

Improving Community Health Worker Performance Through Automated SMS

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ABSTRACT

Community health workers (CHWs) have been shown to be an effective and powerful intervention for improving community health. Routine visits, for example, can lower maternal and neonatal mortality rates. Despite these benefits, many challenges, including supervision and support, make CHW programs difficult to maintain. An increasing number of mHealth projects are providing CHWs with mobile phones to support their work, which opens up opportunities for real-time supervision of the program. Taking advantage of this potential, we evaluated the impact of SMS reminders to improve the promptness of routine CHW visits, first in a pilot study in Dodoma, Tanzania, followed by two larger studies with 87 CHWs in Dar es Salaam, Tanzania. The first Dar es Salaam study evaluated an escalating reminder system that sent SMS reminders directly to the CHW before notifying the CHW's supervisor after several overdue days. The reminders resulted in an 86% reduction in the average number of days a CHW's clients were overdue (9.7 to 1.4 days), with only a small number of cases ever escalating to the supervisor. However, when the step of escalating to the supervisor was removed in the second study, CHW performance significantly decreased.

Categories and Subject Descriptors

H.5 INFORMATION INTERFACES AND PRESENTATION
(e.g., HCI)

General Terms

Experimentation, Human Factors.

Keywords

Mobile tools, reminder systems, community health workers, public health, ICT4CHW.

1. INTRODUCTION

The growing field of mHealth [1] in low-income regions has seen an increasing number of projects targeting community health workers (CHWs). Community health workers are lightly trained

individuals who act as outreach workers, interfacing between the community and the periphery of the health system. Their strength lies in the fact that they are from the communities they serve [2] and are intimately involved with the health concerns of that community. They help magnify the reach of an over-stressed health care system in highly resource-constrained environments by visiting the homes of community members to assess or treat individuals and to offer health advice [3]. This is important because patients often delay seeking care, even in cases severe illness [4], and scheduled visits have been shown to be part of effective interventions [5]. Randomized controlled trials have found that using CHWs as part of a comprehensive public health delivery strategy can positively change behavior and significantly lower mortality rates [5-8]—particularly with maternal and newborn health.

Despite these benefits, many challenges make CHW programs difficult to run and maintain [9, 10]. Supportive supervision is needed to diminish feelings of isolation among CHWs, while infrastructure and logistical support, such as reliable transport and equipment supplies, also impact the effectiveness of such programs [9, 11]. In this paper, we focus on improving the timeliness of CHW visits to their clients. In some cases, the timeliness of client visits is particularly acute. For example, having CHWs visit families immediately after a baby was born led to a drop in neonatal mortality rates [5]. Even when timeliness is not so critical, the success of CHWs is tied to routine home visits. Unfortunately, maintaining the promptness of these routine visits can be difficult. For example, at the time of intervention in our first study, only approximately 60% of clients had been visited on time.

A number of research projects (e.g. [12], [13]), as well as deployed interventions (e.g. [14-17]) have introduced mobile phones as a job aid for CHW programs in a sub-field known as ICT4CHW [18]. In previous work, we defined a category of these projects as ICT-based systems, which have the following properties:

“(1) Every visit is captured ... , (2) structured data is collected, (3) data are sent in real time, and (4) the system allows CHWs to register and track clients.” [18].

Collecting real-time structured data at the household level creates the opportunity to support automated real-time supervision to improve the timeliness of CHW visits. To date, however, this potential has been largely unexplored.

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To improve the promptness of routine visits for CHWs, we introduced an escalating reminder system that augments existing supervision structures within CHW programs. The system, implemented on top of CommCare [14, 19], first sends proactive reminders to a CHW the day before and the day of a scheduled routine visit. Daily reminders are sent while the visit remains overdue. On the third overdue day, the system escalates to sending the CHW's supervisor a notification about the pending visit so the supervisor can intervene to gather more information and support the CHW.

To evaluate the impact of SMS reminders on CHW performance, we conducted a small pilot study in Dodoma, Tanzania followed by two larger studies in Dar es Salaam, Tanzania. The Dar es Salaam studies ran over a 9-month period with 87 CHWs. These two studies augmented a deployment of CommCare with a CHW program run by D-tree International and Pathfinder International, where CHWs make monthly home visits to chronic care patients. To supplement the automatic data captured by CommCare about visits, we interviewed 30 CHWs and a supervisor on their experience during the studies.

This work makes the following contributions:

1. A randomized controlled study showing that an escalating reminder system causes a significant increase in CHW performance, with the average number of days clients are overdue dropping from 9.7 to 1.4 days (85.6%).
2. A second randomized controlled study showed that the step of escalating to supervisor is integral: removing that step from the process and sending SMS reminders to only the CHW significantly decreases performance.
3. Lessons learned about the implementation of an automated reminder system and several ways to build upon our basic approach in the future.

At the time of submission, our system is still running and has sent more than 25,000 SMS messages over the eight and half month period.

In the next section, we describe the bodies of work that guided our own research in reminder systems. Section 3 provides the details of our pilot study in Dodoma, Tanzania while Sections 4 and 5 do the same for the more extensive studies in Dar es Salaam, Tanzania. Section 6 outlines some qualitative results based on interviews with about half of the CHWs involved in the longer-term studies. We discuss our findings and elaborate on the larger context of this work in Section 7 and conclude in Section 8.

2. RELATED WORK

Reminders have been proposed and/or implemented for a variety of public health needs. We divide related work into two parts: reminders systems that have been formally evaluated and those without a formal evaluation.

