Integrating Behaviour Change Theory into mHealth Innovation

About this report:

 We aim to evaluate the potential use of behaviour change theories in text messaging interventions that aim to increase immunization uptake in low and middle income countries. Medic Mobile is a non-governmental organisation specialising in mHealth, with focuses that include antenatal care, childhood immunisations and disease surveillance. It provides a platform based on SMS messaging that co-ordinates and connects patients, community health workers and health centres, and is used by over 9000 health workers in 20 countries across the world. MedicMobile has been instrumental in vaccination programs in many countries, and in 2014, 140000 children were reached by immunisation programmes in Bangladesh, India, Kenya and Nepal using Medic Mobile technology (MedicMobile; 2015). Medic Mobile prides itself on using human-centred-design, where interventions are tailored to suit the needs of the recipients, and interventions are not currently designed based on theoretical models: incorporating such models into the design process could bring a useful additional perspective . We hope to identify those theories that appear most useful and best equipped to most relevant behaviour change theories and bring this together with the current and changing face of mHealth.

Introduction:

 mHealth, the diverse use of mobile phone technology in healthcare, is a rapidly and relentlessly developing field. In 2011, it was reported by WHO that 83% of member states offered some kind of mHealth service, with the 4 most reported initiatives being Health Call centres (59%), emergency telephone services (55%), disaster management (54%) and mobile telemedicine (49%) (Reichenbach et al., 2011). Although there was shown to be more mHealth activity in higher income countries than lower income countries, mHealth may have enourmous potential in low and middle income countries. WHO reports that mHealth interventions could provide improved access to knowledge and information, improved service delivery and reduced response time to crises (Reichenbach et al., 2011). mHealth interventions have the potential to grant increased accessibility to quality healthcare for patients, reduced costs, greater potential for monitoring of a patient's condition, and increased social networking availability for clinicians to allow a higher quality care (Attune, 2013).

 A significant number of mHealth interventions to date have been largely based around the use of SMS messaging to provide information to the public and send reminders. A few notable success stories include Project Masileluke that commenced in South Africa in 2009 that involved 1 million messages with 'please call me' being sent every day for a year to the public. The number the messages were sent from was the number for the national AIDS helpline in Johannesburg, and this intervention helped triple the average daily caller volume (National Geographic, 2015). Another example would be the work of the charity MAMA, or the Mobile Alliance for Maternal Action, which operates in South Africa, Bangladesh and India (Mobile Alliance for Maternal Action, 2015). This group sends SMS reminders to new and expectant mothers to advise on and promote healthy behaviours. The evidence-based, culturally sensitive mobile messages are being downloaded and used by 161 organizations in 54 countries around the world (Mobile Alliance for Maternal Action, 2015). There has been a call for mhealth interventions to be more evidence based, however, not only because these interventions are more successful in the long term but because decision makers in low, middle and high income countries all face a confusing diversity of mHealth products, leading to a higher demand for supporting evidence. Currently the WHO mTERG group reviews evidence and technical data to identify strategies for which there is substantial evidence of value to the health system, again highlighting the demand for evidence based interventions (WHO, 2015).

 Currently there are 7 billion mobile phone subscriptions worldwide, although in the least developed countries there are 89 million internet users out of a population of 940 million equating to a penetrance rate of only 9.5% (International Telecommunication Union 2015). A survey of 168,231 women in Bangladesh in 2012, however, found 71% household ownership of phones, and in 25% of cases family members would use the phone to contact emergency health services. The same study found that only 23% had access to electricity. Thus mHealth shows promise as an effective way of

reaching the most distant communities (Labrique, 2013). A second survey showed than in some less developed countries like Botswana, Kenya and Nigeria, more than 50% of those earning $1 a day or less owned mobile phones (Naef et al., 2014).

Studies have suggested that behaviour change interventions led by behaviour change theory are more successful than those that are not (Connor & Norman, 1995). A paper published in 2008 showed that one third of the193 health behavioural interventions assessed reported using theory in their design (Connor & Norman, 1995). Interventions were more commonly developed, evaluated and reported without an explicit theoretical framework.. This paper focuses on the ability of text-message based interventions to change patient behaviour, in particular to increase uptake of childhood vaccinations, by examining the ways in which studies have utilised ideas grounded in behaviour change theories, the most prominent of which are explained below. In the following section we review a few of the most prominent Behaviour Change Theories, before discussing their application in a number of rigorously evaluated mHealth interventions for strengthening immunization programmes.
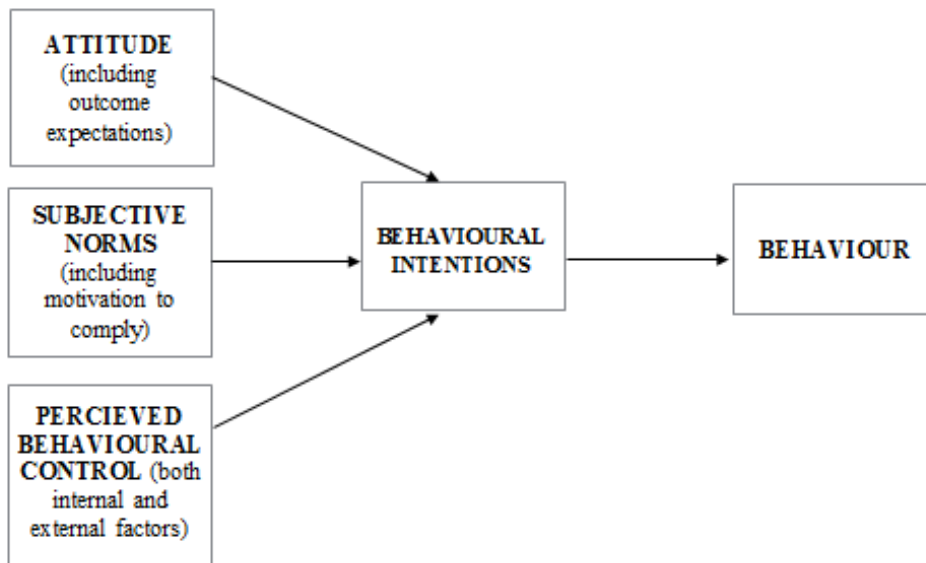
Key Behaviour Change Theories:

The following behaviour change theories are models that attempt to explain why certain behaviours occur by understanding the factors that contribute to them.

