Development of automated text-message reminder system to improve uptake of child vaccination in Ethiopia

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Abstract

Introduction: Non-attendance and delay for vaccination schedules remains a big challenge to healthcare workers. Among the frequently mentioned reasons for missed vaccination in children is forgetfulness of caretakers to show up in vaccination schedules. This necessitates developing an automated reminder system with integration of mobile technologies.

Objectives: This paper aimed to develop and test an automated mobile text message reminder system in the local context of Ethiopia.

Methods: This system is developed using iterative development process through phases of requirement analysis, design, development, testing and refinement. Requirement gathering was done before development of the system. Front end application was developed using java technologies while back end applications were developed with oracle database. Finally, pilot testing of the automated reminder system was done on 30 participants.

Results: The automated system has been developed based on requirements. The text message reminder system has two components: 1. Web based application for client registration and automatic reminder scheduling; 2. SMS application for automatic SMS text messaging. In the pilot testing, all the text messages (100%) were dispatched from the automated system to the respective participants. Finally, the system has shown a notification that the text messages have been sent successfully.

Conclusion: Text message reminder system has been developed for routine childhood immunization program in Ethiopian context. Text message based mHealth interventions should be carefully designed, developed, tested and refined before actual implementation.

Key words: Text Message, Automated Reminder, mHealth, Vaccination, Immunization

Abbreviations

BCG Bacille Calmette Guérin
DPT Diphtheria-Pertussis-Tetanus

EDHS Ethiopian Demographic and Health Survey

EPI Expanded Program on Immunization

FMOH Federal Ministry of Health

Hib Haemophilus Influenza Type B

mHealth Mobile Health

OPV Oral Polio Vaccine

PCV Pneumococcal Conjugate Vaccine

RCT Randomized Controlled Trial

SMS Short Message Service

VPDs Vaccine Preventable Diseases

WHO World Health Organization

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Introduction

Childhood immunization is one of the most successful strategies to prevent illness and death from VPDs (vaccine-preventable diseases) [1,2]. To effectively control VPDs, maintaining high vaccination coverage is required with the target of the WHO to reach 90% coverage [3]. The WHO initiated the EPI program in 1974 [4] and in Ethiopia, it was launched in1980 [3].

The total number of antigens in the Ethiopian national schedule reached to eleven following introduction of additional vaccines like Hib and Hep B, PCV, Rota and IPV vaccines in 2007, 2011, 2013 and 2015 respectively [3]. The Ethiopia immunization program considers a child to

be fully vaccinated if the infant has received BCG, 3 doses of DPT-HepB-Hib, 3 doses of pneumococcal, 2 doses of Rota virus vaccine, 4 doses of OPV, IPV and a dose of measles before the age of one year [3].

Table 1: Schedule of EPI in Ethiopia

Age	Visits	Vaccines
At birth	1	BCG, OPV0
6 Weeks	2	DTP-HepB1-Hib1,OPV1,PCV1,Rota1
10 weeks	3	DTP-HepB2-Hib2,OPV2,PCV2,Rota2
14 Weeks	4	DTP-HepB3-Hb3, OPV3, PCV3,IPV
9 Months	5	Measles

In order to successfully control and eliminate vaccine-preventable infectious diseases, timely vaccine coverage has to be achieved and maintained as scheduled [5]. However, substantial proportions of children in many countries still fail to benefit from all basic vaccines and VPDs still pose a public health risk [6] with the highest rates of child mortality still in Sub-Saharan Africa [7]. Ethiopia has also the second largest number of incompletely vaccinated children from Africa, next to Nigeria [8].

In Ethiopia, the EDHS survey report has shown a steady progress in EPI coverage where all basic vaccination coverage increased from 14% in 2000 to 39% in 2016. In terms of timeliness, the 2016 EDHS report indicated that only 22% of children were vaccinated by the appropriate age [9]. Such suboptimal coverage coupled with the untimely vaccination of children has contributed to outbreaks of vaccine- preventable diseases frequently [9-11]. The WHO also recommends that vaccines must be given before the first birthday within a specified vaccination schedules and intervals [12,13].

Among the frequently mentioned reasons for missed vaccination in children is the lack of communication between child caretakers and health workers [14-16]. From previous studies; prior reminder not given (32.9%), mother's forgetfulness (26.6%), mother being too busy (27%), being unaware of the need to return for subsequent doses (19%) and unknown place of vaccination (16%) were the major contributing factors for missing the vaccination doses and not vaccinating on time [17-20]. This necessitates developing an appropriate vaccine delivery strategy with integration of mobile technologies [21-23].

In order to improve access and quality of care, the Federal Ministry of Health of Ethiopia has recognized and positioned eHealth as a key transformation enabler [24]. To this end, mHealth technologies offer opportunities to advance the healthcare delivery and improve attendance to health facilities [25].

Mobile communications technology has the potential to enhance adherence to health care services by facilitating interactive and timely access to relevant information [26]. The short

message service (SMS) is one of the most widely used mobile communication method that is capable of sending and receiving text messages as a means of communication. SMS based services are now more attractive to service providers and users as a result of the recent mobile phone use penetration and the large scale adoption of the existing services by users [26].

Hence, mobile text message reminders are among the cost effective ways to improve attendance for health programs. Different studies in Bangladesh [27], Beirut [28] and Pakistan [14] demonstrated that a mobile phone intervention can improve child health services.

Although mHealth interventions are promising in health care, little is known about current practice in developing countries, including sub-Sahara Africa where mHealth is a relatively new concept and questions arise regarding the feasibility of the technology [15,16]. The successful implementation of SMS based mHealth interventions also demands development of automated reminder systems with the current knowledge of the local context [29]. Therefore, this paper reports the development and testing process of text messaging reminders that could improve timeliness and coverage of routine child hood vaccinations in Ethiopia.

Objective

To design, develop and test an automated text messaging reminder system for the routine child immunization program in Ethiopia.

