health system. Improved communications could help to manage citizens' expectations and increase trust in vaccine services.

Table 6: Summary of funding opportunities

Approach	Opportunity
Focus	Fund research into **describing and quantifying the prevalence of local behavioural barriers to vaccination** using WHO tools.
Refine	Fund research to **refine and build evidence for promising behavioural interventions** to encourage vaccine uptake.
Expand	Expand the evidence base by funding research to **evaluate behaviourally-informed strategies that have not yet been applied to encourage vaccine uptake**.
Enhance	**Scaling effective interventions:** Fund evaluation of the scale-up of interventions for which there is evidence that they encourage vaccine uptake.
	Addressing barriers to implementation: Fund collaborative behavioural insights and implementation science research to improve the effectiveness of implementation programmes.
	Spreading evidence-based practice: Fund the creation of easy-to-use resources summarising available evidence about interventions to encourage vaccine uptake and facilitate effective knowledge networks.
	Improving supply chain technology: Fund behavioural insights support to the design of vaccine supply chain technology.
	Enhancing vaccine communications: Fund behavioural insights support to national vaccination campaigns and communications.

Next steps

One drawback of this report is that it was written without consultation with governments or organisations that make vaccine policy and deliver vaccination programmes. It would be valuable to meet with representatives of national immunisation technical advisory groups (NITAGs), implementing organisations and the WHO to better understand the barriers to implementing evidence-based practice to encourage vaccination. Are these organisations limited by a paucity of cost-effective solutions to encourage vaccine uptake or is it that the

available evidence does not reach the right people in an interpretable and actionable format? Answers to these questions can inform the direction of research in this area.

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Appendices

Appendix 1: Common behavioural solutions

Common behavioural solutions relevant for encouraging vaccine uptake

Solution	Description	Behavioural biases addressed
Defaults	'Status quo bias' helps explain why people demonstrate a strong tendency to stick with the default option. The default is often interpreted as the 'safe' option that has been wisely chosen by the organisation asking the individual to make a choice[147]. By making the preferred option the default we make it more likely that people will either accept or choose it. Vaccination can be presented as the default option in various ways. Vaccination appointments can be scheduled as standard, or vaccination cards issued at birth providing information dates for vaccination in the upcoming years. Healthcare workers can raise the subject of vaccination using a 'presumptive announcement', assuming that the patient intends to be vaccinated. At a national scale, governments can require citizens to receive certain vaccinations, meaning that people need to seek an exemption if they don't want to comply. All of the above examples still give people the option to take action to not be vaccinated in what is described as an 'opt-out' choice.	Status quo bias, intention-behaviour gap
Active choice	The 'active choice approach'[22] can counter the omission bias by showing that a lack of action is itself an active choice, making omission feel more like commission. In other words, instead of offering parents to get their children vaccinated ('opt-in') or telling them their child is scheduled to be vaccinated ('opt-out'), they can be asked to actively choose between: "I want my child to be vaccinated" and "I don't want my child to be vaccinated".	Omission bias, status quo bias
Removing small frictions and simplification	Removing small frictions by making tasks easier and instructions simpler to understand can have substantial impact. Where vaccinations are concerned, this might include offering evening clinic hours for people who work during the day, providing a mobile clinic that visits communities directly, or consolidating vaccine schedules so people need to attend fewer appointments. An alternative approach is to increase the friction costs of behaviours you want to discourage, for example, making it harder to seek a vaccination exemption on philosophical grounds by requiring parents to seek counselling from a licensed clinician before they can apply[114].	Friction costs, intention-behaviour gap

Framing	Framing refers to the way that a decision or behaviour is communicated to people. Evidence shows that framing health-promoting behaviours as resulting in either a loss or a gain can influence the uptake of these behaviours, depending how risky they are perceived to be[148]. Loss framing could be enhanced by evoking 'anticipated regret'. This is the tendency to take into account the possible regret we might feel in the future when deciding between multiple options. We tend to feel more strongly about negative events when we imagine how different the outcome might have been (the so-called 'counterfactual thinking[17]). A message that combines both a loss-frame and anticipated regret to encourage vaccination might ask "Would you regret it if your child got measles because you didn't vaccinate him/her?" or alternatively display an image of a child with measles with a quote from the parents regretting their decision not to vaccinate.	Loss aversion
Incentives	Providing incentives can help to overcome people's tendency to be 'present biased' - the preference to receive payoffs sooner rather than later[20]. In the vaccination context, this means that the present costs could potentially be offset by a reward or incentive, helping the individual to get the vaccination regardless of the perceived costs attached to it. Lotteries can be a particularly cost-effective form of incentive. People tend to overestimate the likelihood of small probabilities, meaning lotteries can generate disproportionate interest in relation to the value of the prize. Incentives can be either extrinsic (for example a financial reward), or intrinsic, which refers to the internal reasons people have for taking up certain beneficial behaviours. Some studies have found that providing extrinsic motivation can crowd out intrinsic motivation, though current evidence does not conclusively show that this is the case for health behaviours[149]. Tests using extrinsic motivations should evaluate whether there are backfire effects and get ethical review to assess any risks of coercion.	Present bias, intention-behaviour gap
Highlighting social norms	Behavioural scientists often invoke social norms to encourage behaviour. In fact, one major explanation for why vaccination rates are relatively high within the non-mandatory system is the strength of these social norms[150]. On the other hand, survey evidence from parents in the US suggests that the factor most predictive of parents' vaccination decisions is the percentage of parents' social network recommending nonconformity with the vaccine schedule[151]. Interventions based on letting people know when they fail to follow the social norm have proved highly effective in encouraging behaviour change in many contexts such as tax collection, charitable giving and energy consumption[23].	Conformity
Highlighting pro-social behaviour	Highlighting the reciprocal nature of certain behaviours can influence people to take action. For example, an RCT found that the following wording, emphasising reciprocity, was the most effective at encouraging people to register as organ donors: "If you needed an organ transplant would you have one? If so, please help others"[152].	Conformity