The **Social Cognitive Theory** is centred around reciprocal determinism: the idea that a person's behaviour, such as their adherence to a vaccination program, affects and is affected by a diverse range of environmental, personal and behavioural factors (Connor & Norman, 1995). One of the most important personal factors is the concept of **Self-Efficacy**, sometimes considered a behaviour change theory in its own right. Self-Efficacy is defined as one's self belief in their ability to perform an action, for example an individual's belief that they can remain adherent to a vaccination program, and is enhanced through personal accomplishment, vicarious experience and verbal persuasion. Another important concept in the Social Cognitive Theory is action outcome expectancy, the expected effect of pursuing certain actions, for example what an individual expects to result from a course of vaccination. These two factors strongly influence an individual's intention to act, thus affecting whether a behavioural change will occur or not. This model has been useful in designing public health interventions partly because of the inclusion of socio-structural factors, or as aspects of the environment that facilitate or impede behavior (Connor & Norman, 1995). Some examples of socio-structural factors we came across include community perceptions of health workers or trust of vaccination programs.
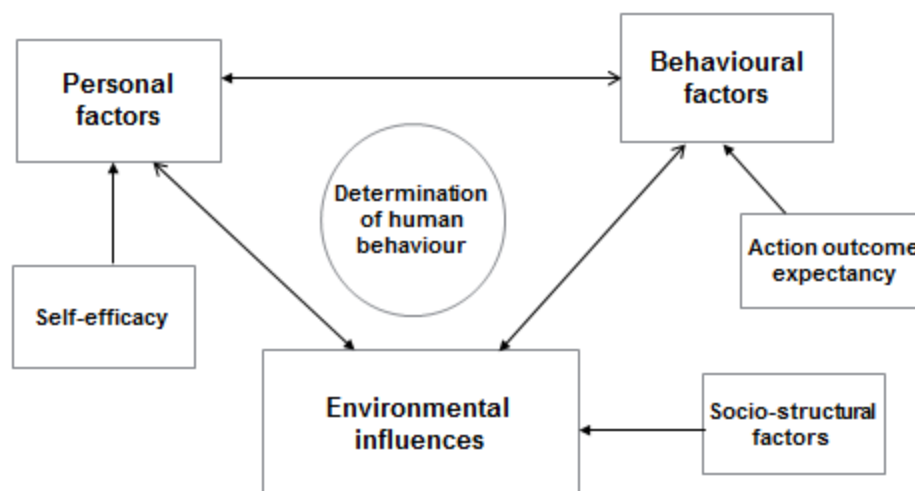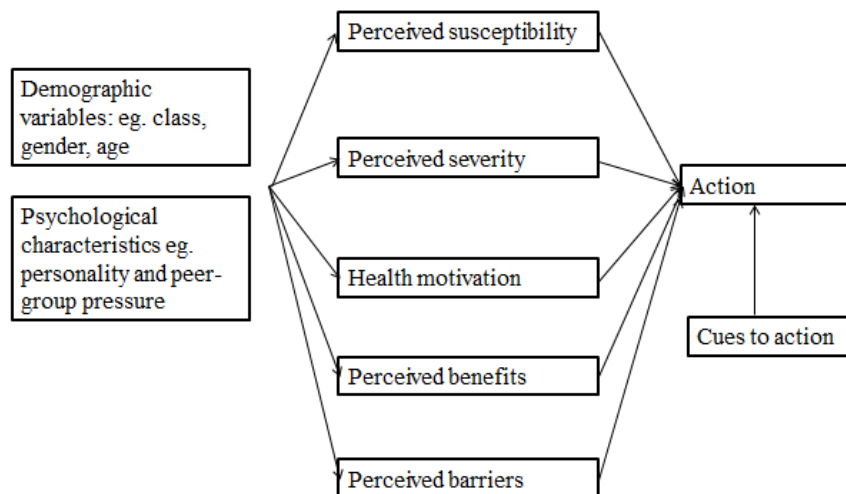

The **Theory of Planned Behaviour**, widely used in relation to health, states that one's attitude towards a behaviour, in this instance receiving a vaccine, depends on social pressures and a self evaluation of the behaviour, both of which are affected by an individual's knowledge of the vaccination program and of its potential benefits or risks. Behavioural

intentions are amalgamations of prior beliefs, and are the immediate cognitive precursors to behaviours. The Theory of Planned Behaviour also includes the construct of 'perceived behavioural control', which is a result of an individual's opinion on how easy or difficult performance of the behaviour is likely to be. For example, how the individual's belief in themselves, and the support systems around them, contributes to their forming an opinion as to whether or not they can follow a course of vaccines. It affects not only behavioural intention but can affect an individual's behaviour directly. Perceived behavioural control has been described as similar to Self-Efficacy with the addition of internal and external control factors exerting a cognitive force (Connor & Norman, 1995).

ATTITUDE (including outcome expectations)

SUBJECTIVE NORMS (including motivation to comply)

PERCIEVED BEHAVIOURAL CONTROL (both internal and external factors)

BEHAVIOURAL INTENTIONS

BEHAVIOUR

The **Health Belief Model** is arguably a collection of associated variables that together have been recognised to change behaviour (Connor & Norman, 1995). Enduring individual characteristics, including demographic and psychological factors, influence the extent to which a person perceives the severity of a threat, their own susceptibility to that threat, and the benefits of and barriers to performing an action that alleviates that threat, The model also incorporates their overall motivation to, for example, improve their health. Through adressing these variables a person can recognise a potential threat and effectively evaluate ways to counteract it (Connor & Norman, 1995). According to the model, while the variables predict the action the individual deems most appropriate, "cues to action" are important to trigger the behavior itself.

Demographic variables: eg. class, gender, age

Psychological characteristics eg. personality and peer-group pressure

Perceived susceptibility

Perceived severity

Health motivation

Perceived benefits

Perceived barriers

Action

Cues to action

(adapted from Connor & Norman, 1995, p.28)

The **Transtheoretical Model** includes stages of change which, unlike other models, introduces a temporal dimension. There are 5 stages:

1)   pre contemplation- i.e. being approached to have a vaccination
2)   contemplation- finding out more about the vaccination and
3)   preparation/determination- deciding on whether to take a vaccine course or not and taking steps to allow that to happen
4)   action- undergoing the course of vaccinations
5)   maintenance- ensuring that one keeps up to date with the course and does not miss any vaccines

Recently a 6th stage, termination, where there is 100% efficacy and the individual will maintain the behaviour in the long term, has been introduced. This model is useful because people at a similar stage face similar problems and can therefore be helped by the same kind of interventions. This model allows an insight into how behavioural change can be facilitated, and was described by Zimmerman in 2005 as 'having the most comprehensive component set', in that it addresses multiple stages in the decision-making process.

However, movement through these stages is rarely linear. Regression is common, for instance, if an individual has the first of a series of vaccines but does not take the rest of them. Equally, an individual in the pre contemplation stage may be spurred into action immediately if presented with information about the health benefits of a vaccination programme or pre-natal monitoring by community health workers. This demonstrates the fluidity and overlap between the 5 stages. In addition to this, a stage is unlikely to reflect a specific cognitive reality, and people move through the stages at different rates, so this means the model is most useful when not rigidly applied (PRIME Education, 2015).
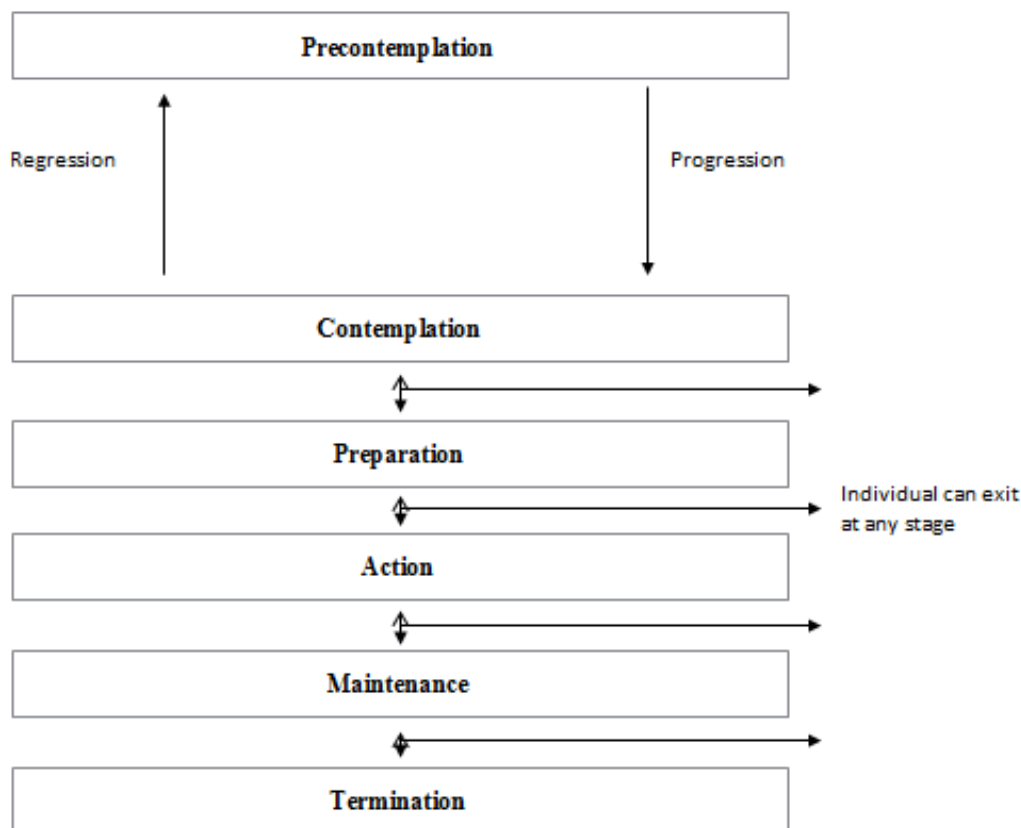
The **Information-Motivation-Strategy Model** is simple and generalizable, and when applied clinically can be a useful tool for targeting patient needs and focusing on contributing factors essential to, for example, vaccine adherence. The