Methods

Description of the automated reminder system

This automated reminder system is a web based application developed as an mHealth intervention package for a randomized controlled trial study that will assess the effectiveness of text message reminders in improving completeness and timeliness of routine immunization program in North-West, Ethiopia.

Study design

The following specific methods were considered during design and development of the automated reminder system:

- Conducting a requirement gathering and analysis
- Conducting a thorough architectural designs of the application in various platforms
- Conducting a complete database designs
- Conducting the necessary user interface designs of the final output
- Coding different components and integrating them to deliver the first prototype of the system
- Testing the prototype through various mechanisms
- Completing the whole system from the prototype and the feedbacks gained

Development of the -system

The system is developed using iterative development process. The development process was conducted through consecutive steps summarized in the table below (Table 2).

Table 2. Text message reminder system development steps

Step 1: Requirement gathering	Step 2: Designing the automated SMS reminder system	Step3: Development and testing of the automated SMS reminder system	Step 4: Pilot testing of the automated reminder system	Step 5: Refinement and finalization of the system

Requirement gathering

Two methods were used to gather need assessment. The first method was observing the EPI work flow of health facilities and making an interview with relevant stakeholders. The second method was by exploring information from secondary sources of data (Figure 1).

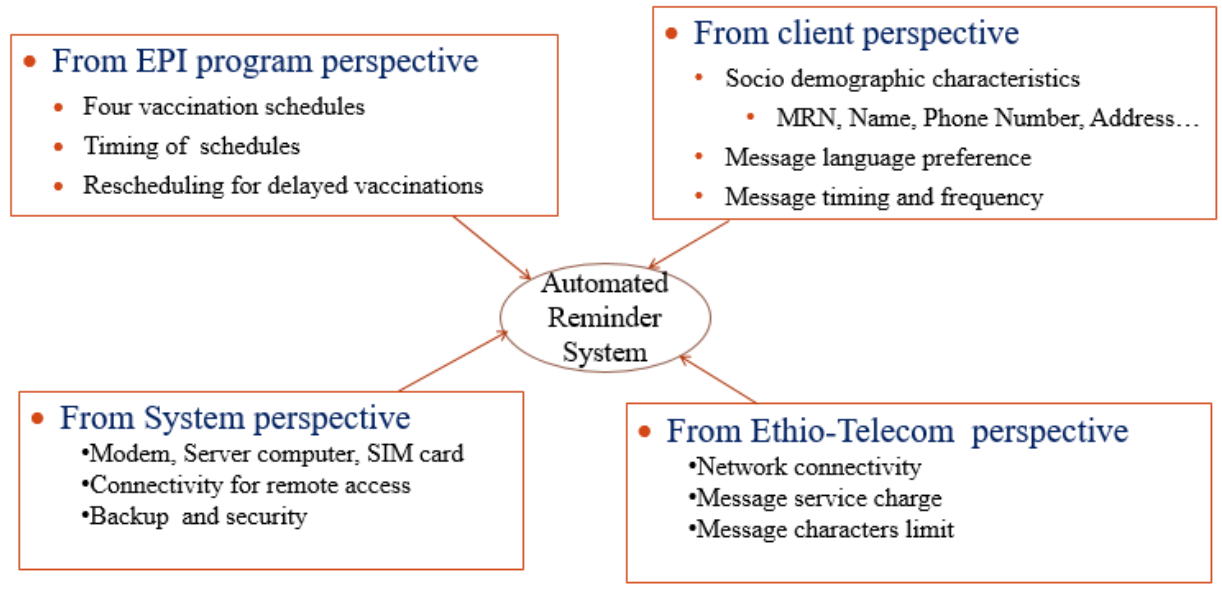

Figure 1: Requirement gathering for the text message reminder system development

System design and development

System design: It illustrates how the vaccination reminder system via text message alert operates (Figure 2). First, caregivers who decided to use the system will be registered in nearby health facilities. During the registration, information on the caregivers and child will be stored. This includes data on caregiver's mobile number and date of birth of the registered child.

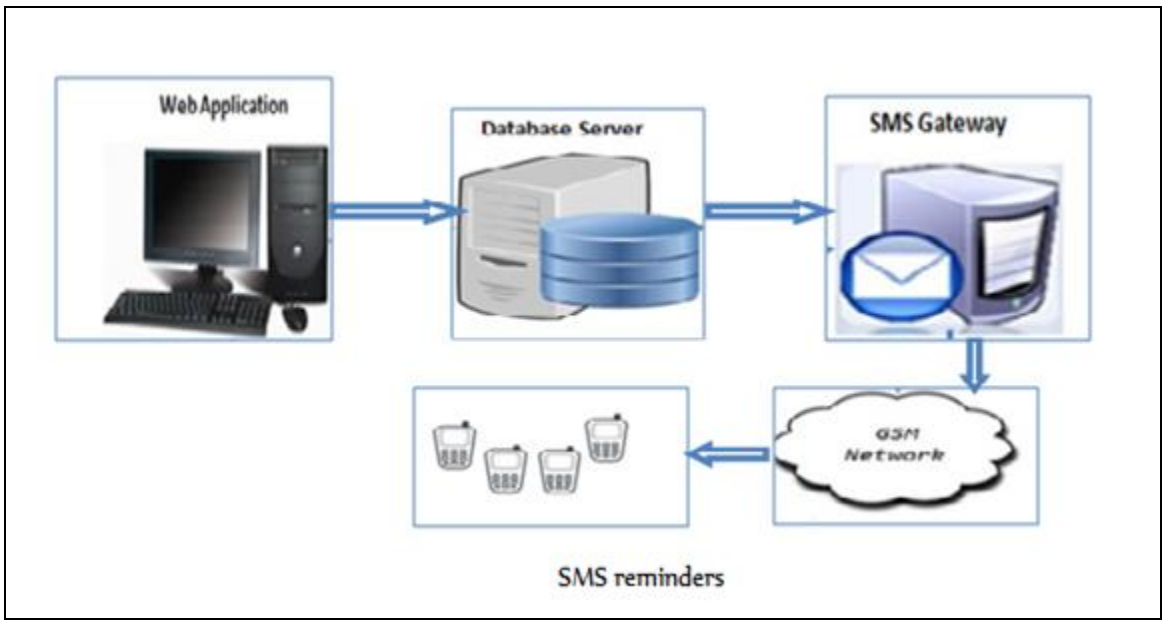

Figure 2: Text message reminder system architecture for routine child vaccination

Automated system development

They system is developed using front end and backend technologies. For the front end development java technologies have been used. For the back end, oracle database has been used. The system is developed with prime face technologies so that it have flexible graphical interfaces and it is easy to use.

