Evaluating the effectiveness of mobile graphic-based reminders to support treatment of tuberculosis patients

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Abstract
Low adherence rates to tuberculosis (TB) treatment are one of the major barriers to improving TB cure rates. Developing regions such as sub-Saharan Africa are adversely affected for a number of reasons, such as low patient follow-up, limited medical, and treatment resources. The use of mobile graphic-based reminders potentially offers a cost-effective, easy to use and time efficient strategy to increase adherence in order to improve cure rates among patients with TB. This paper shows the results of a study in Zanzibar, Tanzania, which investigated the effectiveness of graphic-based reminders in supporting TB patients with low literacy levels to adhere to treatment. Participants were randomly selected from a group of TB patients and assigned into three groups: control (no reminder) group, graphic-based reminder group and speech-based reminder group. A total of 29 participants were analysed. The treatment adherence rates of the control group, speech-based group and graphic-based group were 41.7%, 60% and 85.7%, respectively. The rates in the graphic-based group were significantly higher than in the speech-based and the control groups. Results also show that there were high efficacy and acceptability of mobile reminders in the graphic-based group, with the average response rates of 76.8% compared with 67.1% in the speech-based group ($p<0.001$ of 95% confidence intervals). The findings highlight that mobile phone reminders are improving treatment adherence of TB patients. The graphic-based reminder was more beneficial, cost-effective and accepted for use by the majority of patients including those with limited education.

Keywords
Mobile technology, TB patients, graphic-based reminder, ICT4D

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Background

This study was conducted in the context of supporting tuberculosis (TB) patients to improve treatment adherence. TB remains a public health problem worldwide, particularly affecting resource-constraint developing countries. About 85% of all cases occur in Africa and Asia with sub-Saharan Africa accounting for 30% (WHO, 2013). According to the World Health Organization (WHO) almost one third of the world's population is infected with the bacteria *tubercle bacilli* and is at risk of developing active TB. In 2012, there were almost nine million new cases worldwide and more than one and a half million people die every year, despite successful treatment regimens being available (WHO 2013).

The increase of TB is linked to factors such as increasing populations in areas where the prevalence of TB is already high. Poverty which results in overcrowding contributes to the increase of TB transmission among family members, friends and community. The increase of HIV (human immunodeficiency virus) has contributed to the burden of TB (Adane et al 2013; WHO, 2012). WHO reported that more than 13% of TB cases occur among people living with HIV (WHO 2012).

In order to support TB cure rates, adherence to TB medication regimen is paramount. Currently poor adherence rates are a significant problem for TB patients worldwide. As WHO (2012) highlights, patients do not take their medicine on schedule due to forgetfulness. As a result, the disease takes longer to be cured, medication may no longer be successful and the possibility for further spread of disease communities is increased. A patient who does not take his/her TB medication regularly and reliably is at greater risk of treatment failure, relapse and the development of drug-resistant TB (WHO 2012; Kochi 2001).

Mobile technology has been used in the health sector to support patient treatment, particularly in the context of HIV (Sidney et al 2012; Lester et al 2010). Additionally, the rate of use of mobile phones in developing regions has increased rapidly in the past decades. It has been demonstrated as a tool that improves human service delivery, able to reach a larger population with ease and at a lower cost (Blaya et al 2010; Chib 2013). In 2014, seven billion mobile phones were available in the world. Africa has more than 650 million subscribers with penetration close to 20% (ITU Statistics 2014).

Recently, mobile phone reminder systems have been proposed and shown the potential to support TB patients with treatment adherence (Iribarren et al 2013; Barclay 2008; Kunawararak et al 2011; Nglazi et al 2013). Iribarren et al (2013) proposed a mobile reminder system to promote TB treatment compliance. Participants were categorized into two groups: a control group (without reminder) and mobile intervention group. Those patients in the intervention group were given daily SMS text messages to remind them of treatment adherence. Kunawararak et al (2011) proposed a mobile reminder system in

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which TB patients were given daily phone calls to remind them to take medication. These studies found that mobile reminders improved rate of medication adherence of patients.