2.1 Evaluated Reminder Systems

Sending SMS reminders directly to patients has been used to increase medication adherence for long-course treatment—in particular, studies have found increases in HIV testing [20], medication regimen adherence [21], and follow-ups on clinical visits [22]. Even more studies are in the planning stages [23]. Other projects send messages to pregnant women [24] or aim to increase diabetes adherence [25].

There have also been studies where reminders were sent to health workers instead of patients, including a system to collect data on facility antimalarial stock counts [26], and a project to remind health workers of malaria treatment guidelines [27]. The former has been successful at tracking drug supplies and preventing stock-outs, while the latter sent two messages a week for six months to health workers, leading to increased adherence to malaria treatment guidelines.

Our results build upon, and contribute to, this growing body of work that SMS can produce positive behavior change. Unlike programs where SMS are sent to patients, we are sending SMS reminders to mobile field workers. Additionally, unlike the case with adherence to a treatment regimen, skipping a visit or even several visits is not dangerous, however, the overall impact of the CHW intervention is reduced if visits are skipped or occur very late. Finally, instead of repeatedly sending a large number of static messages to health workers, our system is reactive to CHW performance and provides targeted reminders as opposed to generic guidelines.

2.2 Unevaluated Reminder Systems

There have been many related systems proposed or implemented, but not yet formally evaluated, that provide reminders to patients, health workers or other field staff.

TxtAlert [28] is an open-source SMS reminder system. It is similar to the system we built, but is designed to send messages to patients with the aim of increasing adherence to HIV medication. It currently supports connecting to the TherapyEdge electronic medical record system for polling about client visits.

The Mobile Technology for Community Health in Ghana (MOTEC) project sends automated SMS reminders to both patients and health workers [29]. The project's goals and strategies around automated SMS reminders are closely related to our own, though both projects developed independently. The MOTEC project discusses escalating cases that are continually overdue to supervisors; however, this is yet to be implemented. To our knowledge, there is no published evaluation of the impact of MOTEC's SMS reminders yet.

In a write up at the end of 2009, the ChildCount+ [15] project mentioned that there are plans for an alert system for CHWs. A follow up blog post suggests that the system has since been built [30]. However, as with MOTEC, no formal evaluation of the reminder system has been published.

3. PILOT STUDY OF SMS REMINDERS

As an initial exploration of automated SMS reminders to improve CHW performance, we conducted a nine-week pilot study in April-June 2010 with a community health program in Dodoma, Tanzania. Since the findings from this study are preliminary, we only briefly present the study and lessons learned.

3.1 Context and Experiment Methodology

All CHWs in the Dodoma program are women between the ages of 23 and 55. They are each responsible for 100 households in their catchment area and visit five households per day, making sure to visit each household at least once a month. During visits, CHWs collect routine health information and have the option to refer sick clients to a health facility. If a referral is given, the CHW is required to follow up again with the client, ideally two days later; when this follow-up occurs the referral is considered closed. SMS reminders were targeted at increasing the promptness with which CHWs closed referrals.

The study period was split into baseline and intervention periods that were 39 and 24 days long, respectively. The baseline period was the same for all participants. For the intervention period, participants were randomly assigned to the control group or to the SMS reminder group. CHWs in the SMS group automatically received an SMS message two days after they had reported a referral with CommCare, reminding them of the follow-up visit. Daily SMS messages were sent until the follow-up was recorded.

The main measure was the *change in percentage of closed referrals* for each CHW from baseline to intervention periods. Referral and follow-up information was collected automatically by CHWs using CommCare, and sent immediately to the server by the CHW. Timestamps were assigned to the data based on the phone's clock. If the timestamp was obviously wrong (due to battery problems, for example), the time that data was received by the server was used instead.

CommCare was being used by 15 CHWs in the Dodoma program at the time of this study. Initially, 7 CHWs were assigned to the control group and 8 CHWs were assigned to the SMS group. However, two CHWs in the control group were excluded from analysis because they did not report any referrals during the intervention period.

3.2 Findings and Discussion

Due to the small sample size, we consider the findings to be preliminary and only report on descriptive statistics. CHWs varied greatly in how many referrals they opened during the study, ranging from 1 to 43 in the baseline time period. Table 1 shows a summary of the data. From baseline to intervention periods, the mean percentage of closed referrals decreased by 34.6% for the control group and increased by 33.8% for the SMS group.

While the performance improvement for the SMS group was encouraging, it needs to be considered in light of the unexpected drop for the control group. Individual variability may explain much of this drop, but a methodological limitation may also be responsible: all participants, not just those in the SMS group, were told at the start of the intervention period that they would receive SMS reminders when they had pending referrals to close. This instruction may have negatively influenced the control group's performance by setting a false expectation. We revised instructions to participants accordingly for the subsequent Dar es Salaam studies.

Based on the pilot, we modified on the SMS reminder system in two important ways. First, in the pilot study, the earliest reminder was sent on the evening that the CHW's visit was due, too late to make an on-time visit. For the Dar es Salaam studies, we incorporated *proactive* reminders, with the first one being sent the day before a visit is due. Second, if a referral was not closed during the pilot, the system continued to send SMS messages but had no means of determining *why* the CHW was not reporting a follow-up. This issue directly inspired the escalation to supervisor that we evaluate in the larger studies.

Table 1. Total opened referrals and percent closed for the pilot study (*M*=mean, *SD*=standard deviation).