Technologies used

In this automated system development, the following hardware and technological software products were used:

Hardwares used for system development

The system development needed different hardware materials including:

- Personal computer (PC)
- Flash disc
- Sirreta Modem: This modem is used to handle the SIM card.

Sofwares used for system development

- **Glash fish server:** We have used this web server for development and deployment.
- **Edraw Max**: It is a graphics software that makes it simple to create professional looking flowcharts, workflows, program structures, web design diagrams and database diagrams.

Automatic text message feature design

Each text message was designed within the length of standard characters limit designed for 160 character. Based on the prior assessments text messages were developed both in Amharic and English languages. Each text message will be dispatched automatically to caregivers from the computerized system.

SMS messaging components with large scale text messaging programs require specialized software applications and services to handle message content, automatic scheduling, and message routing services to deliver messages via multiple cellular network carriers. In this system, an SMS gateway encodes and routes text messages.

In case of delayed vaccinations, where a child didn't get vaccines on schedule, re programing will be done to occur after 4 weeks from the previous dose. For example, if a pentavalent vaccination is given later than the scheduled date, then text message reminders for the subsequent pentavalent dose will be reprogrammed to occur at 4 weeks from the date of vaccine receipt as per the national immunization guidelines.

Results

The automated reminder system was developed in two phases. The system design and development was completed on November, 2018 and piloting the automated text message reminder system was completed on March, 2019.

Design and development of the automated reminder system

An automated web based application for client registration, automatic reminder scheduling and automatic text messaging has been designed and developed. Based on the requirement gathering, initially the content, frequency and duration of the text-messages were designed. The developed text message contents were discussed with research team, selected health workers and mothers for refinement. Second, a computerized distribution system was developed on a desktop server interfaced with the network of a local mobile service provider through a global system for mobile communication modem. The automated reminder system underwent repeated refinement before the pilot testing.

Pilot testing of the automated reminder system

Pilot testing of the automated system involved 30 participants. In the pilot testing, all the 30 text messages (100%) were automatically dispatched from the application software to the participants. In addition, the system has shown notifications that the text messages have been sent for respective participants successfully.

Interface design and features of the reminder system

The automated reminder system has two components: 1. Web based application for client registration and automatic reminder scheduling; 2.SMS application for automatic SMS text messaging. The features of the automated reminder system has been presented as follows:

1. **Login page:** This page welcomes the user to the reminder system application. The reminder system has a secured log in page which enables users to access the system based on their access privilege. Only authorized users are able to use the system and this is due for security purposes. A user needs to provide a user name and password to log in to the system. If both of the information are correct, then the system will display the main page. On the other hand, if the user name or password is incorrect the system will display an error message (Figure 3).

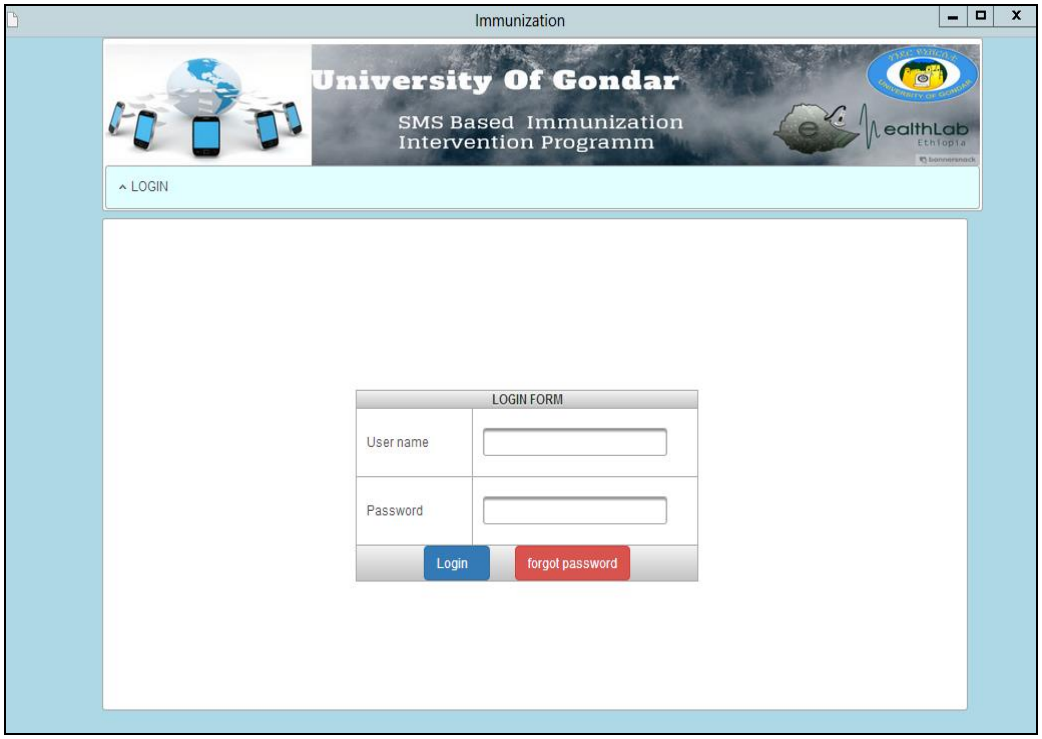

Figure 3. Log in page of the automated reminder system

2. **Client's registration and list setup:** This is the window where each individual caregivers and their infants socio-demographic as well as their health related information's will be recorded. The system has validation rules that will detect the double recording of individual clients. In addition, it has a must to enter fields to capture all-important information's. Registration of new clients for child immunization can be made by clicking the "Create new" button. This page allows the user to add new contact information or edit existing ones. In order to delete any contact the user just clicks the delete link beside the desired contact in the grid in order to delete that contact (Figure 4).