A number of researches have also assessed the effectiveness of mobile reminder systems using control groups. Mbuagbaw et al (2012) investigated the efficiency of mobile SMS reminders compared to traditional care. Participants were randomly categorized into two groups: a control group and an intervention group. Patients in the intervention group received a weekly SMS reminder to take their medication. The participants in the control group were given face-to-face consultations. The study found that patients in the mobile group improved rate of adherence to treatment by 80% compared with 60% of those patients in the control group (Mbuagbaw et al 2012). Prasad and Anand (2012) evaluated a mobile reminder system in supporting patients to keep their appointments. The study found that the attendance rates of patients were significantly higher in the intervention group (79.2%) compared with the control group (35.5%).

Other studies assessing the effectiveness of mobile reminder systems compared to traditional care are presented by Chen et al (2008) and Lund et al (2012). Chen et al (2008) measured the efficiency of mobile phone reminders versus no reminders measuring patients' clinic attendance rate, while Lund et al (2012) examined the effects of the mobile phone reminders over traditional care in improving attendance rates for pregnant women. Sidney et al (2012) examined the usefulness of mobile phone interactive voice response (IVR) reminders and pictorial SMS to help support adherence to treatment among HIV patients. Parikh et al (2010) investigated the effectiveness of speech-based reminders for outpatient appointment in reducing no-show rates. The researchers also assessed the perception, acceptance and engagement with mobile reminder systems among TB patients (Mohammed et al 2012), and the impact of treatment compliance among patients with HIV (Lester et al 2010). A similar study presented by Pai et al (2013) assessed the impact of mobile technology in improving haemoglobin (Hb) levels in the blood of pregnant women. In this study the pregnant women were given automated voice calls to promote adherence to iron supplements. The findings of these studies revealed that mobile reminders improved the patients' medication adherence and clinic attendance rates.

The studies mentioned above show high efficacy and acceptance for improving treatment adherence among patients when compared to traditional care. However, currently these systems do not take patients with low-literacy or illiteracy into consideration. Texts messaging and speech systems have limited use for people with low literacy (Caldwell 2013). Compared to other mobile interventions, a graphic-based application may more readily accept, easier to use and understand (Gupta 2008; Lipkus and Hollands 1999).

Literature shows that the best method to supporting illiterate people to understand content is visual communication (Gupta 2008; Wileman 1993). Visual communication aid is the theory proposed to support people to read and understand the content of messages. Visual aids are a text-free method of communication that has the potential to be especially intelligible to those people who have limited literacy (Medhi et al 2006). Visual communication can also empower people to facilitate cross-language engagement in order to understand one another.

The paper is organized as follows. In section two, discussion of the research methods and design are presented. The findings of an experimental evaluation are presented in section three. In section four, the discussion of the findings are presented. The paper concludes with a reflection on the results and previous works. This study is conducted within the research area of Information and Communication Technology (ICT) for Development (ICT4D), which is concerned with helping and empowering people by making a difference in their everyday lives.

Design and Methods

This study investigated a mobile graphic-based system to support TB patients in their adherence to treatment through reminder methods in order to support patients beyond the literacy and language barrier. The system made use of graphics to remind patients to follow their routine of treatment.

The objective of this trial was to investigate the effects of graphic-based reminder systems. To achieve this goal, the recovery rate were measured based on the effect of:

(1) the mobile graphic-based reminder group versus the control group and
(2) the mobile graphic-based reminder group versus the speech-based reminder group.

The experiment was conducted in Zanzibar, Tanzania with TB patients under the supervision of the TB department at the MnaziMmoja Hospital. Since the subjects of this study were under supervision of healthcare workers, cluster sampling was used to randomly selection the participants. The ethical clearances for the study were granted by the University of Cape Town and the Ministry of Health and Social Welfare in Zanzibar. Before the experiment began, participants were briefed on the purpose of the research and were requested to complete a consent form and permission to audio record the interviews. The participants were also given an overview on how the system worked and assigned tasks to do such as pressing a feedback button once a reminder had been triggered.

Study design

This study used a parallel group design, to evaluate the effectiveness of graphic-based reminders. The study measured two types of trials: (1) between mobile reminders and traditional care; and (2) between graphic-based and speech-based reminders. Participants were randomly assigned into three groups: control group (n=12), speech-based reminder (n=12) and graphic-based reminder (n=12). In order to measure efficacy and acceptance of the technology in the different groups, participants with different levels of education and literacy levels, were included in each group.

