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Feasibility and Acceptability of Mobile Graphic-Based Reminders to Support Adherence of Tuberculosis Treatment in Developing Countries

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Abstract: The phenomenon of rapid increment of the mobile phones can be utilized through supporting patients such as those who have TuBerculosis (TB) for treatment adherence. This utilization will enable these patients to directly communicate or receive health information such as reminder messages from healthcare facilities. However, the current mobile interventions such as text messaging and speech reminder systems have limited use for people with low literacy levels. The aim of this study was to assess the feasibility and acceptability of mobile Graphic-Based Reminders (GBRs) to support compliance of treatment regimens among TB patients, especially, semi-literate and illiterate patients. A total of 59 adults who are active TB and taking anti-TB drugs were enrolled in a randomized controlled trial. The trial was conducted in Zanzibar, Tanzania between 2015 and 2017. Participants were randomized to three groups: GBRs speech-based reminders control group without reminder. Participants participated in qualitative semi-structured interviews on feasibility and acceptability of this technology. Systematically analysed was used to analyse qualitative data. Quantitative data, resulting from experimental event logs which recorded based upon device metrics collected electronically and summarized descriptively using SPSS (Version 21). The results revealed that GBRs is generally acceptable; the feedback from participants was perceived usefulness-the intervention was beneficial in motivating and reminding patients to take medication as well as enabling provision of social support. The GBRs was found to be technically feasible to support compliance of TB treatment as data were obtained from most participants as expected most of the time.

INTRODUCTION

Adherence to anti-tuberculosis therapy: Tuberculosis (TB) remains one of the biggest public health challenges, especially, in developing countries. In 2016, there were an estimated 10.4 million new TB cases worldwide, 10% of which were people living with HIV. All countries are affected by TB but about 85% of all cases occur in Africa

and Asia[1, 2]. Sub-Saharan Africa has the largest number of TB cases. It is estimated that there are over 260 cases per 100 000 people[2]. Out of the 22 countries that are referred to as 'TB high burden' countries, nine of them are in Africa. Non-adherence to TB treatment is one of the major challenges in improving TB cure rates. TB treatment requires patients to take medication for a minimum period of six months[3]. However, patients often do not follow the recommended treatment regimen. This normally leads to an extended recovery period and the development of resistance to the medication, eventually aggravation of the disease.

Potentials of mhealth technologies: The growing area of m-health in low and middle income areas has contributed to an increase in the number of systems targeting patients such as those with HIV/AIDS[4], malaria[5], diabetes[6] and TB[7]. A number of studies have been conducted in the use of mobile technology to support patient's treatment. Recently, mobile reminder systems have shown positive change in improving treatment adherence in comparison to traditional reminder systems such as poster and calendar systems or care without any reminders[8, 9]. Mobile phones have been also integrated as health intervention tools in many healthcare aspects including disease prevention, data collection[10], diagnosis and treatment[11] and adherence management[12]. Thus, in this study, mobile phones are proposed as a tool to support the treatment adherence of TB.

Feasibility and acceptability of mhealth technologies for TB treatment: The feasibility and acceptability of mobile reminders in Tanzania, however have not been well studied. Mobile reminders triggered by voice message contained the name of the patient and indication of the day and time of appointment or dosage improved adherence to TB treatment in South Africa, although, it was challenging to create speech messages in different languages that participants understand.

Supporting TB patients in taking their medication are also presented by Kunawararak *et al*.[7] in which patients were given a daily phone call and Iribarren *et al*.[13] the patients were given SMS reminders to take their pills and follow up their clinic appointments. Another work that presented by Mohammed *et al*.[14] who describe how an interactive SMS text message reminder system was designed to support improved treatment adherence for TB patients.

Daily SMS reminders were sent to registered patients to remind them to take medication. Patients were asked to reply by text message every time they took their pills. The date and time of the patient's responses were recorded. However, the study outcome was that mobile reminders improved patient's adherence to treatment compared with usual care without mobile reminders, the variability of effectiveness of mobile reminders and more thorough assessments of their feasibility and acceptability are needed. This randomized controlled trial based on real-time intervention linked to mobile GBRs to support adherence among patients who are active TB and taking anti-TB drugs in Zanzibar, Tanzania. As previously published[15], adherences to treatment significantly improved for patients receiving mobile GBRs that were sent daily, weekly and monthly basin.