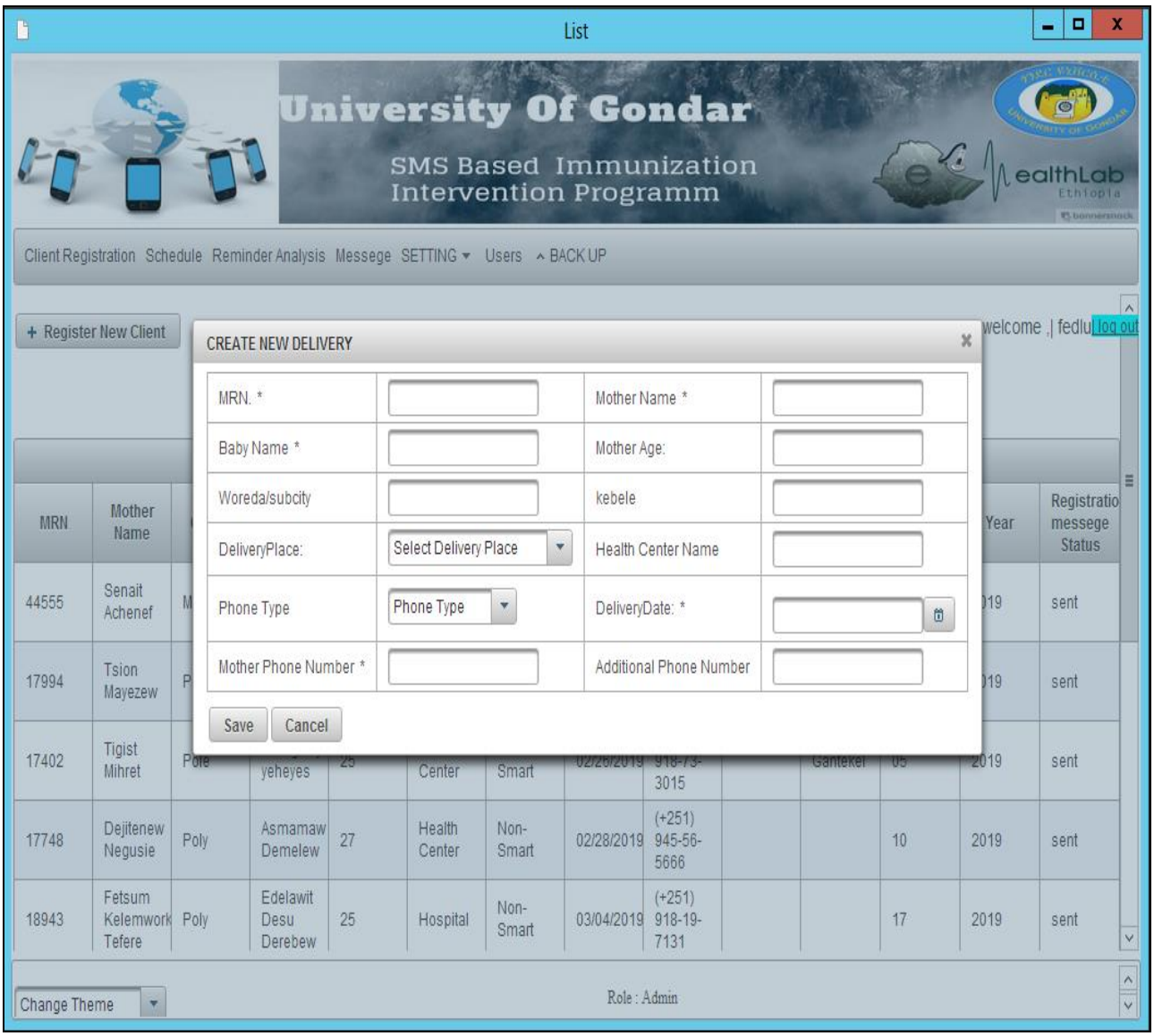

Figure 4. Client's registration and list setup of the reminder system

3. **Vaccination scheduling setup:** The vaccination scheduling setup manages the automatic scheduling of vaccination visits by considering the date of birth of the infant. In case of delayed vaccinations, the reminder system reschedules the vaccination visits by taking in to account the vaccination dates of the previous doses (Figure 5).