	Baseline Period Referrals				Intervention Period Referrals			
	Total		% Closed		Total		% Closed	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Control (<i>N</i> =5)	15.6	16.8	81.1%	29.3%	21.6	17.5	46.5%	47.0%
SMS (<i>N</i> =8)	16.9	13.4	46.7%	35.8%	21.0	15.5	80.5%	34.2%

4. STUDY 1: ESCALATING REMINDERS TO IMPROVE VISIT PROMPTNESS

We conducted a 12-week study at a different community health program in Dar es Salaam, Tanzania. In this program, the CHWs are asked to visit each of their clients every 28 days or less. Unfortunately, CHWs often take longer between visits, or forget altogether, with either situation possibly leading to adverse health effects for their clients.

The goal of this study was to decrease the number of days past four weeks that a client was not visited. Unlike in the Dodoma study, where CHWs received a single daily SMS reminder per incident, we deployed an escalating system where the supervisor was informed daily if a visit was more than three days late.

4.1 Context and Participants

Pathfinder International runs the community health program we worked with in Dar es Salaam [14, 19], with D-tree International supporting the CommCare deployment. At the time of the study, there were 87 CHWs using CommCare. These CHWs, who are both men and women, vary in age from 23–63 years old. Each CHW has approximately 5–30 clients with a chronic care condition. Most clients are HIV-positive, though some have diabetes, tuberculosis, or other long-term and chronic ailments.

The CHWs are asked to visit each client at least once per month. The main purpose of the visit is to provide social support, as there is a heavy stigma around HIV in Tanzania, although referring sick clients to the health facility is also important. HIV medication regimes are complicated and volatile; the way a client responds to medication can change month-to-month, making it important for the CHWs to their visit clients on a timely basis. CHWs work to identify a primary caregiver for the individual and provide basic training, support and instruction for that individual. The CHW also uses CommCare to collect quantitative data about his/her client during the home visit.

Pathfinder CHWs are all volunteers and often are either a primary caregiver for another HIV-positive individual or are HIV-positive themselves. They are provided with a generous transportation stipend during their monthly meetings and incentivized with personal use of the mobile phone they are given for CommCare.

Finally, for the work done in this paper, a staff member working for D-tree, not Pathfinder, acted as the supervisor for the CHWs. The staff member had a personal relationship with the CHWs and was part of the team that originally trained the CHWs to use CommCare. However, being from a different organization the supervisor may have been less of an authority figure to the CHWs.

4.2 Escalating SMS Intervention

We extended CommCare with an escalating reminder system aimed at improving the promptness of monthly visits that CHWs are required to make. The system works as follows:

1. *Proactive reminders.* The evening before a visit is scheduled, the system sends a message reminding the CHW of the upcoming visit, followed by two more reminders the day of the visit (one in the morning and one in the evening).
2. *Overdue reminders.* Once a visit becomes overdue, daily messages are sent each evening, informing the CHW of the number of days the visit is overdue. On the third day overdue, the message also notifies the CHW that the supervisor will call if the visit does not occur and data is not received.

3. *Escalation to supervisor.* On the fourth and subsequent days, an SMS is sent to a D-tree staff member in the late afternoon with the CHW's phone number, requesting them to manually follow up with the CHW to determine why the visit is not happening and what can be done.

The state machine for the escalating response is also visually represented in Figure 1.

4.2.1 Design

The study period was split into baseline and intervention phases, each lasting 40 days. For the intervention phase, CHWs were assigned to the escalating SMS intervention group (SMS+Supervisor) or to a control group. To mitigate the between-group variability seen in the pilot study, this assignment was done by frequency matching using baseline performance data. CHWs were first put into 10 bins according to the percentage of their client visits that were on time on average during the baseline phase (bins represented 10% increments in on-time performance). CHWs in each bin were then randomly assigned to the intervention or control group.

4.2.2 Procedure

Many of the CHWs interact socially with one another and are aware of any special attention their peers receive. To reduce confusion, during the two weeks leading up to the start of the intervention period all CHWs were told that a random subset would begin to receive SMS. We stressed that a CHW receiving an SMS was not a reflection of performance and that all CHWs should continue to visit all of their clients regardless of whether they receive any SMS or not. Finally, to remind each CHW of the purpose of the automated SMS and to set expectations, an introductory SMS was sent to CHWs in the SMS+Supervisor group before their very first reminder SMS.

To ensure that CHWs did not receive an overwhelming number of SMS messages on the first day of the intervention period, we

chose to send SMS reminders only when clients became newly overdue. This decision means that the effectiveness of the intervention may be conservative, since there is the chance that SMS messages were never sent for some clients who were already overdue for a visit when the intervention began.

4.2.3 Measures and Hypothesis

The main performance measure per CHW is the change in how overdue that CHW's clients are from the baseline to intervention periods. First, let us define $clients_h$ as the set of clients visited by CHW h . For a client $i \in clients_h$, let $totalDaysOverdue_i$ be the total number of days in a given time period client i was overdue for a visit, i.e., the number of days in which the CHW's most recent visit to i was more than 28 days. Using this notation, our primary metric is defined as:

$$avgDaysOverdue_h = \frac{\sum_{i \in clients_h} totalDaysOverdue_i}{|clients_h|} \quad (1)$$

Each CHW's overall performance change is then calculated as $avgDaysOverdue$ during the baseline period subtracted from $avgDaysOverdue$ during the intervention period. Based on this measure, our hypothesis was:

- H1. CHWs in the SMS+Supervisor group will show greater performance improvement from the baseline to intervention period than CHWs in the control group.