Experimental setting

Since the intention of the study was to propose a mobile reminder system in the context of developing countries, the application was designed to work offline in order to limit engagement with mobile service provider. The user (a registered TB patient) could

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download the application from the hospital server. Once the application was successfully downloaded it worked offline. The reminder messages were triggered based on the TB treatment schedule as predefined by the health care professionals. The system contained eight reminder messages, as shown in Figure 1. The reminders were set to automatically activate on different days and times, which include daily, after every two days, weekly, etc.

The reminders were categorized into four groups: medication reminders such as taking pills, refilling drugs and submitting smear sputum; clinic follow-up reminders regarding clinic appointment or consultation; education reminders for behaviour improvement such as avoiding pain or spreading the disease to others; and health reminders to improve eating habits.

In order to measure the usage of mobile reminder systems, a feedback button was created that appeared once a reminder message has been triggered. Users were instructed to press this button in order to send a feedback message to database server. When disconnected, a SQLite database stored the feedback offline for automatic forwarding as soon as the Internet connection was available. The database registers the user ID, date and time of every reminder message. This is closely aligned to the Medication Event Monitoring System (MEMS) which indirectly measures adherence rates of patients through an apparatus containing a microelectronic chip that registers the date and time of every bottle opening (Boogaard et al 2011).

Phones were connected to the Internet (using hospital WiFi or mobile data) every time the participants visited the clinic. Once the phone was connected to the Internet, it automatically synchronized the data with the database.

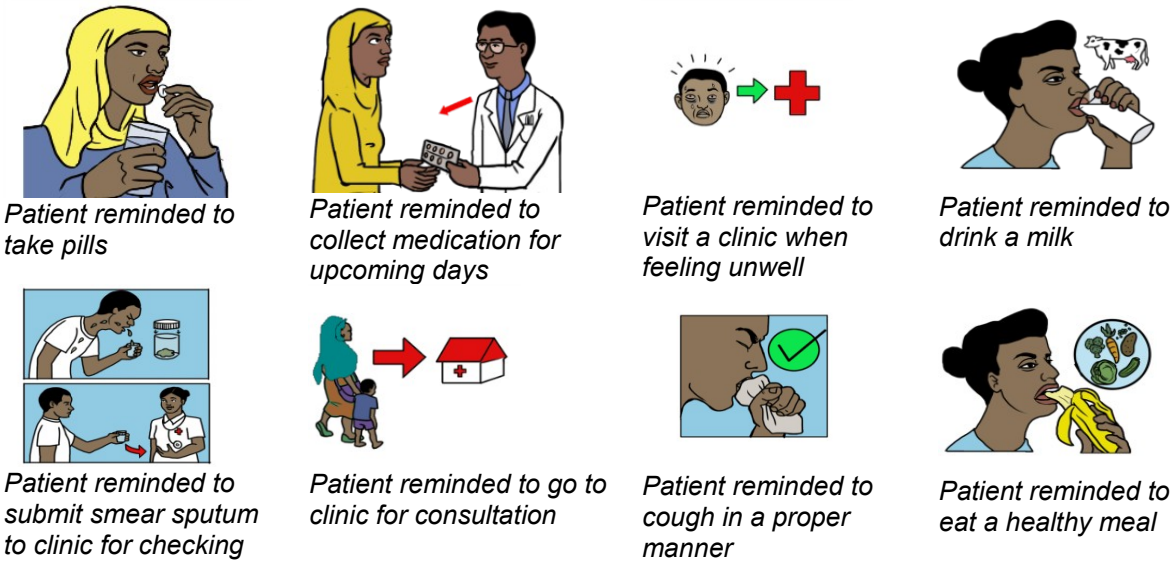

Figure 1. The graphic reminder messages developed in this study for supporting TB patients to comply with their treatment regimen (Haji et al 2014).

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Participants: inclusion/exclusion criteria

The study included subjects who had active TB and had started taking TB drugs. The patients were all aged 18 and above and were undergoing home-based care (out-patients). Patients in intensive and continuation phases were also included. The intensive phase starts from day one of the TB treatment, aimed to prevent the emergence of drug resistance and determines the ultimate outcome of the regimen (WHO 2013). This phase usually lasts two months and is followed by the continuation phase. The study excluded patients under 18 years and in-patients (patients who lived in hospital while under treatment).

Intervention group

Participants in the intervention groups received daily mobile reminder messages. The participants in the graphic-based group received graphic reminders with a ringtone for notification and those in the speech-based group received speech reminders. The reminder messages were triggered at the same times for all groups.