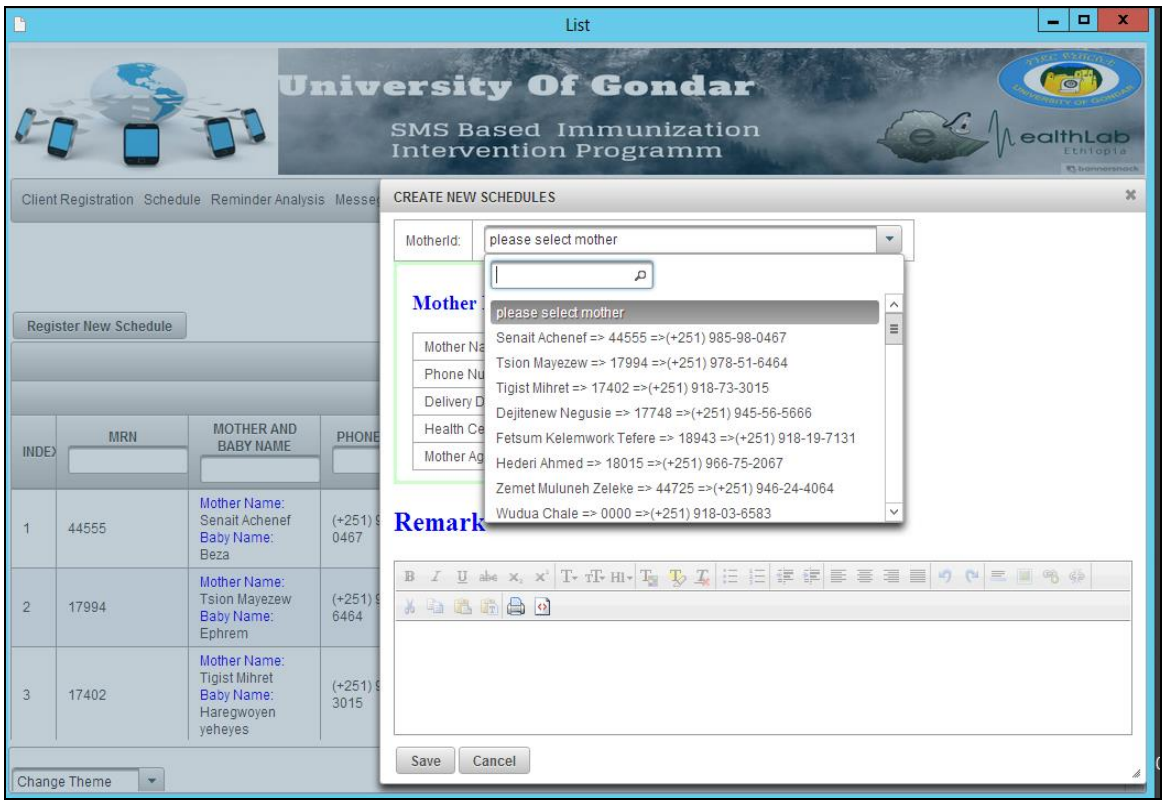

Figure 5. Vaccination scheduling setup of the automated reminder system

4. **Reminder analysis setup:** This window helps to see the status of text messages sent for each client. It has a filter option to look for individual records. The system also has a field too record the vaccination status of each infant (Figure 6).

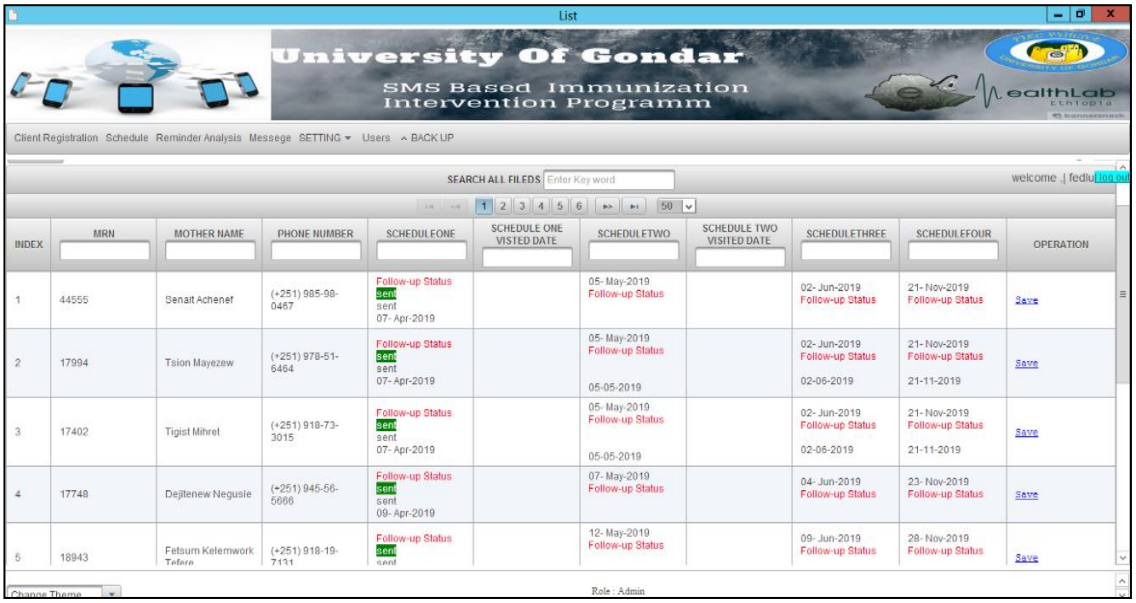

Figure 6. Reminder analysis set up of the automated reminder system

5. **Automated text message setup:** The automated text messages were developed both in Amharic (local language) and English languages for each of the four vaccination schedules. The system has reminder message setting with which the text messages can be edited accordingly (Figure 7).