	By getting vaccinated individuals reduce the likelihood that they themselves will get ill, but they also protect others by reducing the likelihood that a pathogen will circulate within the community. Highlighting the altruistic, prosocial nature of vaccination could encourage uptake; however, there is a risk that this strategy may result in 'free-rider' effects. This happens when individuals decide to 'free-ride' on the protection provided by others being vaccinated but don't incur the costs of vaccination themselves[91].	
Messengers	People tend to weigh information based on where it originates and who communicates it. We are affected by the perceived authority, whether formal or informal, of the messenger. For example, there is evidence that people are more likely to act on information if experts deliver it. One study found that health interventions were more effective at bringing about behaviour change when these were delivered by research assistants and health educators compared to trained facilitators and teachers[21]. Encouraging healthcare providers to be expert messengers of information and recommendations concerning vaccines is likely to be effective. The exception to the effectiveness of expert messengers will be when individuals do not trust healthcare workers and/or the health system. In such a case trusted messengers such as peers or religious leaders might be more impactful.	Conformity
Timely prompts	Timely prompts that remind people to do something at a moment when they are in a position to take action have been shown to be effective at changing behaviour[23]. Reminder and recall messages are examples of timely prompts, but subtle cues can also be impactful. Our behaviour is influenced by the ideas and objects we are exposed to from moment to moment, often subconsciously[153]. An example of this is the 'question-behaviour effect' (also known as the 'mere-measurement effect') which demonstrates that merely asking people about a particular behaviour influences their subsequent actions.	Present bias, intention-behaviour gap
Planning and implementation intentions	Behavioural research has shown that prompting people to make concrete plans that specify when and where a behaviour will take place can increase the likelihood that the behaviour will be carried out[155]. An extension to this strategy is called 'implementation intentions' which asks people to make 'if… then' plans, identifying possible obstacles to the target behaviour and how they will be overcome[156].	Present bias, intention-behaviour gap

Appendix 2: GRADE Quality of Evidence Framework

GRADE Quality of Evidence Framework, taken from Guyatt et al. (2008) GRADE: An emerging consensus on rating quality of evidence and strength of recommendations[10]

Evidence certainty	What it means
Very low	Any estimate of effect is very uncertain
Low	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Moderate	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
High	Further research is very unlikely to change our confidence in the estimate of effect

Appendix 3: Content and timing of reminder and recall messages from studies in Part A, Section 1

Content and timing of reminder and recall messages sent to mobile phones

Author	Location	Details of reminder message	SMS	Voice	Reminder/ recall schedule
Bangure et al.[50]	Zimbabwe	"Immunization protects your child against killer diseases such as polio, whooping cough, diphtheria, measles, pneumonia and tuberculosis. You are reminded that the vaccination appointment will be due in -- days time from today."	Yes	-	7, 3 and 1 days prior to scheduled appointment.
Brown et al.[58]	Nigeria	No detail provided.	-	Yes	Reminder phone calls 2 and 1 days prior to vaccination appointment. Up to four recall phone calls following a missed appointment.
Dissieka et al.[57]	Côte D'Ivoire	Messages in the caregiver's preferred language told recipients to take their child for immunisation in 2 days to protect the child's health	Yes	Yes	One reminder message prior to each scheduled appointment. One recall message 3 days after missed appointment, final recall message 2 days before the next scheduled appointment.
Domek et al. (2019)[54]	Guatemala	"Your child [autopopulate child's name] is due on [autopopulate date] at [autopopulate clinic name] for vaccines."	Yes	-	3, 2 and 1 days prior to scheduled vaccination visit.
Domek et al. (2016)[55]	Guatemala	"Your child [autopopulate child's name] is due on [autopopulate date] at [autopopulate clinic name] for vaccines."	Yes	-	6, 4 and 2 days prior to scheduled vaccination visit.
Ekhaguere et al.[53]	Nigeria	Text reminder in English read: "Reminder from MCH–Your baby's next immunisation visit is in 2 days [or 1 day as appropriate]. Immunisation protects your child against killer diseases. Please bring your baby for this visit." The automated call reminder was in English or Yoruba.	Yes	Yes	Reminder messages 2 and 1 days before scheduled vaccination visits.
Gibson et al.[47]	Kenya	Reminder messages were in caregiver's preferred language: English, Kiswahili, or Dholuo	SMS	-	Reminder messages 3 and 1 days prior to

					scheduled immunisation visits.
Haji et al.[52]	Kenya	Messages told caregivers the appointment date and which health facility to attend	Yes	-	One reminder message 2 days prior to scheduled appointment, one further message on the day of the appointment
Kazi et al.[56]	Pakistan	Message in caregiver's preferred language read: "[Child name] is due for 6-week vaccination immediately take your child to the nearest EPI center."	Yes	-	Four reminder messages in the week prior to the date the child was due to receive vaccination
Nagar[61]	India	Voice call reminders were in local dialect.	-	Yes	Reminder voice messages the day before and the day of scheduled immunisation camps. Thank you call or 'missed camp' message after the scheduled date.
Nguyen et al.[59]	Vietnam	No detail provided	Yes	-	Reminder SMS prior to scheduled vaccination
Seth et al.[48]	India	Reminder messages were in Hindi	Yes	-	No detail provided
Uddin et al.[51]	Bangladesh	Messages reminded mothers to take children to sessions at appropriate times. Where mothers were illiterate, messages used symbols taught to mothers at registration.	Yes	-	One message 1 day prior to a scheduled EPI session, one message at opening time on the day of the session and a final message 2 hours before closing time