Moreover, participants reported that the intervention encouraged adherence through behaviour change, clinic appointments and a desire to show commitment to taking their medication[15]. Within the context of this study, qualitative and quantitative methods were used to assess the feasibility and acceptability of the mHealth GBR system and determinants of mobile phone utilization in supporting patients to TB treatment adherence.

The intervention technology: mobile GBRS treatment adherence: Mobile GBR system is an application developed using the Java programming language for the Android platform. Android for mobile devices was selected due to two main factors. First, Android was chosen because it is open source[17] and second, it is the most popular operating system that runs on smart phones.

The aim was to provide a user friendly system that enables patients to easily use and understand the meaning of reminders. The first interface after the system is launched is the log in screen where the user is asked to enter his/her credentials (Fig. 1). After user presented the right credentials the reminder system containing the graphic messages are sent to the user's phone and are triggered based on the TB treatment schedule. The system contains various reminder messages that are divided into four groups: medication reminders such as take pills, refill medications and submit smear sputum; clinic follow-up reminders regarding clinic appointments or consultations; education reminders for behaviour improvement such as avoiding pain or spreading the disease to others and health reminders to improve eating habits. These reminders are set to automatically activate on different days and times based on the TB treatment regimen, which include daily, after every two days, weekly and monthly. The system also contains an 'update' option which allows a registered user to update his/her password information. The m-health GBR system is specifically designed for supporting TB patients to adhere to treatment within the context of resource-limited and low-literacy settings. It is a two-way communication system in which a patient is

Fig. 1: The components of M-health GBR application

asked to respond by pressing a 'feedback button' to indicate that he has received the reminder and the medication has been taken.

A feedback button was created that appeared immediately after a reminder message has been triggered and dismissed. The response is then sent to the local hospital database. When disconnected, a SQLite database was created to store the responses offline and automatically forward these as soon as an Internet connection becomes available. At every appointed time, the respondent's phone was connected to the Internet using the hospital's wireless connection or mobile data. Once connected to the Internet, the data was automatically synchronised with the database server. The medication response reports can then be viewed by a health care worker for further treatment processes. This will also help the health care worker to follow the routine of a patient's treatment regimen.

In order for the reminder message to be activated an alarm manager service with a broadcast receiver was implemented. A broadcast receiver can be defined as a component that responds to system-wide broadcast notifications. This allows a reminder message to be activated at a defined time. For instance, if a user's phone clock is the same as the time of the reminder (i.e., 7 h or 7 am), then the broadcast receiver class is activated. This process then calls a reminder class (activity class) that contains a graphic message reminder.

Furthermore, a 'reboot' (boot completed) function that allows the reminder application to automatically start was implemented. This allows the application to continue running after the device is rebooted. The idea is that when a mobile phone is switched off all applications are terminated. The 'boot completed' function allows the application to self-restart and work as usual.

In order to comparatively measure the effectiveness of the GBRs, the speech-based reminder system was used. This system was used instead of other reminder methods that are text-based because some participants were illiterate and therefore unable to read the texts but could understand verbal communication. This application worked similarity to the GBR system. The difference between them is that in the GBR prototype, graphics with audio for notification are triggered as reminder interventions while in the speech-based prototype, only audio (speech) is triggered as reminder interventions.

MATERIALS AND METHODS

Study site and participants: A total of 59 participants participated in the study using a mixed-methods approach. The participants were adults who are active TB and taking anti-TB drugs are based in Zanzibar, Tanzania. Semi-structured in-depth interviews were conducted to assess the feasibility and acceptability of the intervention. The study was conducted between 2015 and 2017.

Study procedures: The participants in the experiments were TB patients who had started taking TB medications. The target population was all TB patients nationally. However, sampling was used in order to identify a subset of the total population. Multiple cluster sampling was used in this study in order to generate a useful sample. Since, the participants of this study were under supervision of healthcare workers, cluster sampling and using a random number generator was used to randomly select the participants according to the desired sample size. After participants showed an interest in participating in the study, they were randomly sampled within the clusters and assigned to three groups: a control group-without reminder (n = 22), a speech-based group-received only speech messages (n = 18) and GBR group-received speech and graphic messages (n = 19).

Participants in the GBR group and speech-based reminder group, first, received the audio-notification alerts-in each reminder message, telling them that they have received an important reminder message for example "Habari! Huu ni mfumo wa ukumbusho, umepokea ujumbe muhimu, tafadhali angalia simu yako" [English translation: Hi! This is the reminder system you have received the important message, please check your

phone]. After this, the users of the GBR system were directed to view graphic messages and those receiving the speech-based reminder were directed to press a button to listen to speech messages, for example, "Habari! Huu ni mfumo wa TB, unakumbushwa muda wa kunywa dawa zako umeshafika" [English translation: Hi! This is the TB reminder system you are reminded that the time to take your medication is approaching].