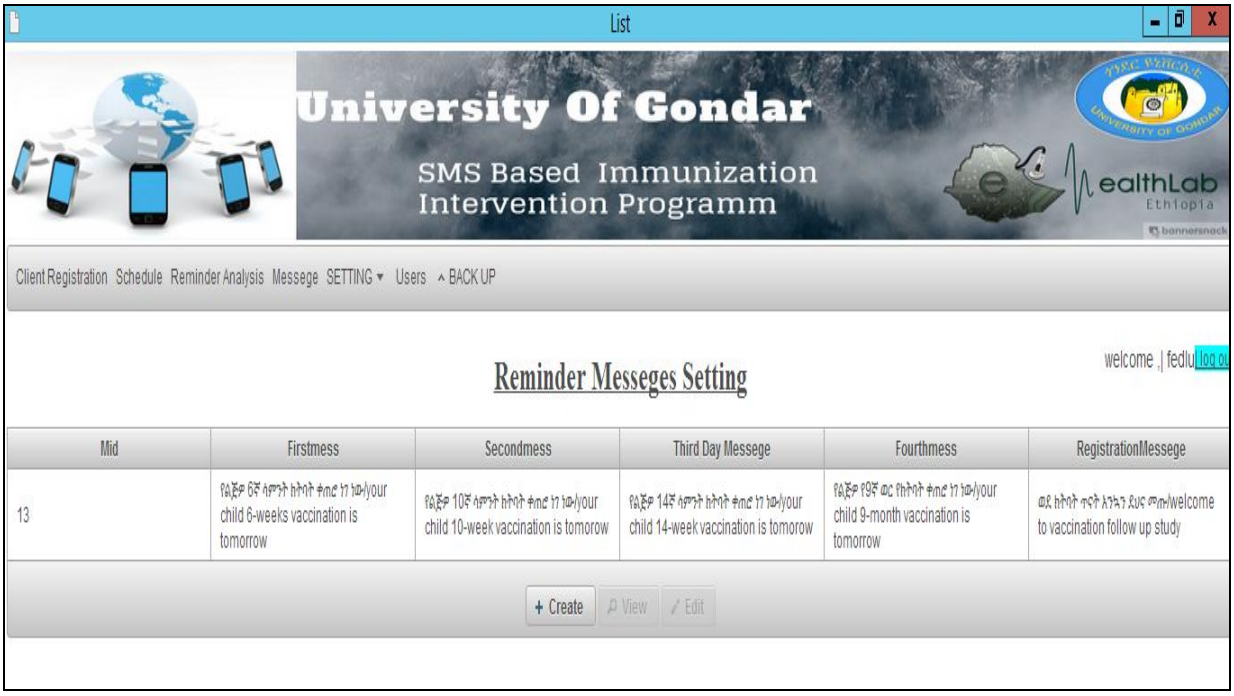

Figure 7. Text message set up of the automated reminder system

6. **Export options:** The automated reminder system can export the data sets to excel and PDF versions (Figure 8).

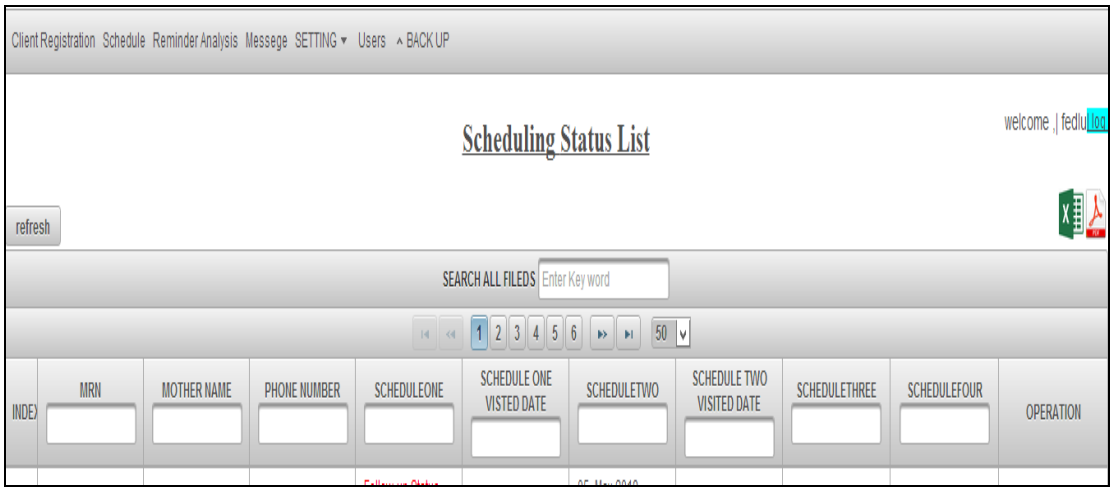

Figure 8. Export options of the automated reminder system

7. **Automatic text messaging and sent message notification:** The system manages an automated dispatch of text-messages based on pre-determined phone number of caregivers. When a text reminder has been sent to a caregiver, the system will display a notification message that says "Text message has been sent to the client". On the other hand, when the system was unable to send the text messages automatically, it shows sending error messages (Figure 9).

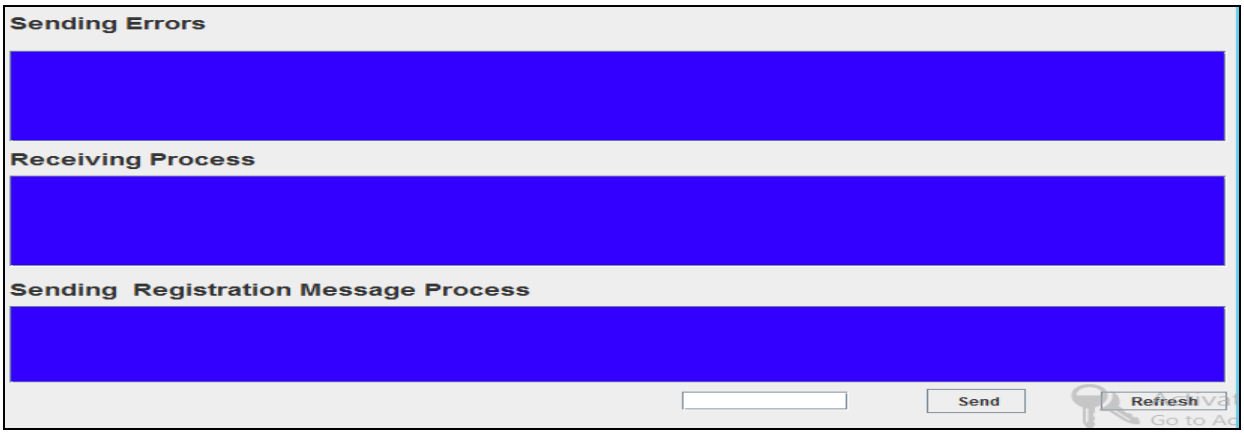

Figure 9. Text message sending and error notification of the automated reminder system

Discussions

Existing practice on vaccination schedule is via written appointment. Nevertheless, such approach may not be sufficient as parents may forget due to a tight work schedule and daily routines. Missed appointments are also an avoidable which impact upon the health outcomes of clients. Similarly, poor awareness about immunization schedules and forgetfulness were the most cited reason parents gave for not completing their child's immunization timely [30].