4.2.4 Data Analysis

Although 87 CHWs participated in this study, 13 participants were removed before analysis for one of the following reasons: no data submitted during the intervention period (11 CHWs), no active cases (1 CHW), and technical issues with CommCare or the phone (1 CHW). This removal left 34 CHWs in the SMS+Supervisor group and 40 CHWs in the control group. Finally, during the course of the intervention, there were occasional phone problems (e.g. accidentally deleting the CommCare application) and discrepancies (e.g. a CHW reporting s/he had already sent data) reported from CHWs in the field. If there was a discrepancy, we removed the client from our analysis. This happened for 27 clients during the intervention period, which represented 3.7% of the total number of clients visited during that period.

To analyze the change in average days overdue, we used a Mann-Whitney U test. Since this data violated the normality assumption of parametric tests like the t -test, a non-parametric test such as Mann-Whitney U is more appropriate.

4.3 Results

Overall, CHWs in the control condition made 1,269 visits during the study period (675 baseline and 594 intervention), while CHWs in the SMS+Supervisor condition made 919 visits (428 baseline, 491 intervention). Across both groups, CHWs had an average of 10.7 clients, with a range of 1-28.

As expected, the average number of days CHWs were overdue per client in the control group did not change noticeably from the baseline to intervention period (8.2 days to 9.3 days). In contrast, the SMS+Supervisor group saw an 85.6% decrease in the average number of days overdue, from 9.7 days to 1.4 days. A Mann-Whitney U test comparing the performance change from baseline to intervention periods between the SMS+Supervisor and control groups showed that the SMS+Supervisor intervention significantly reduced the number of days that clients were overdue

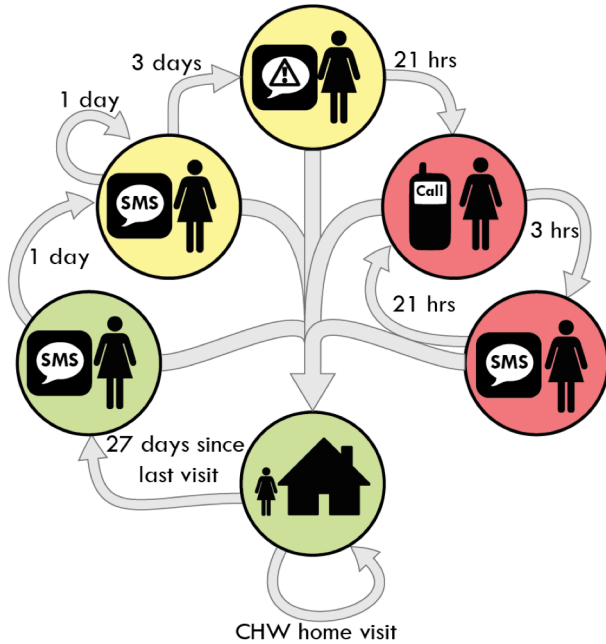


Figure 1. Escalating reminders for Study 1 and Study 2. The green states represent proactive reminders that occur before the visit is due. Yellow states are the overdue reminders and red are the escalation to supervisor.

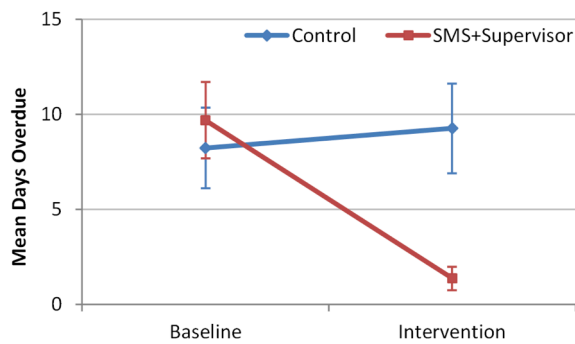


Figure 2. Study 1 performance, showing decrease in mean days overdue for the SMS+Supervisor group. Values on the y-axis are group means, the average of the avgDaysOverdue metric (defined in Equation 1) for all CHWs in that group. Error bars: 95% confidence intervals. (N=87)

(the mean ranks of the SMS+Supervisor and control groups were 25.47 and 47.72, respectively; $U = 271.00$, $p < 0.001$, $r = .500$).

For CHWs in the SMS+Supervisor group, 63.1% of the visits occurred before any SMS were sent. Another 21.0% occurred during the proactive stages—when the CHW starts receiving SMS, but before the visit is overdue—meaning that 84% of visits occurred before the client was actually overdue. An additional 9.4% of visits occurred before the warning message about the supervisor call was sent, meaning that only 6.5% of visits escalated to the supervisor. There were 18 unique CHWs (53%) whose visits escalated to the supervisor. Seven—less than half of those CHWs—reached the supervisor state more than once, with one particular CHW having an escalation to the supervisor on six separate occasions.

5. STUDY 2: REMINDERS WITH AND WITHOUT SUPERVISOR INVOLVEMENT

Study 1 offers strong evidence that an escalating SMS reminder system can positively impact the promptness of routine CHW visits. A downside of the escalation is that it requires involvement from the CHW's supervisor. Although only 6.5% of cases in Study 1 reached this escalation step, involving the supervisor is still more costly and burdensome than sending SMS messages alone. The goal of Study 2 was to quantify the effect of escalating to the supervisor versus SMS messages alone. If the CHWs were motivated to avoid having the missed visit sent to their supervisor, then the effect of the escalation step may have been greater than the 6.5% of cases that were sent to the supervisor.