To ensure balanced representation and ensuring the validity of the research, each group contained both males and females, literate and illiterate patients, patients of different age groups, rural and urban residents and patients from different treatment phases (i.e., intensive or continuation). Only patients who understood Kiswahili local language in Zanzibar and who are undergoing home-based care (out-patients) were included. Healthcare workers assisted to categorize the patients into groups identified by who is literate, illiterate, receiving intensive care, continuation care, etc.

After completion of the sampling process, another stage was participant's recruitment. Participants were briefed on the purpose of the research and were trained on how the system works and assigned tasks such as pressing a 'feedback button' (as described in Section 2) once a reminder has been triggered and only after taking their medications. In order to ensure the participants were comfortable and convenient to the study, they were approached either at the clinic during their appointed times or at their homes in the presence of a healthcare worker. The recruitment sessions were conducted: in groups of more than one participant or with individuals, one participant at a time. Each participant received a gift or small payment to offset the transportation cost or provision of lunch when participating in the study.

Ethical consideration: The Ministry of Health and Social Welfare in Zanzibar granted ethical clearance for this study [Protocol number: ST/0002/JULY/014]. Before the experiment began, participants were requested to complete consent forms and permission forms for the researchers to record the interviews using image/video and audio. The consent forms for those illiterate participants were signed by their volunteers who support them in their treatment regimens such as family members or friends.

The researchers ensured that the participants were granted privacy and confidentiality. No participant was forced to reveal information to the researchers that they did not wish to reveal. The researchers ensured that the participant's anonymity was maintained. No personal identifiers such as names or phone numbers were linked to any participant. The researchers were aware that they were in a position of responsibility as they were dealing with personal information that the participants had agreed to disclose.

Data collection: All participants in the GBR and speech reminder groups were accessed mobile phones contained reminder systems. An application event log was used to collect data that was generated from responses while patients were using the applications.

The feasibility of the study was measured by collection of response rate including number and time, resulted from application event logs and adherence variables resulted from Self-Reported (SR) and Pill Count (PC) were used to indicate the treatment adherence rates for the control groups and intervention groups.

SR was conducted through face-to-face interviews with respondents. Patients were asked to report how they felt about the treatment adherence at each appointment time, weekly. The patient's responses were marked (on a paper) based on a range from worst possible pain to no pain of feelings. The results were then analysed in term of adherence rate before and after the trials.

PC was conducted through pill recorded system. The patients were asked to complete their record book (green card) with spaces to indicate if the pill was taken. Every time the patients attended the clinic for medication, refills were registered and pills that were not taken were counted. Patients were also asked to describe whether that medication was taken in full or less than the prescribed amount.

Furthermore, the followings null and alternative hypotheses were made in order to determine the significant different of number and time of reminder responses between GBR and speech-based reminder groups.

Null Hypothesis (Ho_1): The number of responses in the GBR is not greater than the number of responses in the speech-based reminder.

Alternative Hypothesis (Ha_1): The number of responses in the GBR is greater than the number of responses in the speech-based reminder.

Null Hypothesis (Ho_2): The time taken to respond to the GBR is not less than the time taken to respond to the speech-based reminder.

Alternative Hypothesis (Ha_2): The time taken to respond to the GBR is less than the time taken to respond to the speech-based reminder.

The acceptability of the technology was measured by semi-structured interviews conducted post-survey. The interviews were conducted with individual respondents, face-to-face. The interview questions included, for example user's perception (how the user perceived the technology) and usefulness (which mobile reminder system of the two interventions the users found more useful for supporting their treatment).

Field/text notes and audio recordings were used to capture the participant's feedback. The researchers directly took field notes and audio recordings at the time of the interviews with respondents. This was done in order to obtain the participants' feedback regarding the system.

Data analysis: The study generated two types of data: quantitative data, resulting from experimental event logs and qualitative data, resulting from observations, semi-structured interviews. The quantitative data, obtained from event logs was converted into numerical form. The numerical data was then entered and analysed using SPSS software (Version 21) in order to generate descriptive information. The qualitative data was systematically analysed by the researchers, subjecting it to a three stage analysis method: data reduction, display and conclusion drawn. All transcripts were read individually by the researchers and every interesting idea or concept was written using analytic memos. The data was then discussed in detail by the researchers including healthcare workers to obtain reliable concepts.