flexibility of the model is one of its greatest strengths- it can incorporate new beliefs into the main three components of the model as they arise. These three main components are:

1) Information: a patient must know what change is necessary. Information includes concepts such as the patients existing beliefs about effective management strategies, their knowledge of the disease and of its development, or the side effects of the treatment.
2) Motivation: a patient must have the desire to change their behaviour. This incorporates a patient's attitudes towards adherence, their feelings about treatment, their confidence in treatment's success, perceived social support and subjective norms about how others with this condition would behave.
3) Strategy: if a patient is sufficiently well informed and motivated to follow a certain course of treatment, they must have the necessary tools to achieve and maintain the change. Resources like money, time, the support of loved ones and social support or other self-regulation strategies all fall within this bracket, and are vital for long term adherence. Thus we see that information is itself a prerequisite, but with insufficient motivation information alone is insufficient to achieve behavioural change. By increasing both information and motivation, and presenting a patient with strategies, we can increase the likelihood of adherence (Connor & Norman, 1995).

A frequent criticism common to all of the discussed theories is that they fail to some degree to incorporate the significance of the plethora of environmental, social and economic factors in decision making. The theories may also fail to take irrational or non-conscious determinants into complete consideration. However, as basic models these theories can provide a basis by which behaviour may be successfully predicted. "Importantly, behaviour change theories need not be used in isolation. For example, they might be used alongside iterative, participatory or user-centered methods that address some of the limitations of theory-based approaches to intervention design. It is also noteworthy that meta analyses of the effectiveness of the theories have been difficult, because models are applied differently and different data sets are obtained.

Summary

Having highlighted these key Behaviour Change Theories, we hope to identify those theories that appear most useful and best equipped to inform SMS-based mHealth interventions aiming to improve immunization uptake. We aim to approach this by analyzing the use of these models in recent mHealth innovation, and we will discuss how such interventions have the potential to seriously improve health in low and middle income countries.

Methods:

After generation of keywords we performed a review of the white and grey literature documenting specifically the results of text message based interventions that aimed to improve immunisation uptake. In analysing these documents particular attention was payed to studies of interventions conducted in low and middle income countries. Key search terms in our quasi-systematic review included those linked to text messaging, for example "text", "message" and "SMS", those associated with immunisation such as "immunisation", "vaccination" and "uptake", and "low"/"middle-income countries".

Efficacy of educational text message interventions in changing immunisation behaviour:

Overview

Studies looking into the ability of SMS text message based interventions to increase knowledge levels have shown mixed levels of success. One intervention in South Africa aiming to improve mothers' antenatal health knowledge was deemed to fail in achieving this objective overall: at the end of the study period there was no significant difference in antenatal health knowledge level between the control and intervention group (Lau et al., 2014). In the study a total of 101trimester-tailored messages were sent to mothers, at varying rates dependent upon the gestation time at which the mothers were enrolled in the study such that by the exit point all the mothers had received all the messages.

A possible failure of the study was due to the messages solely attempting to increase heath knowledge, without any direct call for action on the part of the mothers (in contrast to reminder-recall based messaging interventions). It was also noted that the failure could have been due to the fact that 43% of study participants dropped out of the study. This could in itself indicate flaws in the design of the study: if the intervention was not perceived as valuable or relevant by the mothers as valuable then the dropout rate may have increased, and remaining participants may have been less likely to engage with the information presented in the text messages.

Nevertheless, focus group sessions held as part of the study gave more promising insights. There was evidence that the messages were perceived as coming from a highly knowledgeable authority, perhaps even more knowledgeable that the health professionals with which the participants had direct face-to-face contact:

"*It's like it's the Department of Health, ne? So it's coming straight from the people who know what they are talking about*". A study assessing an intervention to deliver maternal and child health care based text messages, which included those involving immunization, in rural Tamil Nadu, India, had more success in achieving its objectives than the South Africa study (Datta et al., 2014).

Datta et al looked at six villages near Vellore, Tamil Nadu, and like the South Africa study intended to provide health education, not to directly change behavior. While India is considered a middle-income country, household earnings in the area studied are very low. 120 individuals from 120 households were recruited, and the study had three phases. First, a questionnaire assessed baseline aptitude towards text messaging. The results of this phase highlight a practical problem with text messaging as a tool in some areas of low income countries because only 69.17% of individuals were able to read text messages and 52.5% able to write them. However, 98.33% of individuals surveyed believed that text messages could be an effective form of health education. Other practical barriers included the cost of mobile phones and the absence of regional language (eg. Tamil) font in many mobile phone handsets. While some of these are concerns common to many text message based health interventions, the authors of the Tamil Nadu study stressed that there were benefits to be gained from such interventions despite the limitations. They also noted possible strategies for improving access to text messages, for example the incorporation of pictures.

The second stage of the study was the sending of MCH-related text messages to the participants. These included messages about immunisation, but gave generic information rather than instructions, for example:

"*Vaccines advised for newborn babies include: BCG, and Polio drops at birth, DPT and Polio drops at 1½ months, 2½ months and 3½ months age, Measles and Vitamin A solution at nine months. Three doses of Hepatitis B vaccine can also be given as per doctor's advice.*"

"*Pregnant mother should receive two TT injections during her pregnancy.*" (Datta et al., 2014)

The final stage was a second questionnaire evaluating the increase in MCH knowledge at the end of the study period. A significant increase in knowledge about MCH was found in the participants, including about vaccination: for example, before the study 60% of participants could name at least 2 common childhood vaccines whereas afterwards 68% could do so, and knowledge of the number of TT injections that a mother should receive during pregnancy leapt from 46% to 82%. Both of these increases were statistically significant (P<0.05).

One limitation of the above studies is that they assessed only knowledge increase, not any subsequent behaviour change. Lau et al acknowledged the difficulty of objective measurement of behavioural change, giving the example of the difficultly on assessing whether a participant was eating more healthily. Other health behaviour parameters, such as adherence to maternal and child vaccination schedules, were not measured. There is little research in this area: a study assessing the impact of MCH immunisation knowledge on related behaviour could prove useful.