As the use of information and communication technologies (ICT) has become the nervous system of all modern economies, making health institutions smarter is usually achieved through the use of ICT intensive solutions like mHealth. Among the mHealth interventions, SMS is one which stands for short message service, which is a communications protocol adopted as a synonym for text messages [26].

Mobile SMS has become more popular because it is easy and simple to use, and every type of mobile phone has this kind of application. Health workers are also increasingly utilizing SMS based reminder systems to improve health service uptake and continuity of care. Hence, simple and effective SMS based mHealth interventions that can be integrated in the existing health systems are required to increase caregiver's attendance for timely immunization of children in Ethiopia [31].

SMS based reminder systems effectiveness varies across different settings [26]. In line with this, a randomized controlled trial (RCT) study is being conducted to test the effectiveness of text message reminders in improving continuity of vaccination services in North-West, Ethiopia. This trial is expected to produce evidence on the effectiveness of text message reminders on the

uptake of routine child hood immunization which will then be scaled up into similar geographic areas in the country. Therefore, this text message based mHealth intervention package is developed as an intervention package for the RCT study.

This paper demonstrated how best to develop an automated reminder system for vaccination program in Ethiopian context. The study indicated the importance of obtaining feedback about the content of text messages and iteratively testing the developed system before actual deployment. Research findings also revealed that tailoring the reminder system based on client preferences and applying multiple modalities results in better system development [32]. Evidences also showed that text messages should incorporate methods of ensuring that the text messages are developed and tested in the most appropriate way before they are deployed [29,33].

Strengths and limitations: The developed reminder system is secured with a password protected user interface which gives access to the system. The system works offline with desktop application and can be accessed remotely with network connectivity. The application has back-up system. The system is easy for updates on different domains. As a challenge, poor network connectivity and bugs within the system affected the sending process of the text messages during testing of the system. This led to repeated testing of the automated system until it successfully sent all the desired messages. Since the automated system is modem based, it only confirms the automatically dispatched text messages sent status from the system. However, it could not confirm the actual delivery of the text messages to the mobile phones of each caregiver.

Conclusions

Text message reminder system has been designed and developed for routine childhood immunization program in Ethiopia. Text message interventions should be carefully designed, developed, tested and refined before actual implementation. Moreover, the development of automated reminder systems should take in to account the local context and involvement of different stakeholders.

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Competing Interests

Authors have no competing interests

Availability of data and materials

Data sharing is applicable up on request

Ethical approval and consent to participate

This study obtained ethical approval from University of Gondar Institutional Ethical Review Board Ref. No: O/V/P/RCS/05/060/2018. In addition, study permissions were acquired at all levels of governmental administration systems including health offices and health facilities. For the pilot testing, informed consent was obtained from each of the study participants.

Contributions

ZM: Initiated the study and the text message reminder development process. ZM, FH, BT and KG: Did the requirement gathering and system design. FH and ZM: Developed the automated reminder system. BT, KG and AM provided technical guidance during development of the reminder system. ZM, FH, BT, KG and AM: Did the pilot testing and refinement of the system. ZM and FH drafted the manuscript. BT, KG and AM revised the manuscript. All authors read and approved the final manuscript.

References

1. WHO/UNICEF. Global Immunization Vision and Strategy 2006-2015, Geneva. 2015.

2. FMOH. National Strategy for Newborn and Child Survival in Ethiopia National Strategy for Newborn and Child Survival in Ethiopia. 2019;(June 2015).

3. FMOH. Ethiopia National Expanded Program on Immunization, Comprehensive Multi - Year Plan 2016 – 2020. Federal Ministry of Health, Addis Ababa, Ethiopia. 2015;1–115.

4. WHO. World Health Statistics: Monitoring health for the SDGs. 2016; Available from: www.who.int/gho/publications/world_health_statistics/2016/en/ %0A%0A%0A

5. WHO/UNICEF. Ethiopia: WHO and UNICEF estimates of immunization coverage: 2017 revision. 2017;1–27.

6. Restrepo-Méndez MC, Barros AJD, Wong KLM, Johnson HL, Pariyo G, et al. 2016. Missed opportunities in full immunization coverage: Findings from low- and lower-middle-income countries. *Glob Health Action*. PubMed https://doi.org/10.3402/gha.v9.30963

7. Black RE, Cousens S, Johnson L, Lawn E, Rudan I, et al. 2010. Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet*. PubMed https://doi.org/10.1016/S0140-6736(10)60549-1

8. CDC. Global Routine Vaccination Coverage. 2015;

9. Dayan GH, Shaw M, Baughman L, Orellana C, Forlenza R, et al. 2006. Assessment of delay in age-appropriate vaccination using survival analysis. *Am J Epidemiol*. 163(6), 561-70. PubMed https://doi.org/10.1093/aje/kwj074

10. USAID. Extended Program on Immunization (EPI) coverage in selected Ethiopian zones: A baseline survey for L10K's Routine Immunization Improvement Initiative. JSI Research and Training Institute Inc. / The Last Ten Kilo Meters Project (L10K). 2015;

11. Pertet M, Wanjala C, Jaoko M, Odindo D, Kirika L, et al. Completion, timeliness, and under - vaccination of childhood vaccinations in a nomadic pastoralist community of Kenya. Int J Contemp Pediatr. 2018.

12. Fadnes T. et al. Is vaccination coverage a good indicator of age-appropriate vaccination? A prospective study from Uganda. 2011;29(19):3564-70. doi: 10.1016/j.vaccine.2011.02.093.