The Mann-Whitney U test was used to compare the number and time of responses between the GBR and speech-based reminder groups (quantitative data). This non-parametric test-Mann-Whitney-is more appropriate to use in this analysis than parametric tests such as the t-test. This is because firstly, the variances of the data between the two groups were very different. Secondly, this data was made up of independent random samples obtained from populations of the same characteristics.

A $p<0.05$ (95% confidence interval) was considered to detect a significant difference for all analyses. According to Johnson[18], a significance level is a value for which a p-value is less than what is defined in a given hypothesis test ($p<0.05$). Usually, the p-value corresponds to the probability of observing the values by chance.

RESULTS AND DISCUSSION

Characteristics of participants: The overall distribution of the study participants is shown in Table 1. All participants (59) were analysed. Their average age was 40 years (ranging from 18-72 years) and 51% were women. Twenty-three (39%) participants were either illiterate or semi-literate, 37% resided in rural areas, 61% were receiving treatment in the continuation phase and the majority of participants were self-employed (37%).

Intervention feasibility: The total percentage response rate during the study was 7 7.8% as detail shown in the Table 2. The participants found the mobile reminder system to be useful in supporting them to remember the days and times of taking medication and clinic appointments. This contributed to have the greatest effect on response rates. However, there were some challenges occurred with the mobile phones including cell phone problems; some patients expressed that sometimes the phone's battery would run out. This was mostly caused by frequent blackouts. Another reason mentioned was that the phone was muted or switched off particularly during meeting or prayer times. These challenges may contribute to some reminders not triggered on time or not opened at all.

Table 1: Demographic information of participants

Parameters	Frequencies (N = 59)	Percentage
Gender		
Male	29	49
Female	30	51
Treatment type		
Intensive	23	39
Continuation	36	61
Age group		
18-27	12	20
28-37	13	22
38-47	16	27
≥48	18	31
Literacy level		
Can read and write	36	61
Cannot read and write 23	39	
Residence status		
Urban	37	63
Rural	22	37
Occupation		
Employed	14	24
Unemployed	16	27
Self-employed	22	37
Students	7	12

Table 2: Summary of the results of mean number and time of reminder response for GBR and speech reminder groups

Variables	Experiments
Total percentage response (%)	77.8
Graphic	68.5
Speech	58.9
The mean response time (min)	
Graphic	23.8
Speech	32.9

The following sections present the findings as per the evaluation metrics including the effect of reminders on improving adherence to treatment, effect of reminders on the number of responses and efficiency of response time to reminders.

The effect of reminders on improving adherence to treatment: There was a difference between the adherence rate to the treatment in the control group, speech group and GBR group. The patient's SR adherence rate for the control, speech and GBR groups were 56, 77.1, 89.1%, respectively. The PC adherence rates were 63.4% in the control group, 80.3% in the speech reminder group and 95% in the GBR group. Both SR and PC variables show that treatment adherence rate was higher for GBR group than for control group.

Similarly, the SR and PC variables show that treatment adherence rate in the GBR group was higher than in the speech reminder group. Thus, the treatment adherence rate in the mobile GBR group is larger than in the speech reminder group and control group.

The effect of reminders on the number of responses: A Mann-Whitney U test indicated that the number of responses to the system was significantly higher for GBR group (mean ranks = 24.82, median = 69.75) than for speech reminders (mean ranks = 13.19, median = 69.5), U = 65.75, p = 0.0031.

This analysis reveals that there was a higher response to the system in the GBR group than in the speech reminder group. This was the case for all patients who sent more feedback for the GBR than speech reminder groups.

Results from the experiment indicate that there was a significant difference in the number of reminder responses between the GBR and speech reminder groups. With $p<0.001$, therefore, the Null Hypothesis (Ho_1) is rejected in favour of the alternative Hypothesis (Ha_1). Thus, the number of reminder responses in the GBR group is greater than the number of reminder responses in the speech reminder group.

The efficiency of response time to reminders: The mean response time to the system was 23 in the GBR group and 31.5 in the speech reminder group. A Mann-Whitney U test indicated that the response time to the system was significantly lower for the GBR than the speech reminder (the mean ranks of the GBR and speech reminder were 4.33 and 10.68, respectively; U = 2.25, p = 0.0045).