This phase of the research was conducted over a six-month period following Study 1. Since the context, participants and experiment methodology used here are largely similar to Study 1, we only highlight the differences.

5.1 Experiment Methodology

Study 2 was split into a 90-day baseline period and a 90-day intervention period. Since the baseline period followed directly after Study 1, and with the same CHWs, some CHWs continued to receive escalating SMS reminders during the baseline, while others did not. For the intervention period, CHWs were first labeled as active (i.e. had submitted at least one form) or inactive (i.e. had not submitted any forms) in the 27 days preceding the intervention. Active and inactive CHWs were then randomly assigned to one of two conditions: SMS+Supervisor or SMS-Only. The SMS+Supervisor condition was exactly the same as in Study 1. The SMS-Only condition differed in that CHWs were

only provided with proactive and overdue reminders, but escalation to the supervisor never occurred.

We hypothesized that removing the supervisor escalation would result in a relative decrease in performance. To accommodate the two baseline conditions, our hypotheses were:

H2. For CHWs who received escalating SMS reminders during the baseline period, the SMS-Only intervention (removing the supervisor) would decrease performance compared to continuing in the SMS+Supervisor condition.

H3. For CHWs who did *not* any receive SMS reminders during the baseline period, the SMS+Supervisor intervention would result in a larger increase in performance than the SMS-Only intervention.

At the start of the intervention period, all participants received an SMS notifying them of the upcoming intervention. Members of the SMS+Supervisor group were told they would receive SMS and phone calls, while members of the SMS-Only group were told they would receive SMS reminders, but without phone calls. Following Study 1 and to standardize the intervention across all groups, all pending overdue messages were cancelled at the start of the intervention period, and CHWs only received SMS reminders for clients becoming newly overdue.

Data was analyzed using the same approach as Study 1. Since we expected different outcomes depending on whether or not CHWs had received SMS messages during the baseline period, we stratified the analysis and analyzed the two groups separately. Of the original 87 CHWs, 26 were excluded from analysis for the following reasons: incorrect phone number (2 CHWs), having no data during baseline, intervention, or both periods (22 CHWs), and technical problems with the phone (2 CHWs). In the end, there were 32 CHWs originally from the intervention group in Study 1 (16 SMS+Supervisor, 16 SMS-Only) and 29 from the control group in Study 1 (14 SMS+Supervisor, 15 SMS-Only).

5.2 Results

Overall performance results are shown in Figure 3. Note that the number of days clients were overdue is longer than in Study 1 due to the increased length of the study. With Study 1, the intervention time period was 40 days, meaning a client could be a maximum of 40 days overdue. With Study 2, the intervention time period was 90 days and, consequentially, a client could be a maximum of 90 days overdue.

For CHWs who had been in the SMS+Supervisor group during the baseline period, removing the escalation to supervisor (SMS-Only) negatively impacted performance: the number of days a CHW's clients were overdue increased on average from 9.1 to 26.9. A Mann-Whitney U test showed that this performance change was significantly different from the CHWs who continued to receive the SMS+Supervisor intervention, confirming hypothesis H2 (the mean ranks of the SMS+Supervisor and SMS-Only intervention groups were 12.75 and 20.25, respectively; $U = 68.00$, $p = .023$, $r = .340$).

For CHWs who were originally in the control group for Study 1, Figure 3 shows the average number of overdue days decreased by 9.4 days and 6.7 days for the SMS+Supervisor and SMS-Only groups, respectively. However, no statistically significant difference was found between these two intervention groups, in contrast to hypothesis H3. (Mann-Whitney U test: the mean ranks of the SMS+Supervisor and SMS-Only groups were 14.71 and 15.27, respectively; $U = 101.00$, $p = .880$, $r = .043$).

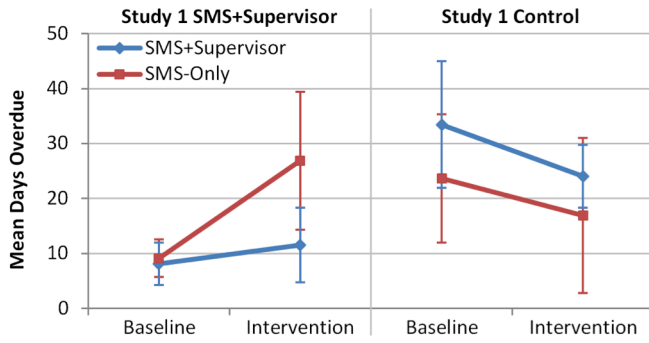


Figure 3. Study 2 performance, showing: (left) an increase in mean days overdue when the supervisor was removed for CHWs who had been in the SMS+Supervisor group in Study 1 ($N=32$); and (right) CHWs from the Control group in Study 1 ($N=29$). Numbers are higher than for Study 1 since Study 2 was longer. Error bars: 95% confidence intervals.

5.3 Limitations

No support was found for our hypothesis that the two intervention conditions would differentially impact performance for CHWs who had been in the control group of Study 1. This null result may have been due to a lack of statistical power. For CHWs who had originally been in Study 1's control group, the SMS-Only and SMS+Supervisor groups in Study 2 only had 14 and 15 participants, respectively, with high individual variability. Consequently, a larger study will be needed to confirm this result.