Behaviour change theories relevant to these studies, which suggest knowledge changes lead to behaviour changes:

The **Health Belief Model** stresses the importance of "enduring individual characteristics" that affect health perceptions and motivations, and therefore choices *(see figure 2).* Informative text messages could help shift beliefs about immunisation, increasing, for example, perceived threat of susceptibility and perceived threat of severity in mothers. It could also add to peer-group pressures, reduce perceived barriers and increase perceived benefits. Purely knowledge-based messages do not incorporate a "cue to action", however, and this may reduce their ability to change behavior via the Health Belief Model.

The theory of **self efficacy** places importance on the belief that a behaviour is or is not within one's control. In combination with people's pre-existing situation-outcome and action-outcome expectancies, which could be partially formed by the content of the SMS messages, a strong belief of self efficacy contributes to behaviour through the formation of intentions. Providing information through SMS text messaging based interventions could put power into mothers' own hands, and empower them to take further responsibility for their child's medical needs. Evidence from MedicMobile's dialogue with mothers has suggested that this is the case:

"The mothers also said that these messages motivated them to take greater personal responsibility for their child's health beyond immunization—in part because they came from a local, trusted community organization."

(MedicMobile annual report, 2013)

The very act of sending a text to mothers directly involves them in their and their child's medical care. Furthermore, Datta et al found that knowledge increases relating to maternal health were overall greater than those related to child health (Datta et al., 2014). A possible explanation for this is that it is easier and feels more achievable for mothers to change their behaviour concerning their personal health (eg. to change their dietary intake) than it is for them to change their behaviour relating to child care. Mothers have had years of experience caring for themselves, but may lack a feeling of Self-Efficacy for making interventions about how they look after a child which is likely already a challenge, particularly for first time mothers. Therefore, in the context of purely informative text messaging interventions, messages concerning maternal health may make better use of the Self-Efficacy theory of behavior change than those concerning child health. This is speculative, however, and there is a lack of research to further evidence this point.

The **theory of planned behavior** may be relevant because it centres partly on what an individual perceives *others* to think of them, because this influences the individual's subjective norms. Receiving text messages, and therefore being

directly involved in the healthcare process, could make parents much more aware of immunisation in society, and what is expected of them by healthcare authorities. These expectations may be particularly influential when they come from *"local, trusted community organisations",* as in the earlier quotation from MedicMobile. Lau et al found through focus groups that the text messages were perceived to be coming from an information source of considerable knowledge and authority. One mother felt that the messages "*came from educated people", while another (quoted earlier) judged that the knowledge providers "know what they are talking about* (Lau et al., 2014)*.*

  Incorporating knowledge could provide some social pressure to take responsibility for learning about and knowing about local healthcare provision, for example routine childhood vaccinations. This was again alluded to in the focus groups in Lau et al: the participants reported that they were more compliant with treatment of sexually transmitted infections, took folic acid and vitamins, had endeavoured to eat more healthily and take more exercise, and regularly attended the clinic. One mother described feeling more motivated "*to do the right thing."* (Lau et al., 2014).

  Social pressure influencing subjective norms in the Theory of Planned Behaviour need not be authoritarian or paternalistic: Lau et al found that mothers appreciated the care and effort that health service providers were making in sending the text messages:

  "*And it's also good because it just shows that there are people out there that's taking time to send you that SMS*" (Lau et al., 2014).

  However, some papers have concluded that information-based interventions alone may not be sufficient to achieve behaviour change. A key point from the SAGE Working Group on Vaccine Hesitancy, in their report[4] published in *Vaccine*, 2015, was that "knowledge is important, but not enough to change behaviour". This view is echoed by Conner and Norman in *Predicting Health Behaviour* (Connor & Norman, 1995, P.4).

  Bertrand,et al. conducted a "systematic review of the effectiveness of mass communication programs to change HIV/AIDS-related behaviours in developing countries" (Betrand et al., 2006) found that approximately half the studies reviewed were successful in increasing knowledge, this did not necessarily translate into positive behaviour change. In the introduction of this paper it was discussed how the information-motivation-strategy model stresses that information alone is not sufficient to change behaviour.

  Betrand et al. also pointed out that "communication is a two-way process" (Betrand et al., 2006): the Health Belief Model could be relevant here, as the study could exemplify that it is important to recognise a person, community or society's pre-existing beliefs before attempting to change them. Research in high income countries has shown that education-based mHealth interventions can be counterproductive and reinforce the decision of already vaccine-hesitant parents not to have their children vaccinated. While reasons for low vaccine uptake differ between populations, it is clear that mHealth interventions have the capacity to hold a lot of power and should always be planned with careful attention to the population that they are designed to serve.

  As text message interventions that are educational alone are seemingly not as effective as they could be, we next investigate the potential of cue-to-action based reminder-recall messages to improve upon these interventions' techniques in generating behavior change.

Efficacy of reminder-recall texts:

Overview

Forgetfulness and competing priorities have been reported to stand in the way of children receiving the required immunisations in a variety of contexts (Wakadha et al., 2013; Kharbanda et al., 2009). Therefore text message reminders as part of mHealth intervention may be effective in augmenting immunisation rates in low-resource settings.

Although there is little published research on mHealth immunisation interventions in low-income countries, there have been several studies assessing feasibility that have shown positive attitudes among patients and providers (see Table 1). However, one important concerns expressed by parents was the cost of receiving text message reminders (Ahlers-Schmidt et al., 2012; Kharbanda et al., 2009). This highlights that interventions are most likely to succeed if they are funded by the healthcare provider rather than the patient, or target communities where unlimited text plans predominate.

While these opinion surveys and focus group discussions (FGDs) show that text message interventions have the *potential* to be effective, they do not provide quantitative evidence of how much they will actually increase immunisation rates. Large-scale randomised control trials (RCTs) would be needed to provide such evidence, but very few of these have been conducted in developing countries to date (Wakadha et al., 2013), leaving efficacy unreported.

Another limitation common to these studies is that the sample of people interviewed is usually small and taken from a single geographical region, hence their views are not necessarily representative of attitudes in other communities. Perceptions of severity and susceptibility to different diseases, and barriers to vaccination may also vary in different settings. For example, concern for vaccine safety in the context of the flu vaccine in New York (Kharbanda et al., 2011) may be much more significant than in the context of the Pentavalent vaccine in rural Kenya (Wakadha et al., 2013) or other immunisation programmes more relevant in the developing world. Additionally, Odeny et al., (2014) highlights that there is very little literature on the theories behind existing mHealth interventions and that the development of message content is poorly documented. It is therefore poorly understood *why* such interventions work, thus limiting their adaptability to a wider range of interventions in developing countries.