This finding shows that patients in the GBR group responded significantly faster than the speech reminder group. As found in the number of response, this was the case for all reminder times.

These findings therefore, show that there was a significant difference in the response time to the system between the speech and the GBR groups with $p<0.01$. So, the Null Hypothesis (Ho_2) is rejected in favour of the Alternative Hypothesis (Ha_2). Thus, the time taken to respond to the GBR is less than the time taken to respond to the speech-based reminder.

Intervention acceptability: The qualitative findings show that the GBR system rated highly on indicators of preference and satisfaction. The patients felt that the graphic reminder can be useful in supporting them to remember taking their medication and follow-up clinic appointments. Almost all participants indicated the graphic application as being more helpful as a TB reminder system, although few participants found both interventions helpful in supporting the TB treatment. Here, is some of the verbatim feedback from respondents.

Respondent A said: "I really appreciated the system, all images gave clear messages. This application seems to be worthwhile in helping us in treatment regimen. I think this idea should be used also for management of other disease such as HIV, leprosy and diabetes".

Respondent B said: "This is a fantastic idea. I really enjoyed the system because it has made my life easy. It helped me remember taking my medication and clinic appointment days. The graphic system was most helpful and I wish this system to be implemented. The problem with speech system was that when it was too noisy you wouldn't be able to hear what a person said (speech reminder)".

The findings further suggest that a GBR system could be used even for patients who have problems with hearing. The qualitative feedback also conveyed the patient's experiences with the mobile reminder systems. For example, one patient indicated that the system helped him to experiencing that 7 am is the time to take the medication (7 am is usual a suggested time for TB patients to take medication in Zanzibar, Tanzania). This was a different from the traditional care with which he was taking his medications irregularly. The target of the system is not only to remind patients to take their tablets and attend clinic appointments but also to help them change their behaviour. For instance, one patient reported that, although, he had a habit of remembering to take his tablets, the reminder system supported him in complying with other treatment behaviours. He further added that the system could be beneficial to others, especially those who have a habit of forgetting their medication and clinic appointments.

Other participants indicated that the system encouraged them to eat vegetables. The participants suggested that the GBR system was more effective and easier to understand than the speech reminder.

Patients were also asked whether they were taking their tablets before or after the reminder. More than 80% said that they took their tablets after the reminder arrived. The rest said that they either took their tablets before or after the reminder. Of those who took their medication before, nearly half of them indicated that they usually remembered to take their medication even though the reminder did not come. Some patients responded that they immediately sent feedback after taking their tablets while others said that it took them approximately 5-10 min to send feedback after taking their medication. Usually, the majority of patients who claimed taking their tablets before the reminder arrived were the ones who had a habit of remembering and others family members remind them to take their medication.

The qualitative findings also indicated that the main reasons for patients missing some pills were: forgetting to take the pills being away from home and a few cases of

patients running out of tablets. Those patients who reported running out of tablets explained this as a loss of pills or missed appointment, particularly for the patients in the control group.

There were some challenges reported by participants during the speech reminders. Participants said that if they did not hear speech they were not able to identify which reminder was triggered, so, they were not able to retrieve the content of the message. This mostly happened in busy areas where the background noise was at high levels. However, this did not necessarily mean that they did not take their medication.

The patients expressed that during the GBR system, even if they did not hear a notification alert, they did not consider it a problem because they were then able to retrieve content of the image message. Patients hoped that such a system would encourage them to comply with the TB treatment as well as educate them on good behaviours about the disease.

Principal findings: Mobile phone reminder systems are increasingly relevant, particularly in developing countries. Researchers recognise that mobile phone reminders are a contextually significant tool for supporting TB treatment. The findings of this study confirm the potential of mobile reminders for improving TB treatment adherence. It was found that the GBR system highly improved patient's adherence over traditional care and speech reminder system.

It is important to note that the PC adherence was assessed based on the pill refill behaviours such as calculating the number of pills that were not taken compared to those that were collected. Pill-taking behaviour was not directly measured. The pill-taking behaviour can only be measured by observing while a patient is taking the tablets.

The SR adherence was assessed through face-to-face interviews with patients. Patients were asked to report how they felt about the treatment adherence. However, the SR method is the most feasible to use in clinical practice settings[19, 20], although, the SR data might be limited by the fact that it can contain recall bias, the possibility of overestimating adherence and the tendency to advocate socially acceptance responses[19].