An additional methodological limitation may have contributed to the null result. As with Study 1, we sent SMS reminders to CHWs only about clients who became *newly* overdue during the intervention period. This decision was made so as not to overwhelm CHWs with reminders on the first day of the intervention. However, it may have reduced the overall effect of the reminders because a CHW may not ever receive a reminder for a client who was already overdue at the start of the intervention period. Indeed, for CHWs who were in the control condition for Study 1, approximately 70% of their clients were already overdue before the start of the intervention in Study 2.

6. CHW AND SUPERVISOR INTERVIEWS

While the quantitative data reported above shows that the escalating SMS approach improves CHW performance, the subjective impact of the automated reminders on the CHWs and the supervisor is also important to consider. Following Study 1, we conducted structured interviews with 30 of the CHWs. Participants were chosen by convenience, selected from those who were present during a D-tree monthly meeting. A total of 16 CHWs from the control group and 14 from the SMS+Supervisor group were interviewed. The CHW interviews consisted of 11 questions organized around self-assessment of routine visit performance. For those CHWs from the SMS+Supervisor group,

Table 2. Reasons given by CHWs for not visiting clients during Study 1 ($N=30$).

Answer	Frequency
Client is traveling ($N=9$)	23.1%
CHW is busy ($N=8$)	20.5%
CHW forgot ($N=3$)	7.7%
CHW is sick ($N=2$)	5.1%
Phone trouble ($N=1$)	2.6%
Other ($N=16$)	41.0%

we also asked about feedback on the escalating reminder approach; due to a logistical issue, 11 of the 14 CHWs answered these questions.

After Phase 2, we also interviewed the supervisor from D-tree who had been responsible for making phone calls during the study. The conversation was a semi-structured interview with three main themes investigated: perception of her workload and how she managed it; perceived benefits and drawbacks of the system, both the SMS messages and her phone calls; and suggestions about system design and how it could be improved.

We present interview findings organized around the most salient themes that emerged.

6.1 Overall Response to SMS Reminders

When asked about the frequency of SMS reminders for overdue clients, 10 of the 11 CHWs in the SMS+Supervisor group agreed that the system should continue to send daily (rather than less frequent) SMS reminders, suggesting that CHWs felt comfortable with the number of messages they were receiving. In fact, respondents estimated on average that they had only received 9.4 SMS reminders during the 40-day intervention period ($SD=6.68$). Our system actually sent an average of 18.7 ($SD=12.1$) SMS to this set of CHWs. This substantial difference suggests the CHWs do not mind the SMS messages. In general, CHWs were aware that they often had clients overdue: of the 30 CHWs interviewed, only 4 stated they had zero overdue client visits.

Preference was for the SMS reminders to be sent in the morning (8 CHWs vs. 2 CHWs preferring evening and 1 preferring afternoon) to allow the CHW time to plan her day. This time of day is in contrast to the preferred time of day to receive the escalated phone call from the supervisor; the supervisor reported that most CHWs preferred to receive her phone call in the evening when they were free to talk.

In addition, the supervisor felt like her role in the escalating reminder approach did not require a lot of work, though she admitted that she did not make phone calls every day if she was busy with other work.

6.2 Overdue Visits

CHWs gave many reasons for having overdue visits (see Table 2). The most common reasons were that the client was traveling or that the CHW was busy or forgot to make the visit. For "other" most CHWs said the client was not home or was doing fine and did not require a visit. The supervisor found that by the time missed visits had escalated to her, there was generally a good reason. As she put it,

"Most of the time there is a reasonable reason. That maybe 'I am sick, I am travel[ing], phone problem,' that's the reason. Although ... [the CHW saying s/he is busy] also happens"

She says sickness, traveling and problems with the phone are the "big three reasons" that CHWs give for not going on a visit, which roughly corresponds to the CHW response.

One issue with the overdue reminders is that they continue to be sent even if the CHW has a good reason for not completing the visit in the near future. Although supervisors are in the best situation to decide if reminders should be canceled, there is currently no way for the supervisor to feed that knowledge back into the system. In the supervisor's words,

"...it is a lot of reminders while the reasons are known that 'Ok, this one [CHW] is sick. When she is ok she will visit the patient.' But, still the reminder is coming to me. And even if you say that

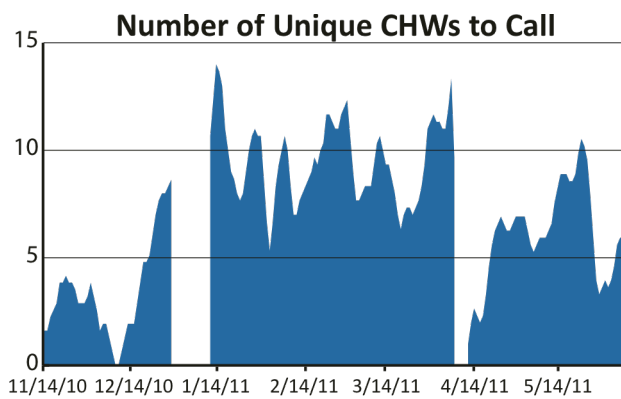


Figure 4. A histogram of the number of unique CHWs for the supervisor to call per day. A three-day running average was used to smooth the data. The gap in early January coincides with a database synchronization error. In early April, it is the result of the start of Study 2.

"Ok, the [CHW's] phone is stolen," sometimes still the reminder is coming to me 'til I wrote an email ... or I write an SMS to [the person running the automated reminder system]"

This frustration highlights the importance of providing tools so that the supervisor has control over the messages that are sent.