Table 1: Summary of studies assessing feasibility of text message interventions in low-income populations. FGD-Focus Group Discussion

STUDY	STUDY POPULATION	FINDINGS
ODENY ET AL., 2014	41 mothers and healthcare workers at HIV clinics in Nyanza, Kenya	-HBM* used to construct questions for 5 FGDs* about HIV -Responses used to craft message with the following features: congratulatory, short, polite, personalised, educational, sent in working hours, 3 days before the appointment -Mothers thought texts would strengthen their perceptions of severity, susceptibility and benefits of attending appointment -Participants identified SMS as 'cue to action' to get mothers to the clinic -Emphasises importance of privacy, and not sending personal information through texts
WAKADHA ET AL., 2013	72 mother in rural Kenya	-Identified barriers to getting children immunised with Pentavalent vaccine, including maternal illness and community opposition -Messages used were congratulatory, short, personalised, and sent 3 days before the appointment -Highlights importance of not sending personal details, as most mothers use someone else's phone -Mothers reported to be influenced by text, however the number of messages was unimportant -Overall positive attitude to receiving SMS reminders
AHLERS-SCHMIDT ET AL., 2012	190 low-income parents at a Midwestern Pediatric clinic, USA	- Parents open to receiving appointment and immunisation reminders by text -Those with unlimited text plans more likely to agree to reminders -Reminders preferred one week or less before immunisation date -Most would not pay for this service
KHARBANDA ET AL., 2011	40 pregnant women in New York City, USA	-Responses in FGD* analysed according to HBM -Barriers identified: misconceptions about vaccine safety and influenza severity and being unaware of need to vaccinate -Overall positive attitude towards receiving informative texts about the flu vaccine, even among mothers who opposed the vaccine on ground of safety -Mothers thought texts would help overcome barriers by encouraging communication with doctors, and would also provide a 'cue to action'
KHARBANDA ET AL., 2009	28 parents of adolescents in New York, from ethnically diverse backgrounds	-FGDs* revealed parents are open to receiving reminder texts about adolescent immunisations, and this is preferred to conventional mail or phone reminders -Reported barriers as competing priorities and being unaware of adolescent vaccine requirements -Short and personalised messages were preferred -Cost of texts and difficulty using mobile phones were expressed as concerns -Most said they would act on a text

Table 2: Summary of studies assessing efficacy of mHealth immunisation interventions in low-income populations.

STUDY	POPULATION	FINDINGS	RELEVANT THEORIES	LIMITATIONS
BANDURA ET AL., 2015	304 urban parents in Kadoma, Zimbabwe	-Significant increase in uptake of government immunisation program achieved by 3 reminders -This helps meet 90% government target for coverage -Reminders reduce delay in vaccination -Authors' cost assessment deemed intervention worthwhile -Participants open to reminder texts; preferences consistent with previous studies	-Reminder is *cue to action* (HBM) /*environmental trigger* (SCT) -Repeated reminders prevent relapse to earlier stages of TTM -Wording of messages increases *Self-Efficacy/PBC* -Lack of personalisation does not follow suggestions of previous papers, and contributes little to Self-Efficacy - Short and emotive messages are easily remembered -Several messages provide *information*, *motivation* and *strategy* (IMSM) in the necessary order -Participants were receptive to reminders, as they were already convinced of need to vaccinate by routine health education	-Limited transferability, as only included urban families with pre-registered mobile numbers
STOCKWELL ET AL., 2011-ADOLESCENT & PEDIATRIC TEXT4HEALTH STUDY	361 low-income parents of adolescents in New York city & 174 low-income parents in New York city	-Significantly more adolescents receiving needed MCV4/Tdap vaccine in intervention group following weekly SMS reminders -Significant increase in attendance of post-shortage Hib vaccine recall appointment in intervention group receiving SMS	-Reminder is *cue to action/environmental trigger* -3 reminders in paediatric study sufficient to allow progression and prevent relapse to earlier stages of TTM -Personalised messages increase *Self-Efficacy/PBC* of parents; consistent with reported previously patient preferences -Community based message design allows *targeting* of message content to cultural and environmental factors most relevant to community -Sending precise appointment details contributes to *strategy* (IMSM) and increases likelihood of attendance by making parents think through getting to the clinic	-Limited transferability as conducted among urban mobile-phone owners in a developed country -Adolescent study used matched controls, so reduced reliability compared to an RCT

		reminders -Overall immunisation rates remain low -Average of 3 reminders in paediatric study sufficient to achieve vaccination; consistent with previous studies		
STOCKWELL ET AL., 2012	9213 low-income, urban children and their parent in New York	-Small but significant increase in flu vaccination rate in intervention group -However coverage remained low -Average of 5 messages needed to achieve immunisation; more than reported by other studies	-Personalised messages increase Self-Efficacy/PBC -Short messages *tailored* to age of child are easily understood, hence easily remembered - Community based message design allows *targeting* of message content to cultural and environmental factors most relevant to community -Low efficacy could be due to low *perceived severity* and *susceptibility* to flu and low *perceived benefit* of vaccine (HBM) or controversial *social and personal attitudes* towards vaccine (SCT) -SMS reminder less effective as *trigger/cue to action* when such *barriers* (HBM) are in place	- Limited transferability as conducted among urban mobile-phone owners in a developed country -Barriers to uptake of controversial flu vaccine not relevant to barriers for developing world vaccines
KAEWKUNGWAL ET AL., 2010	544 cases in rural Thailand, as part of 'Better Border Health Program'	-Increased compliance to immunisation programme -On-time vaccinations more likely -Positive attitude among healthcare providers towards	-Timing of reminders, a few days before appointment, is consistent with other studies -Mothers need to be aware and convinced of need to vaccinate before they are receptive to reminders, hence SMS effective when incorporated into wider health program -Must transition from *pre-contemplation* to *contemplation* (TTM) before triggered to *action* stage by reminder -Highlights importance of *targeting* message content to progression of community through stages of behavioural change models	-Before-after study design; less reliable evidence than an RCT as undocumented external factors could be responsible for change -Poor

		intervention		documentation of message design does not allow appraisal of why it worked	*Abbreviations:* *HBM- Health Belief Model*
MEDICMOBILE KURNOOL POLIT PROJECT, 2011	Low-income community in Kurnool, Andhra Pradesh, India	-Increase in childhood vaccination rate for 3rd dose	*-Report too brief for useful analysis*	-Before-after study design; less reliable than RCT as undocumented external factors could have caused change, such as other immunisation campaigns -Source from a MedicMobile produced report, which is less reliable than published articles from peer reviewed journals -Poor documentation of method does not allow proper analysis	*SCT- Social Cognitive Theory* *TTM- Transtheoretical Model* *PBC- Perceived Behavioural Control* *IMSM- Information- Motivation- Strategy Model*

Efficacy

Sound evidence of the effective use of SMS in a childhood immunisation programme is provided by **Bandura et al. (2015).** [1] Furthermore, it is very recent, so the methods used are up to date with the best current knowledge of message content, timing and frequency. Its recent publication date probably explains why it is not yet widely cited.

A sample of 304 parents, whose mobile numbers were already registered at an urban clinic in Kadoma city, were randomly assigned to either the intervention or the control group. Both groups continued to receive routine immunisation health education, however the intervention group were sent three reminder messages (7, 3, and 1 day before the appointment) for each of the three immunisation dates (at 6, 10, and 14 weeks after birth), where their child would be vaccinated in accordance to the updated national immunisation programme.