Control group

In the control group, patients received routine medical procedure but did not receive any mobile reminders. They were assessed every week either at the clinic during their appointment times or at their home.

Duration

The experiment was implemented for the duration of five weeks from December 2014 to January 2015. The participants were contacted every week for further follow-ups. The study was conducted in a short period due to financial and time constraints.

Measures

The measured variables used were adherence rates, efficacy and acceptability of the technology. The adherence rates were measured by comparing the patients' health records before and after the trial. There are various methods used to measure or evaluate adherence to TB treatment.

For this study, we used the Visual Analogue Scale (VAS), and Pharmacy Refill Data (PRD) (Mbuagbaw et al 2011) to evaluate adherence. VAS was used as the primary method that measures treatment adherence of patient through self-evaluation (Mbuagbaw et al 2011; Arnsten et al 2001). During follow-up times, a patient self-reported on his/her adherence. The PRD was used to measure pill success rates. Every time the patient attended the clinic for medication refills, the visit was registered and the remaining pills were counted. PRD was used to verify and support VAS. The efficacy and acceptance of the technology were assessed by application responses (event logs) and the user feedback collected through face-to-face interviews.

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Data analysis

The data collected in this study generated two types of data: quantitative experimental responses and qualitative data resulting from semi-structured interviews from patients. The quantitative data was obtained from application responses and converted into numerical form. The numerical data was then entered and analysed using a statistical package for the social sciences (SPSS) software (version 21). A paired-samples t-test was conducted to compare the rate and time of response in the graphic-based reminder and speech-based reminder groups. A p-value less than 0.05 was used to detect a significant difference for all analyses. The qualitative data obtained from interview was analysed by the researchers.

Results

The overall distribution of the study participants is shown in Table 1. A total of 29 participants were enrolled for the final analysis: control group (n=12), speech-based reminder (n=8) and graphic-based reminder (n=9). Seven participants were not included in the analysis due to various reasons including loss of phone in the middle of the experiment (n=1), declined to continue (n=1), and missed some data (n=5). Of the analysed participants, 55% (n=16) were males and 45% (n=13) females. The average age was 39 years (range: 18-72). Findings showed that 59% (n=17) of study participants were receiving treatment in the continuation phase. Twelve (41%) participants were either illiterate or semi-literate and 34% (n=10) of the participants resided in rural areas.

Characteristics	Gender Male (%)	Age Mean (range: min-max*)	Treatment phase X (Y)^
Control (n=12)	7 (58)	40 (20-72)	5 (7)
Speech-based (n=8)	4 (50)	38 (18-60)	3 (5)
Graphic-based (n=9)	5 (56)	39 (18-65)	4 (5)

*min = minimum, max = maximum: ^X = patients in intensive phase, Y = patients in continuation phase, % = percentage

Table 1. Gender and distribution of participants

Adherence rates

Participants' adherence rates were 41.7% in the control group, 60% in the speech-based group and 85.7% in the graphic-based group (Table 2). This finding showed that the adherence rates were significantly higher in the graphic-based than in the speech-based and control groups. The pill success rates were higher in the graphic-based group, with a score of 100% compared to 90.1% in the speech-based group and 66.7% in the control group.

	Control	Speech-based	Graphic-based
PRD (pill success rates)	66.7%	90.1%	100%
VAS (adherence rates)	41.7%	60%	85.7%

Table 2. Treatment adherence rates by groups

Evaluating efficacy of the graphic-based reminder

As described earlier, two prototypes were implemented: graphic-based and speech-based reminders. A total of 2445 reminder responses were captured and analysed.

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The findings showed that there was a significant difference in the response for graphic-based reminder (μ=76.76, σ=5.33) and speech-based reminder (μ=67.12, σ=6.25) rates; t(16)=-4.38, p=0.00047. This means that the response rate was higher in the graphic-based reminder group than in the speech-based reminder group.

There was a significant difference in the feedback response for graphic-based reminder (μ=24. 0, σ=5.13) and speech-based reminder (μ=34.29, σ=8.24) times; t(6)=8.12, p=0. 00019. The response time to press the feedback button was shorter in the graphic-based group than in the speech-based group. In other words, average response time in the graphic-based group was 24 minutes and in the speech-based group was 34 minutes as shown in Table 3.