6.3 Escalation

While Study 2 demonstrated the positive impact of escalating reminders to the supervisor versus SMS messages alone, the interviews further highlighted the nuances of this escalation. During the semi-structured interview with the supervisor, we learned that CHWs were not always available when she called. As a result, the supervisor informally added a subsequent point of escalation, where she would call the local champion, a hard-working CHW who is given more responsibility to help supervise neighboring CHWs. These champions are peers to CHWs and often have an established personal relationship with the CHWs in his/her area, providing another point of accountability and source of information. As the supervisor stated,

"... some [CHWs] are not reachable at all. Therefore, if ... I'm not reaching them, I have to call them another time and another time ... And then I ... call the champion and ask 'how about this [CHW? She] ... is not reachable, why?' So the champion has to check for me."

She estimates that, on average, she only calls twice in a month to follow up with a champion about a CHW.

6.4 Personal Relationships

For this project, personal relationships were an important factor of success, as has been identified by other ICTD projects [31]. The CHWs were quick to understand the escalation process and

"... when the the [sic] message come to her or to him second times she know that 'ok, ... [the supervisor] will call'. Therefore she tried to ... complete her work. ... even if she see that 'ok there is a problem that I cannot--even if I visit that client I cannot send the message' sometimes they call me that 'oh, [supervisor] ... my phone message failed to be sent' or sometimes they call the [phone number that the automated SMS comes from]"

The CHWs understood what was happening and were comfortable enough to tell the supervisor—even contacting her proactively on their own if there was a problem or another reason that the visit could not be completed.

6.5 Change in Workload Over Time

When asked about how her workload changes over time, the supervisor responded that

"as times goes ... the calling SMS is reduced."

An investigation of the number of unique CHWs requiring a phone call per day (Figure 4) provides support for this statement. The supervisor suggests that the

"first phase stimulate[d] them [the CHWs] to work hard, that's why the second phase is more easy."

It does appear that there is a trend of fewer CHWs requiring a follow up phone calls in the second study. The peaks and valleys in Figure 4 are the result of deleting reminders for which there was a discrepancy or known reason (e.g. the client was traveling or the CHW had a technical issue with his or her phone).

7. DISCUSSION

These studies demonstrate the value of an escalating SMS reminder system for improving CHW performance. In Study 1, CHWs who received the intervention showed an 85.6% decrease in the average number of days their clients were overdue (from 9.7 to 1.4). Study 2 confirmed the added benefit of escalating to the CHW's supervisor compared to SMS messages alone, showing that removing the escalation step resulted in a significant decrease in performance. While neither of these larger studies provides conclusive evidence about the effect of SMS messages without supervisor involvement compared to no intervention, preliminary findings from the pilot study suggest there may be a benefit.

7.1 Lessons Learned

7.1.1 CHW Communication Channel

It became immediately clear after deploying the system in Study 1 that any automated communication system must support two-way communication. We had originally instructed CHWs to follow up with the D-tree supervisor if there was any confusion with any aspect of the system. However, within three days of starting the intervention period in Study 1, a CHW tried to call the automated number (it will just ring indefinitely). During that 40-day intervention period, there were a total of 21 attempts to contact D-tree or the research team over SMS or voice with the automated number, not counting CHWs who called more than once in a row. In one notable message, a CHW commented that she was sick and asked to be assigned a client who was physically closer than the one referred to in the reminder SMS she had received.

To address this problem, we quickly extended our system to automatically send an email to the research group whenever there was a missed call or incoming SMS. In future versions, we would like to expand this functionality, either to allow CHWs to directly communicate with the system, or perhaps to spoof a different phone number so that when CHWs call or text back there is an actual person to respond.

7.1.2 Easing the Supervisor's Burden

Keeping the supervisor informed contributes significantly to the effect of the SMS reminders. One concern, however, is that we may overburden supervisors with copies of each reminder being sent. Fortunately, a few simple changes would lessen this burden and likely have little or no impact on the observed effect. Currently, the system sends the supervisor one message per client who needs to be visited. Instead, we could aggregate messages together by CHW (e.g., “CHW <name> has received n reminders today”), or send a single message with a link that contained more detailed information (e.g., “ n reminders were sent to m CHWs today, for more detailed info see: <link>”). As reported in the interview section, the supervisor also commented that CHWs often had good reasons for not visiting their clients when she called them. Another useful modification would be to build a tool to allow the supervisor to cancel or temporarily suspend SMS reminders.

7.2 Sustainability

7.2.1 Cost

An important aspect of sustainability is the on-going cost of running the reminder system. In this section, we present a preliminary analysis of the incremental cost of running this system on top of an existing ICT4CHW deployment, as we have presented in this paper.

During Study 1, we sent an average of 28.1 ($SD=25.24$) SMS per CHW. This includes messages sent to the supervisor, which accounted for 15.3% ($N=137$) of total SMS messages sent by the system. If we factor in that there were 9.1 clients per CHW in the SMS+Supervisor group for Study 1, there were an average of 3.1 SMS per client for the 40-day period. For a one-year period, this would be equivalent to 28.1 SMS per patient. At the time of writing, SMS costs are approximately \$0.03 per message, though it is possible to buy in bulk to lower the price.

At that price point, the intervention adds an estimated \$0.84 per client per year of running the ICT4CHW program with automated escalating reminders. Sending aggregated SMS to CHWs and to the supervisor instead of one-message-per-CHW would help reduce this cost. To put this dollar cost in perspective, the median cost of the “most commonly prescribed regimen for adults” for HIV treatment is approximately \$62 per patient per year [32].