13. Minh An DT, Lee K, Van H, Trang H, Huong T, et al. 2016. Timely immunization completion among children in Vietnam from 2000 to 2011: A multilevel analysis of individual and contextual factors. *Glob Health Action*. Feb 29;9:29189 PubMed

14. Kazi AM, Ali M, Zubair K, Kalimuddin H, Kazi AN, et al. 2018. Effect of mobile phone text message reminders on routine immunization uptake in Pakistan: Randomized controlled trial. *JMIR Public Health Surveill.*. 4(1):e20 PubMed https://doi.org/10.2196/publichealth.7026

15. Aranda-Jan CB, Mohutsiwa-Dibe N, Loukanova S. 2014. Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa. *BMC Public Health*. Feb 21;14:188. PubMed https://doi.org/10.1186/1471-2458-14-188

16. Oyo-Ita A, Wiysonge Charles S, Oringanje C, Nwachukwu Chukwuemeka E, Oduwole O, et al. Interventions for improving coverage of childhood immunisation in low- and middle-income countries [Internet]. Cochrane Database of Systematic Reviews. John Wiley & Sons, Ltd; 2016.
Available from: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD008145.pub3/abstract

17. Patel TA, Pandit NB. Why infants miss vaccination during routine immunization sessions? Study in a rural area of Anand district, Gujarat. Indian J Public Heal. 2011

18. Haji A, Lowther S, Ngan'ga Z, Gura Z, Tabu C, Sandhu H, et al. Reducing routine vaccination dropout rates: evaluating two interventions in three Kenyan districts, 2014. BMC Public Health. 2016/02/18. 2016;16:152.

19. Bangure D, Chirundu D, Gombe N, Marufu T, Mandozana G, et al. 2015. Effectiveness of short message services reminder on childhood immunization programme in Kadoma, Zimbabwe-a randomized controlled trial, 2013. *BMC Public Health*. 15(1), 137. PubMed https://doi.org/10.1186/s12889-015-1470-6

20. Mutua MK, Kimani-Murage E, Ngomi N, Ravn H, Mwaniki P, et al. 2016. Fully immunized child: coverage, timing and sequencing of routine immunization in an urban poor settlement in Nairobi, Kenya [Internet]. *Trop Med Health*. 44(1), 13. doi:https://doi.org/10.1186/s41182-016-0013-x. PubMed

21. Wakadha H, Chandir S, Were V, Rubin A, Obor D, Levine OS, et al. The feasibility of using mobile-phone based SMS reminders and conditional cash transfers to improve timely immunization in rural Kenya. Vaccine. 2012/12/19. 2013;31(6):987–93.

22. Gibson DG, Hariharan N, Moulton LH, Ochieng B, Kagucia EW, et al. 2016. The Mobile Solutions for Immunization (M-SIMU) Trial: A Protocol for a Cluster Randomized Controlled Trial That Assesses the Impact of Mobile Phone Delivered Reminders and Travel Subsidies to Improve Childhood Immunization Coverage Rates and Timeliness in Western Kenya. *JMIR Res Protoc*. 5(2):e72 PubMed https://doi.org/10.2196/resprot.5030

23. Babirye JN, Engebretsen IMS, Makumbi F, Fadnes LT, Wamani H, et al. 2012. Timeliness of childhood vaccinations in Kampala Uganda: a community-based cross-sectional study. *PLoS One*. 7(4), e35432. PubMed https://doi.org/10.1371/journal.pone.0035432

24. FMOH. Ethiopian National eHealth Strategy. 2016;

25. Kazi AM, Carmichael J-L, Hapanna GW, Wangoo PG, Karanja S, Wanyama D, et al. Assessing Mobile Phone Access and Perceptions for Texting-Based mHealth Interventions Among Expectant Mothers and Child Caregivers in Remote Regions of Northern Kenya: A Survey-Based Descriptive Study. JMIR public Heal Surveill. 2017;

26. Lin C-L, Mistry N, Boneh J, Li H, Lazebnik R. 2016. Text Message Reminders Increase Appointment Adherence in a Pediatric Clinic: A Randomized Controlled Trial. *Int J Pediatr*. 2016:8487378. PubMed https://doi.org/10.1155/2016/8487378

27. Uddin MJ, Shamsuzzaman M, Horng L, Labrique A, Vasudevan L, et al. 2016. Use of mobile phones for improving vaccination coverage among children living in rural hard-to-reach areas and urban streets of Bangladesh. *Vaccine*. 34(2):276-283 PubMed https://doi.org/10.1016/j.vaccine.2015.11.024

28. Ghadieh AS, Hamadeh GN, Mahmassani DM, Lakkis NA. 2015. The effect of various types of patients' reminders on the uptake of pneumococcal vaccine in adults: A randomized controlled trial. *Vaccine*. Oct 26;33(43):5868-5872 PubMed https://doi.org/10.1016/j.vaccine.2015.07.050

29. Higgs ES, Goldberg AB, Labrique AB, Cook SH, Schmid C, et al. 2014. Understanding the role of mhealth and other media interventions for behavior change to enhance child survival and development in low-and middle-income countries: An evidence review. *J Health Commun*. 19 Suppl 1:164-89 PubMed https://doi.org/10.1080/10810730.2014.929763

30. Yusof Y, Almohamed A. Children Vaccination Reminder Via SMS Alert. Conference Paper, November 2011. DOI: 10.1109/ICRIIS.2011.6125750

31. Brown W, Giguerec R, Sheinfilc A, Ibitoye M, Balanc I, et al. 2018. Challenges and solutions implementing an SMS text message-based survey CASI and adherence reminders in an international biomedical HIV PrEP study (MTN 017). *J Biomed Inform*. 80, 78-86. PubMed https://doi.org/10.1016/j.jbi.2018.02.018

32. Lacy Clayton and Joanne Serembus. Evaluation of a Reminder System for Perinatal Psychiatric Appointments, 2018

33. Githinji S, Jones C, Malinga J, Robert W. Snow, Ambrose Talisuna and Dejan Zurovac. 2015 Development of a text-messaging intervention to improve treatment adherence and post-treatment review of children with uncomplicated malaria in western Kenya. *Malar J*. 14, 320. PubMed https://doi.org/10.1186/s12936-015-0825-x

34. CSA. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia. 2016.