There were statistically significant increases in immunisation rates for all 3 doses, bringing coverage above the 90% government-set target (see figure 1). The authors have performed other useful statistical analyses, for example calculating that 15-16% of immunisations received in the intervention group are attributable to the SMS intervention. Furthermore, the repeated reminders effectively prevented the delay of appointments. For the first appointment at 6 weeks, those receiving texts were 89% more likely to get their child immunised on time, for example. This means that children were vaccinated at the exact target age, which may help with predicting vaccine stock distribution and worker
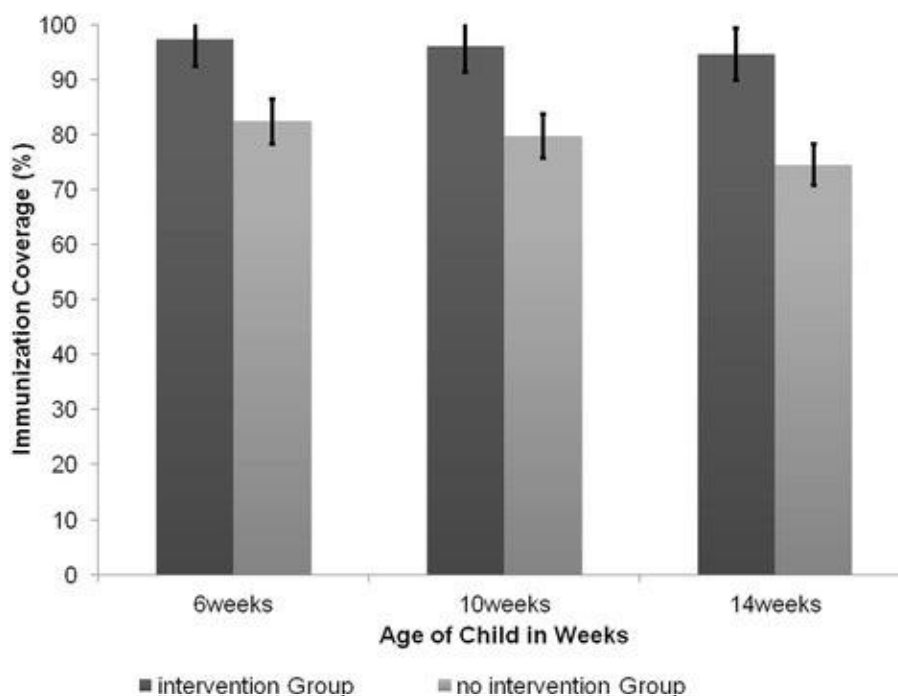

Figure 1: Immunisation coverage at 6, 10, and 14 weeks, Kadoma City, Zimbabwe, 2013. (Bandura et al., 2015)

schedules. The scale of these changes is especially significant due to herd immunity, where the vaccine protects even those children who haven't received it, as unimmunised individuals become too scarcely distributed in the population for a disease to spread.

All participants were willing to receive text messages, and the majority thought that the messages would be beneficial. Most parents also preferred to receive texts a day before the appointment date. These findings confirm the results of several feasibility studies conducted in a range of socio-economic settings, such as FGDs in Kenya (Odeny et al., 2014;

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[1] This study is of note because it is perhaps the only good-quality RCT conducted in one of MedicMobile's priority countries, Zimbabwe.

Wakadha et al., 2013) as well as in low-income populations in the US (Ahlers-Schmidt et al., 2012; Kharbanda et al., 2011; Kharbanda et al., 2009).

   Closer examination of message content in relation to behavioural change theory may help understand why this intervention proved to be effective. The translated messages were as follows:

- A week before: "*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 7 days' time from today*."

- Three days before: "*You are reminded that the vaccination appointment will be due in 3 days from today*."

- A day before: – "*Your vaccination appointment is due tomorrow, visit the nearest clinic*".

 The reminder message serves as a 'cue to action' in the context of the Health Belief Model (HBM). Kharbanda et al. (2011) and Odeny et al. (2014) have also previously described reminder-recall texts as cues, hence the HBM is probably the theory that is applied most often in the literature.   In the Social Cognitive Theory (SCT), the SMS is referred to as an 'environmental trigger', however in both cases, it is essentially a prompt to get the child vaccinated.

 The Transtheoretical Model(TTM) offers an explanation for why sending repeated texts is useful: a single SMS encourages transition from the 'contemplation' phase to 'preparation for action' and then to 'action', however, sending several messages has the added benefit of maintaining individuals in the 'preparation for action' phase and preventing relapse into previous stages, seeing as the two-way progression between stages in a key feature of this model.

 The concept of 'Self-Efficacy', affiliated to the HBM, or 'perceived behavioural control' (PBC) from the Theory of Planned Behaviour (TPB) is also drawn upon by these messages, particularly by the content of the first message. The idea that '*immunisation protects your child*' intends to create a sense of control for the mother, making them believe that they are able to do something to protect their child's health, which increases the likelihood of acting on the messages.

 Despite suggestions by Odeny et al. (2014), Wakadha et al. (2013), and Kharbanda et al. (2009) that personalised messages would be preferred by mothers, the messages were not personalised with the child's name in the Kadoma study. It could be argued that this detracts from the effectiveness of the messages, as mothers may feel that generic messages that do not address them personally contribute less to their 'Self-Efficacy' than messages tailored to their child. However, the intervention was clearly still effective in this population, hence this compromise may be acceptable to minimise costs.

 The emotive component of the first message, referring to 'killer disease' may also make mothers more likely to remember by engaging something called 'flashbulb memory' In theory, because memory and emotion are processed in the same part of the brain, experiences evoking stronger emotional responses will be remembered better, which makes mothers more likely to remember the immunisation date (Martin et al., 2010). .

 In terms of the information-motivation-strategy model (IMSM) (Martin et al., 2010), the initial emotive message provide 'motivation' for mothers to get their child immunised, as well as 'information' regarding why vaccination is needed, although the latter is not the primary purpose of a reminder SMS. Subsequent messages containing details such as date (e.g.: *'in 3 days' time'*) and location ('*visit the nearest clinic*') offer the 'strategy' component, telling mothers how to get their children vaccinated. The order in which these messages are sent reflects the order of stages in the model: Mothers first need to understand why vaccination is necessary before they become motivated to get it done, and only after this will they be receptive to messages telling them how to get their child immunised.

 The use of short messages, inherent to short message services (SMS), is a further successful feature of this intervention. Indeed, previous studies have reported that parents prefer messages to be brief (Odeny et al., 2014; Wakadha et al, 2013; Kharbanda et al., 2009). Stockwell et al. (2012) suggests this is because short messages are easier to understand, particularly in low-income populations, where levels of health literacy are generally lower. Information must first be understood before it can be remembered (Martin et al., 2010), so it follows that short messages are more easily remembered.

A final important point to note is that the intervention group received texts in addition to routine immunisation health education. This draws on this idea of 'cognitive filtering', where people are more likely to notice and remember details about immunisation dates and locations when it fits with what they already know and believe. That is, conventional educational campaigns are needed to convince mothers of the importance of childhood vaccination before text message reminders can be effective. This emphasises that mHealth interventions should be incorporated into a wider immunisation campaign instead of being used in isolation.

There are, nevertheless, a few limitations to this study undermining its usefulness. Most significantly, participants were only eligible if they owned mobile phones and were residents of Kadoma City. The issues of incomplete mobile phone penetrance and living far away from the clinic were not considered. This limits the transferability of these findings to remote rural populations, where barriers such as transport costs or phone sharing may prevent immunisation (Wakadha et al., 2013).

Other good quality RCTs, which are widely cited and appear in high impact, peer-reviewed journals were conducted in developed countries, albeit in low-income communities. Many of the relevant studies on immunisation were published by the same group of institutions, based on data collected from New York City health centres in 'minority' regions (Kharbanda et al., 2011; Stockwell et al., 2011; Stockwell et al., 2012) (see *Table 2*). As a result, they face the same limitations in generalisability as the Kadoma study (Bandura et al., 2015), as poorer urban districts are not as low-resource as rural areas of the developing world.

Stockwell et al. (2011) reports two separate studies, both in mainly Latino, low-income communities in New York City. Both are also based on the Text4Health program- a newly designed health messaging platform that was integrated with the EzVac immunisation registry, with text messages designed using community input.