These findings that mobile reminder systems help to improve the patient's treatment adherence have been reported by various studies. For instance, Iribarren *et al*.[13] and Hardy *et al*.[21]'s studies which assessed adherence to TB treatment and ARV treatment using a SR patient survey, found that mobile reminder systems were more effective for improving the patient's adherence rate than traditional care. The findings of this present study also indicated that in comparison to traditional care and speech reminders, a GBR system improved treatment adherence among TB patients.

The Mann-Whitney U analysis indicated that there was a significant difference in the number of responses between the speech and GBR groups ($p<0.01$). The number of responses to the system was higher in the GBR group than speech reminder group.

A number of studies have also assessed the effectiveness of the mobile reminder between two mobile interventions. For example, Chen *et al*.[22] investigated the effectiveness of a mobile reminder- between SMS and phone call reminders-for improving patient's clinic attendance. Their study found one intervention which was SMS to be more effective than a phone call to support patients in clinic attendance.

In the same way, this current study found that one intervention-the GBR system-to be more useful to support TB treatment than the other-the speech reminder system. The findings further indicated that the times taken by patients to respond to the system between the speech reminder group and the GBR group were significantly different with $p<0.01$. This result illustrated that the patients using GBRs replied faster to the system (replied sooner after having received reminders) than that with the speech reminders. It is worthwhile to note that the patients receiving GBRs may have taken medication sooner after receiving the reminder messages than with the speech reminders. This finding concurs with the findings by Vervloet *et al*.[6] who found that the majority of patients responded quickly to the system and 30.1% of doses were taken within 15 min of the SMS reminder being sent. Their study investigated the effect of SMS reminders on adherence to oral anti-diabetics.

The qualitative findings indicated that patients perceived the mobile reminders to be useful in supporting them to remember taking their medication, attend clinics as well as encouraging good habits. The GBR system was preferred over the speech reminders and supported the patient's compliance with their treatment regimen. Almost all patients including literate and illiterate (or semi-literate), showed acceptance of the GBR system. A possible explanation for this finding could be attributed to the acceptability and awareness of the technology as the patients believed that this technology could be more useful to support their treatment. These findings concur with the findings by Sidney *et al*.[23] and Rodrigues *et al*.[24] that participants showed high acceptance of IVR reminders over SMS in supporting them for treatment adherence.

Finkelstein *et al*.[25] indicates that if the participants show preferences for a technology, they will be more likely to use and respond to the system. Finkelstein *et al*.[25] further mentions that when the patients are using a method they prefer, they will be more likely to comply with the treatment regimen.

Amongst the study's objectives was to be able to provide everyone, even people living in rural remote areas with healthcare services through mobile phones. The key objective of mobile technology is to provide a service

remotely in order to facilitate services for all that is cost effective[26]. This is evidenced in this present study as it was found that the use of an offline mobile reminder system to support the treatment of TB is effective. Unlike SMS text messages and phone call reminders, the system is disengaged from the mobile service provider. The system does not engage network providers because it works offline on mobile phones. It is cost saving as the system does not require fees paid to a mobile provider as in the case of SMS text messaging and phone call reminder systems. As such the study findings show that the applicability of this system (GBRs) can be potentially high in increasing TB adherence in low-literacy and resources constrained environments.

Apart from the positive responses, there were some challenges experienced by participants. The participants raised issues of stigmatization that reminder message, the speech reminders, contained words that directly represent a sign of a disease or patient. Participants indicated that they would prefer not to disclose their health status with other people due to the possibility of stigmatisation. They mentioned that words such as TB, medication, sputum and clinic as directly representing a sign of a patient. This mostly happens when the speech reminder messages triggered and opened in front of other people.

Other challenges occurred with the mobile phones including cell phone problems; some patients expressed that sometimes the phone's battery would run out. This was mostly caused by frequent blackouts, particularly rural areas. Another reason was the mobile phone ownership, however, the participants accessed the mobile phones, specifically for experiments, it was found that some participants do not own mobile phones that support the GBR system. The last challenge related to mobile phone was usability skills as some participants were not familiar with smartphone, so it was challenge for them to use the GBR system.

Strengths: This analysis has a number of strengths. First, the process of development of an m-health GBR system for supporting TB treatment in low-literacy and resource-limited settings. Second, it is an in-depth qualitative investigation of the experiences of study participants on the state-of-art adherence to treatment measurement technology. Third, the study was conducted in low-literacy and resource-limited environment which has implications for similar settings. Although, cultural differences may have an impact on acceptability of the technology.