The escalating reminder system also has a time cost, which is more difficult to quantify. Namely, the D-tree supervisor did not find that being responsible for approximately 35 CHWs at any given time was a significant amount of work, though she did admit to not making phone calls on some days because she was busy with other responsibilities.

Additionally, beyond the incremental cost of implementing a system like this, the amount of effort for an organization to maintain the system and keep it running smoothly must be considered. Any organization deploying an ICT4CHW project will need some level of technical expertise on their team. Phones need to be setup correctly, data collection forms need to be authored, and data needs to be moved around for analysis. This level of technical expertise is sufficient for maintaining an additional reminder system similar to the one presented in this paper. No further technical capacity should be required.

Finally, we must balance even small incremental costs against likely benefits. Patients not visited on time can develop complications leading to more serious medical conditions requiring even more expensive care and scarce medical resources. We believe that the costs described above will be outweighed by

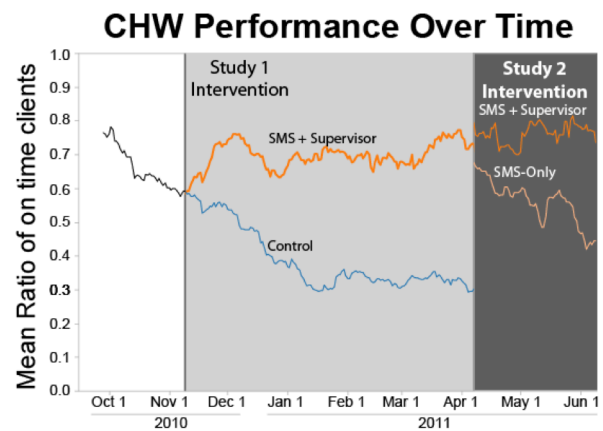


Figure 5: CHW performance using a different metric—ratio of on-time clients. Study 1 lasted 40 days, but the intervention continued until Study 2 began. At the beginning of both Study 1 and Study 2, SMS interventions only occurred with clients who were already on time, meaning that very overdue clients could be lost. The Study 1 control group is not shown during Study 2 intervention.

improved health outcomes. However, a detailed analysis of this cost-benefit tradeoff is left to future work.

7.2.2 Novelty Effect

Technology interventions in low-income settings are rarely studied for extended periods of time. Introducing new technology can create excitement and stimulate activity, but initially observed levels of improved performance may not be sustainable over time. The automated reminders system has been running continuously since November 2010. Figure 5 shows the CHW performance over a nine-month period. In the graph the performance metric is the ratio of on time clients—those who had been visited in the previous 27 days—to the total number of clients, averaged by the group given by the label.

The graph gives a holistic view of performance over time, making it easy to see the effects detected in the two studies. Longitudinally, the SMS+Supervisor group has maintained a high level of performance over the nine-month period of the entire set of studies. There is a noticeable rise in performance directly after starting the reminder system, as well as a dip towards the end of 2010. This can partially be explained by the CHWs working less during the holiday period, but also suggests the novelty effect wearing off. After the dip, the performance of the CHWs settles into a steady state, with a significantly higher level of performance compared to the control group.

At the time of submission, our system is still running and has sent more than 25,000 SMS messages over the eight and half month period.

7.3 General Limitations

The studies presented here measure reported follow-ups and are not correlated with ground truth of actual follow-ups. We explored the option of performing spot checks, but it was not realistic based on the resources available. The sensitive nature of the Pathfinder clients adds an additional challenge, as supervisors are not always welcome to visit clients at will.

If all CHWs were reporting visits that did not actually occur, we would expect no visits to ever become overdue. However, we have seen that a significant number of visits become overdue, which suggests that at the minimum, a subset of CHWs are

reporting actual visits. Additionally, that CHWs would call or SMS the automated number as well as the supervisor to explain why a visit had not occurred provides further evidence that CHWs were reporting actual visits.

We anticipate that similar studies in the near future will make use of GPS and the decreasing cost of mobile phone technology to address this limitation.

8. CONCLUSION AND FUTURE WORK

This work is one step towards a continuing research agenda looking at simple and cost-effective interventions that yield high benefit for health care delivery in low-income regions. Study 1 demonstrated that our automated escalating reminder system significantly reduced the number of days CHWs were overdue on average in making routine client visits, from 9.1 to 1.4 days. Study 2 demonstrated that escalating to supervisor is integral to this process, despite only a small portion of overdue clients ever escalating to that level: when the supervisor was not informed and only SMS reminders were used, CHW performance decreased.

Several directions for future work could be explored to further improve on the escalating reminder approach. First, simple tools to allow supervisors to cancel or postpone reminders may reduce the supervisor's workload. This interaction could be done through SMS, a mobile application or a web portal. Empowering CHWs directly to respond to reminders in a structured way may also be beneficial. For example, an SMS interface could parse CHW responses, allowing them to postpone the reminder a set amount of time or request a supervisor phone call. Limiting the number of actions a CHW could take through this interaction would help address the difficulty of training CHWs to use the system.

Combining supervisor SMS would likely have little impact on the observed benefits for CHW performance, but could result in potentially significant cost reductions due to the lower number of required SMS messages. We plan to explore whether the positive outcomes seen in our studies can be maintained while reducing the number of SMS reminders sent to CHWs.

Finally, we would like to explore alternate methods of behavior change. Sending messages to groups of CHWs, for example, may invoke social pressure that would achieve behavior change without escalation to the supervisor. Similarly, it may be possible to escalate first to local champions before the supervisor in order to maintain a reduced workload while we scale.

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