The **adolescent immunisation program** involved a random sample of 195 parents of 11-18 year olds due for meningococcal (MCV4) or Tetanus-diphtheria-acellular pertussis (Tdap) immunisations with 166 matched controls. The controls received only the 'standard care procedure' which involved no reminders, while the intervention group were sent automated text reminders at weeks 1, 2, 3, 6 and 7 of the trial, or until the immunisation was recorded by the EzVac system.

The number of adolescents receiving the needed immunisation was determined at three time-points during the trial, and a significantly larger percentage of the intervention group had been immunised in each case (see figure 2).
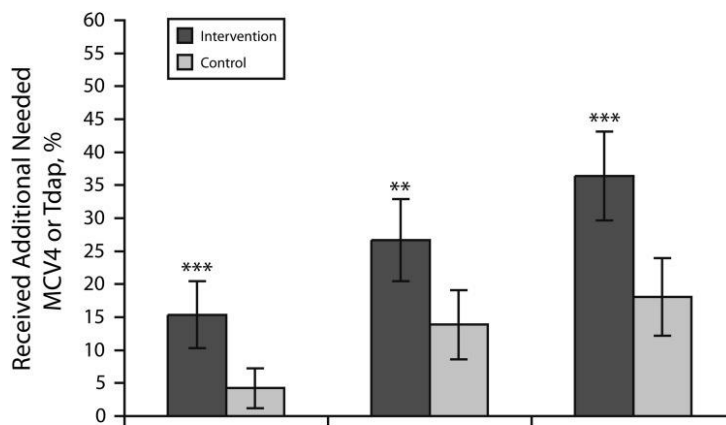

Figure 2: Percentages of patients aged 11–18 years who received an additional needed adolescent vaccine at 4, 12, and 24 weeks: Text4Health–Adolescents, New York City, 2009. (Stockwell et al., 2011)

In the **pediatric Text4Health study**, 174 parents were randomly allocated to either the control group, who received only conventional mail reminders, or the intervention group, who received three SMS notifications as well, reminding them to take their children to receive the *Haemophilus influenzae* B (Hib) vaccine after a shortage. Significantly more parents who received both Hib reminders attended a recall session compared with parents who only received a mailed reminder (21.8% vs 9.2%), although, as in the adolescent study, the authors acknowledge that the overall coverage is still low.

A median of three texts were sent before the vaccine was received by the adolescents, which is consistent with the number of reminders sent in the Pediatric study, and in other studies (Bangure et al., 2015). In these urban settings, three reminders were sufficient to allow progression through the phases of the TTM and prevent relapse to the earlier stages. The authors highlight that these repeated reminders increase the effectiveness of the programme, while increasing the price the healthcare provider has to pay only minimally, compared to sending a single reminder, which is a major advantage over conventional mail-based reminders. In terms of costs incurred by each family, this was reported at $0.3 maximum, for those without an unlimited text plan, hence this was probably not a significant barrier in this study, as only 1.8% of parents in the adolescent study opted out. Nevertheless, this may not be the case in lower-income populations, where mobile-provider plans may also be different.

Additionally, the messages were personalised with the patient's first name, language (English or Spanish), clinic location, and date and time of immunisation appointments. FGDs in a variety of settings have supported the use of personalisation, as it is preferred by parents (Odeny et al., 2014; Wakadha e al., 2013; Kharbanda et al., 2009). As expressed by one mother in rural Kenya:

> *"You know if one calls you by name you know at least they recognize you and it is not like they sent the SMS for granted. So that would mean they know me and want me to go. In the first place, that would motivate me to go".*

That is, when mothers perceive messages as caring and personally addressed to them, it is more likely to contribute to their Self-Efficacy or PBC, making it more likely for an intervention to be effective (Odeny et al., 2014).

Furthermore, the use of community based message design is an important strength of this trial. Assessing the preferences of the target population allows the messages to be targeted to their needs. Interventions that do this are more successful (Martin et al, 2010), as they allow researchers to craft messages that apply specifically to the target population, and consider the relevant cultural and environmental factors, even if these are not explicitly stated.

As previously, the reminder serves as a cue to action, and the included details of date and location contribute to the 'strategy' part of IMSM. Interestingly, according to the elaboration likelihood model (ELM), the more specific details that are included, the more the parents will think through and plan how they will get to the clinic, and so the more likely parents will be to get their child (Martin et al., 2010).

The main limitation of this study is the same as for the Kadoma study (Bandura et al., 2015); participants had to have a pre-registered phone number, so, effectively, these trials only showed that SMS interventions are effective *among mobile phone owners.* In low-resource, rural populations, this may represent only a fraction of the population. For example, mobile phone penetrance in the Asia Pacific and Sub-Saharan Africa regions for 2014 were 44.6 and 39% respectively (GSMA Intelligence, 2015). However, these regions with currently low rates of mobile phone subscriptions also show the fastest growth rates, with penetrance expected to rise to 57.2% in the Asia Pacific region, and 48.7% in Sub-Saharan Africa by 2020 (GSMA Intelligence, 2015). Predictions such as these are important to consider because the design and implementation of mHealth interventions is not instantaneous; by the time they are ready to be scaled-up to entire populations, more people will also have access to mobile phones, impacting the chances of success of the interventions.

Stockwell et al. (2012) reports a very large scale RCT involving 9213 children between 6 months and 18 years of age, from a mainly Spanish-speaking, low-income area of New York. Eligible patients were randomly allocated to either the control or the intervention group. Both received the 'usual care' of a telephone reminder to get the seasonal flu vaccine and access to educational posters about influenza at clinics, but parents and adolescents in the intervention group additionally received weekly texts for up to five weeks, or until the vaccine was received. Messages were developed through community focus group discussions. The first three provided educational information about vaccine safety and

flu severity, tailored to the age of the child, while the last two informed about dates, and all were personalised to the patient's language of choice.

There was a significant difference between intervention and control groups in vaccination rate (39.9% vs 43.6%), however the increase in coverage was small and overall immunisation rates remained low. The median number of texts were sent before immunisation was five- a greater number of reminders than implicated by others (Bangure et al., 2015; Stockwell et al., 2011).

The authors suggest that the reason for the modest efficacy of this SMS intervention, using the construct of the HBM, can be attributed to the misconceptions about the benefits of the vaccine, and the low perceived severity of and susceptibility to influenza. These controversial public attitudes can equally be described as social factors, and personal concerns as personal factors in the SCT. The texts still act as 'environmental' triggers, or 'cues to action', however, where people do not believe a vaccine is effective, or believe that it is actively harmful, simple reminder texts are unlikely to improve vaccination coverage. Education programs may therefore be more important in the context of controversial vaccines such as this.

In fact, it was for this reason that the HPV and flu vaccines were excluded from the previously described Text4Health trials (Stockwell et al., 2011): to eliminate the barrier of patient attitudes towards the vaccine, so that the effectiveness of the reminder texts could be assessed more accurately.

Tailoring the messages to the age of the child may also make this intervention more effective, as messages tailored to an individual's name, age or language are more likely to be adhered to (Glanz et al., 2014). This could be because, if the message is addressed to them personally, recipients may feel more responsible, or a greater sense of Self-Efficacy and PBC, as is the case with personalised messages. Note that tailoring and targeting are not the same, the difference being that tailoring is specific to individuals, while targeting is aimed at a population sub-group, with the latter being achieved through FGDs.