CONCLUSION

In conclusion, we found that mHealth GBR system and notifications to support TB treatment adherence were largely acceptable based primarily on perceived utility and feasible within a context of low-literacy and resource-limited settings. Future efforts should focus on increasing the complexity of the system such as developing a device, modality and context theory. This can enable users to interact with a system with multiple modes. Another aspect would be to develop a GBR system for other mobile platforms apart from Android and to create generic applications and builders for reminder systems.

LIMITATIONS

The results of this trial have limited generalizability as they are based on a small pilot study of 59 participants over five weeks of follow-up which is indeed short timeline of capturing the life cycle of patient's adherence to TB treatment. Patient's satisfaction could have increased or decreased-due to familiarity or initial enthusiasm-if the research was conducted over a longer period of time such as six months as a timeline of TB treatment. Another limitation was that the application was developed on an Android platform which requires the use of Android smartphones only.

IMPLICATIONS

The study has provided insight into the support of TB treatment using GBR systems in low-literacy and resource-limited contexts. The study might benefit the understanding of treatment for TB patients of all literacy levels in a way that mobile GBR systems provide reminders about TB treatment regimens and helping to improve compliance with treatment and influence behaviour. Unlike speech-and text-based reminder applications, the graphic application may be more readily accepted as well as easier to use and understand by a majority of patients with diverse characteristics, needs and requirements including patients with physical disabilities such as the hearing impaired, patients of all ages, patients with different skills and levels of experts and patients from all over the world with different languages, cultures and educational backgrounds.

The reminder response role could also be important factor. This is because when a patient miss to send response the health worker can contact the patient to confirm whether he/she has received the reminders by completing an action.

Graphic applications can also be used to support the treatment of other diseases such as HIV and diabetes. Furthermore, graphic and other forms of visual communication could be prioritized over other forms of electronic communication for areas with mixed literacy where there are urgent development needs. Graphic applications can also be applied to other areas such as education, disaster management, transportation, communication and agriculture.

However, research indicates that graphic objects are cross-cultural and a universal language that can easily be recognized by every person[27]. It is recommended that to be accepted, the graphics must be developed based on the user's requirements and needs.

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REFERENCES

01. Stop, T.B., 2011. The global plan to stop TB: 2011-2015. World Health Organization, Pregny-Chambesy, Switzerland.
02. WHO., 2013. Global Tuberculosis Report 2013. World Health Organization, Geneva, Switzerland, ISBN:9789241564656, Pages: 289.
03. WHO., 2015. Global Tuberculosis Report 2015. World Health Organization, Geneva, Switzerland, ISBN:978-92-4-156505-9, Pages: 204.
04. Okuboyejo, S., N.A. Omoregbe and V. Mbarika, 2012. A framework for the design of a mobile-based alert system for outpatient adherence in Nigeria. Afr. J. Comput. ICT., 5: 151-158.
05. Barrington, J., O. Wereko-Brobby, P. Ward, W. Mwafongo and S. Kungulwe, 2010. SMS for life: A pilot project to improve anti-malarial drug supply management in rural Tanzania using standard technology. Malar. J., Vol. 9, 10.1186/1475-2875-9-298.
06. Vervloet, M., L. Van Dijk, J. Santen-Reestman, B. Van Vlijmen, P. Van Wingerden, M.L. Bouvy and D.H. De Bakker, 2012. SMS reminders improve adherence to oral medication in type 2 diabetes patients who are real time electronically monitored. Int. J. Med. Inf., 81: 594-604.
07. Kunawararak, P., S. Pongpanich, S. Chantawong, P. Pokaew, P. Traisathit, K. Srithanaviboonchai and T. Plipat, 2011. Tuberculosis treatment with mobile-phone medication reminders in Northern Thailand. Southeast Asian J. Trop. Med. Publ. Health, 42: 1444-1451.
08. Pop-Eleches, C., H. Thirumurthy, J.P. Habyarimana, J.G. Zivin and M.P. Goldstein *et al.*, 2011. Mobile phone technologies improve adherence to antiretroviral treatment in a resource-limited setting: A randomized controlled trial of text message reminders. AIDS (London, England), 25: 825-834.
09. Nglazi, M.D., L.G. Bekker, R. Wood, G.D. Hussey and C.S. Wiysonge, 2013. Mobile phone text messaging for promoting adherence to anti-tuberculosis treatment: A systematic review protocol. Syst. Rev., Vol. 2,
10. Zurovac, D., A.O. Talisuna and R.W. Snow, 2012. Mobile phone text messaging: Tool for malaria control in Africa. PLoS Med., Vol. 9, 10.1371/journal.pmed.1001176.
11. Naughton, F., J. Jamison and S. Sutton, 2013. Attitudes towards SMS text message smoking cessation support: A qualitative study of pregnant smokers. Health Educ. Res., 28: 911-922.
12. Fenerty, S.D., C. West, S.A. Davis, S.G. Kaplan and S.R. Feldman, 2012. The effect of reminder systems on patients adherence to treatment. Patient Preference Adherence, 6: 127-135.
13. Iribarren, S., S. Beck, P.F. Pearce, C. Chirico, M. Etchevarria, D. Cardinale and F. Rubinstein, 2013. TextTB: A mixed method pilot study evaluating acceptance, feasibility and exploring initial efficacy of a text messaging intervention to support TB treatment adherence. Tuberculosis Res. Treat., Vol. 2013, 10.1155/2013/349394.
14. Mohammed, S., O. Siddiqi, O. Ali, A. Habib, F. Haqqi, M. Kausar and A.J. Khan, 2012. User engagement with and attitudes towards an interactive SMS reminder system for patients with tuberculosis. J. Telemedicine Telecare, 18: 404-408.
15. Haji, H.A., H. Suleman and U. Rivett, 2015. Development of a mobile image-based reminder application to support tuberculosis treatment in Africa. World Acad. Sci. Eng. Technol. Int. J. Biomed. Biol. Eng., 9: 620-627.
16. Haji, H.A., U. Rivett and H . Suleman, 2016. Improving compliance to tuberculosis treatment: Supporting patients through mobile graphic-based reminders. J. Publ. Health Developing Countries, 2: 235-247.
17. Rogers, R., J. Lombardo, Z. Mednieks and B. Meike, 2009. Android Application Development: Programming with the Google SDK. O'Reilly Media, Inc., Sebastopol, California, USA., ISBN: 9780596555641, Pages: 433.
18. Johnson, D.H., 1999. The insignificance of statistical significance testing. J. Wildl. Manage., 63: 763-772.
19. Hawkshead, J. and M.A. Krousel-Wood, 2007. Techniques for measuring medication adherence in hypertensive patients in outpatient settings. Dis. Manage. Health Outcomes, 15: 109-118.