		Number of responses				Time of responses		
6.25160.0004 734.298.2460. 00019	Mean (μ)	Std. Dev (σ)	Df*	P-value	Mean (μ)	Std. Dev (σ)	Df	P-value
Graphic-based67.12 Speech-based	76.76	5.33			24.0	5.13		

*degree of freedom, Std. Dev=Standard Deviation

Table 3. Analysis of the technology effectiveness

Participant feedback

The findings show that participants experienced the mobile reminder system in supporting their treatment as useful. The acceptance rate of technology was higher in the graphic-based group when compared to the speech-based group. The participants made comments such as:

> "I really appreciated the system. I understood the meaning of all graphics."
>
> "The application seems to be worthwhile in helping us to comply with our treatment regimen."
>
> "This mobile reminder system was very helpful compared to usual case, everyone liked it."
>
> "I found the system was very good and could be very useful in supporting us, it helped me a lot, as currently I have a problem of forgetting to take my pills on time."
>
> "This is a fantastic idea, I like it very much. I clearly understood all graphics correctly. The system was helping me a lot to remember taking my medication and attending clinic appointments."

It has to be highlighted that participants in the speech-based reminder group reported challenges during the study, which might have influenced the outcome. Participants indicated that they did not always hear the voice and were therefore not able to retrieve the content of the message.

The study findings indicated that the use of graphic-based reminders is feasible and allowed participants to clearly understand the content of the message. The participants expressed that they would like to continue receiving graphic-based messages reminding them to take their medication and follow-up their clinic appointments.

Discussion

This study was designed with the aim of investigating the effectiveness of graphic-based reminders in supporting treatment adherence in patients with TB. The study assessed the impact of graphic reminders by comparing it to no reminders and speech reminders. Similarity to the studies highlighted in the literature review, we found that mobile reminders were effective and beneficial when compared to traditional care.

This study also found that the major challenge faced by TB patients to comply with the treatment is forgetfulness. The majority of patients responded that they often forget to take medication or attend clinic for their appointments. However, we found other reasons such as poor health, work and family commitments also mentioned as barriers for TB treatment.

The study results also showed that a graphic-based reminder system could more cost-effective than SMS text message and phone call reminder systems. The graphics reminder system worked offline on mobile devices independent of mobile network availability. In this system, the mobile service provider was not part of the communication service, which can be beneficial when compared to SMS text message and phone call system.

Literature shows that costs and telecommunication infrastructures (Betjeman et al 2013) are among the challenges to the adoption and deployment of mobile healthcare systems in developing countries. In order to reduce costs, offline applications should be considered as an alternative to implementing mobile application for TB support. The benefit of such a solution is particular relevant in areas where mobile signal strength is unreliable (Aker and Mbiti 2010; Wu et al 2010).

The study had some limitations. Firstly, the duration of the implementation of the trial was short, considering the timeline of a six months TB treatment. In order to compensate for this, we did not measure the treatment outcome rates, such as success rate, failure or relapse. This can be only measured in the fifth and sixth months of the TB treatment. Our study focused on the evaluation of the impact and usefulness of the technology. We measured treatment adherence rate as it could be assessed at any time during the treatment period (WHO, 2012; Kochi 2001).

The second limitation was that the proposed application was developed on an Android platform, which required the use Android smart phones only. The study findings showed that the majority of study participants had mobile phones (93%) but not necessarily Android phones. However, Android phones are widely available in developing countries,

including Zanzibar. The motivation to use the Android platform was that, in 2013, Android was at 78.4% of the operating system market share, making it one of the most used mobile operating systems globally (Michael 2013). The price of Android phones is rapidly declining which become very closer to the price of feature phones which are largely available in Africa continent

The use of graphic reminder systems could be beneficial to supporting TB patients to adhere to treatment. Graphics and other visual communications could be prioritized over other forms of electronic communication for areas with mixed literacies where there are urgent development needs. This transcends TB and can be applied to the management of other diseases.

Conclusion

This paper presented the findings of an experimental study into the potential of mobile phone reminder systems to support TB patients during their treatment. In order to support patients regardless of their literacy level, our intervention used graphic-based reminders. To evaluate the effectiveness of graphic-based reminders, we measured the treatment adherence, efficacy and acceptability of the technology over the control group and speech-based reminders. Whilst the trial was implemented for a short period only, the results indicated that graphic-based reminders are beneficial and an effective strategy to support TB patients, including those with limited literacy. Further research will include deploying the system over a longer period and involving larger numbers of patients in order to further evaluate the effectiveness of graphic-based reminder systems.

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