The large sample size of this trial makes it a powerful study, and it provides strong evidence that SMS reminder interventions can be useful. It is however of limited use, as it is only relevant to urban populations with wide-spread mobile phone ownership. These result may also not be generalised to other vaccines soliciting different public and personal attitudes.

Traditional telephone and paper-based vaccine reminders have had little effect on low income populations, but SMS was more successful. A suggested reason for this is a low level of health literacy in low-income populations, where short (max. 160 character) messages are understood, hence remembered and acted on more readily than a poster or flyer with lots of writing.

Kaewkungwal et al. (2010) showed that smart phones applications and text message reminders can successfully be incorporated into a wider health campaign- the 'Better Border Health Program' in rural Thailand– to improve attendance at antenatal care (ANC) and expanded program for immunisation (EPI) appointments.

The automated text messages reminders sent directly to parents a few days in advance increased the chances of receiving EPI 1.48-fold, and the odds of on-time vaccination 2.13-fold, hence increasing both compliance and punctuality. In addition, the program was received positively by healthcare workers, who reported that the mobile module reduced time and effort of case-tracking, appointment generation, and updating immunisation data. Although Thailand is a middle-income country, this pilot study was conducted in Thai-Myanmar border areas, where displaced migrants make up a significant proportion of the population. The barriers reported in this region, such as poverty, limited healthcare access, and low levels of health education, are likely to make this study relevant to other low-income communities as well. Additionally, the mobile module is similar to the model used by Medic Mobile, where health workers use mobile phone applications to register new births, and after sending this information to a centralised database the worker receives automated reminders about the vaccinations due for the infant (see figure 3).

A before-after study design was used, with 396 cases before the program was implemented, and 148 after. This does not provide as reliable evidence as an RCT, as undocumented external factors may have contributed to the increase in EPI uptake. The authors however described the population as 'stagnant', so the conclusion that the program was effective is likely to be accurate.

As in previous studies, the authors highlight that these SMS reminders were effective when implemented as part of a comprehensive health program, rather than in isolation.

Kaewkungwal et al. (2010) also emphasises the importance of maternal awareness of needed immunisations in the success of these programs. Put in the context of the TTM, mothers must first transition from 'pre-contemplation' to 'contemplation' before reminders can be effective. Once again, this shows the significance of targeting SMS interventions to the appropriate stage and level of health literacy of the community.

MedicMobile's 2011 pilot project in Kurnool, Andhra Pradesh (in partnership with DMF India, a local healthcare NGO) aims to increase vaccination uptake by sending text messages to mothers. This was possible because at the time of the study over half the population of India had a mobile phone, which supports the need for high mobile phone penetrance for an mHealth immunisation to be effective (see figure 3). Over the course of the study the vaccination rate rose from 67% to 97% for children due to receive their third dose of vaccine. It is unknown, however, whether there were other immunisation campaigns being run in this community at the same time, so this increase in uptake cannot definitively be attributed to the pilot project.

While both this pilot study and that reported by Kaewkungwal et al. (2010) were conducted in low-resource settings, their lack of a theoretical basis and documentation of the message design process do not allow an in-depth appraisal of *why* they are effective (Odeny et al., 2014). It is therefore difficult to improve these interventions, or to adapt them to other communities.
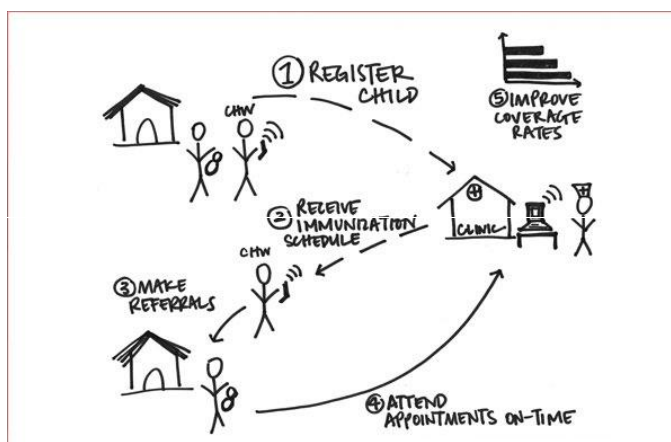

Figure 3: mHealth registration and follow-up network used in Kurnool, Andhra Pradesh, India, 2011. (MedicMobile, 2011)

In summary, the evidence base for reminder-recall text message interventions that serve as a cue to action is somewhat better than that for text messaging interventions that use educational strategies alone. In light of the behaviour change theories we have discussed, interventions that incorporate both educational and cue-to-action aspects show the greatest promise in generating behaviour change and improving immunisation uptake.

Implications for Practice:

Key aspects of behaviour change theories that have emerged as themes through this paper are:

1. The provision of health information and the sending of "cues to action" (for example reminder-recall texts) are inter-reliant public health techniques. An effective intervention with incorporate both strategies.

2. SMS reminders should be incorporated into a wider immunisation campaign, and should be used alongside more traditional public health education techniques: reminder messages serve as cues to action (HBM) or environmental triggers (SCT), however personal and public attitudes towards the disease and the vaccine determine whether parents actually go to immunisation appointments or not. Furthermore, though the few existing studies on the effectiveness of text message reminders for immunisation in developing countries show promising results, they tend to show only modest increases in vaccine coverage so far. This supports the idea that mHealth interventions should be used in conjunction with other forms of health education as part of broader immunisation campaigns, and not in isolation.

3. Text messages should be sent from from or be endorsed by organisations trusted within the local population: this could again be achieved by endeavoring to integrate a new intervention into existing health services or immunization campaigns.

4. Messages should be personalized and tailored to the patient's name, age, and language. This is an important feature of effective SMS interventions, perhaps because recipients feel they are being personally addresses, and hence feel more empowered to get their child immunised.

5. Messages should be targeted to the specific social and personal circumstances of a population, through the use of community FGDs, helps to design the kind of intervention to which patients will be receptive (i.e.: educational vs reminders). Messages should be designed using community based feedback to target the message content to barriers that are specific to that population. MedicMobile's current methods of engaging with communities, for example their use of design cards, suggests that the organisation is well placed to do this.

Two focus areas are suggested for further research:

1. Large-scale RCTs need to be conducted in low-resource, rural settings to improve the transferability of their results to developing countries, which are most relevant to organisations such as Medic Mobile,
2. Future studies must be designed with a clear theoretical foundation to allow a better understanding of how and why certain interventions work, as well as application to a wider range of contexts, including HIV treatment and antenatal care.

Other important points highlighted include that interventions should be of minimal or no cost to patients; they should be funded by the healthcare, or target communities where unlimited text plans predominate. Data security, on a national scale or within the home, is also an important consideration in any mHealth intervention. Policy suggestions made by Odeny et al. (2014) regarding message content and timing are based on a firm theoretical basis and confirmed by a number of independent studies: when designing future interventions, the messages should be short, congratulatory, polite, personalised, informative, and sent in working hours, less than one week in advance.

Conclusion:

Knowledge and behaviour change have an irrevocable but complicated relationship, and so text messages drives to change immunisation behaviour should be approached carefully. However, unlike many more traditional public health measures the use of SMS messaging has the potential to extend far beyond increasing health knowledge: other benefits, such as the ability to send reminders or to reach remote locations, underlines why mHealth could be such a powerful tool. As stressed by Obregan et al., 2009, in "Achieving polio eradication: a review of health communication evidence and lessons learned in India and Pakistan",[7] : "there is no vaccine against resistances or refusals that are rooted in social-cultural, religious and political contexts... These challenges demand effective communication action.

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