20. Nackers, F., H. Huerga, E . Espie, A.O. Aloo and M. Bastard *et al*., 2012. Adherence to self-administered tuberculosis treatment in a high HIV-prevalence setting: A cross-sectional survey in Homa Bay, Kenya. PLoS One, Vol. 7, No. 3.
21. Hardy, H., V. Kumar, G. Doros, E. Farmer and M.L. Drainoni *et al*., 2011. Randomized controlled trial of a personalized cellular phone reminder system to enhance adherence to antiretroviral therapy. AIDS Patient Care STDs, 25: 153-161.
22. Chen, Z.W., L.Z. Fang, L.Y. Chen and H.L. Dai, 2008. Comparison of an SMS text messaging and phone reminder to improve attendance at a health promotion center: A randomized controlled trial. J. Zhejiang Univ. Sci. B., 9: 34-38.
23. Sidney, K., J. Antony, R. Rodrigues, K. Arumugam and S. Krishnamurthy *et al*., 2012. Supporting patient adherence to antiretrovirals using mobile phone reminders: Patient responses from South India. AIDS Care, 24: 612-617.
24. Rodrigues, R., A. Shet, J. Antony, K. Sidney and K. Arumugam *et al*., 2012. Supporting adherence to antiretroviral therapy with mobile phone reminders: Results from a cohort in South India. PloS One, Vol. 7, No. 8. 10.1371/journal.pone.0040723.
25. Finkelstein, S.R., N. Liu, B. Jani, D. Rosenthal and L. Poghosyan, 2013. Appointment reminder systems and patient preferences: Patient technology usage and familiarity with other service providers as predictive variables. Health Inf. J., 19: 79-90.
26. Mthoko, H.L. and C. Pade-Khene, 2013. Towards a theoretical framework on ethical practice in ICT4D programmes. Inf. Dev., 29: 36-53.
27. Kheir, N., A. Awaisu, A. Radoui, A. El Badawi, L. Jean and R. Dowse, 2014. Development and evaluation of pictograms on medication labels for patients with limited literacy skills in a culturally diverse multiethnic population. Res. Social Administrative Pharm., 10: 720-730.