

Combating Rural Child Malnutrition through Inexpensive Mobile Phones

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ABSTRACT

Most organizations in the developing world still rely on paper for record keeping, giving rise to many problems in aggregation, storage, transmission and analysis of data. Errors and time delays associated with paper data are particularly problematic in the domain of healthcare. We present a case study of CommCare, a low-cost mobile phone data collection solution deployed to enhance the paper-based record management system of a non-profit organization working in prevention of child malnutrition in rural central India. Through a three-month unsupervised field trial with ten rural health workers we report data management gains in terms of data quality, completeness and timeliness for 836 recorded patient cases, and demonstrate strong preference of the system by health workers. We found that the motivation for use and acceptance of the system was tied to respect and social power in local communities associated with using the device, as well as non-work-related uses of the phone.

Author Keywords

Low-end mobile phones; malnutrition; data collection; health workers; developing region.

ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

General Terms

Design; Experimentation; Human Factors; Performance.

INTRODUCTION

In rural settings within developing countries, records are mostly maintained on paper forms (see Figure 1). Very often there are multiple points of entry of the same data transferred into numerous paper forms, before it gets transcribed and aggregated on a centralized computer system at an urban location. This process of copying and compiling data on paper is both error-prone and time

consuming, with long delays between initial data entry and data aggregation and digitization. High error rates in data are particularly problematic in the domain of healthcare where an errant entry may prevent lifesaving treatments from reaching patients. Furthermore, because of delays in aggregation, it may take weeks or months before decision makers view the data, resulting in corresponding delays in remedial actions such as providing emergency medical care.

Networked digital devices such as mobile phones, personal digital assistants (PDAs), tablets and laptops are increasingly being used for improving the efficiency and effectiveness of data collection, as these technologies allow single-point digitization and efficient aggregation of data. Several initiatives in the past two decades have used PDAs for primary data collection in the developing world [1, 3, 10, 13, 14, 15, 23, 29]. Most recent innovations in data collection in the developing world have moved from PDAs to smartphones [8, 16]. However, even though the cost of smartphones is rapidly falling, they remain too expensive for many applications. In contrast, about 60% of the nearly 5 billion existing mobile phone subscribers live in developing countries [17, 20], and most of these subscribers own low-cost phones. There is an opportunity to use these low-cost phones for data collection in the field where resources are most acutely constrained.



Figure 1. A Community Nutrition Educator (CNE) records child health information on paper forms in a village in rural Madhya Pradesh, India.

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CommCare [5] is an open-source mobile software application that can run on inexpensive Java-enabled phones to support and monitor community health programs. The CommCare system was developed and deployed specifically for data collection and reporting in resource-constrained settings. Two previous studies of CommCare include deployments to health organizations in Tanzania [4, 22] and Zambia [6]. These studies of the CommCare system focused on the iterative design process and offered preliminary discussions on potential gains in data entry time as well as the perception of the system among patients. In this paper, we extend this work to study CommCare in India, deployed by an organization working to prevent child malnutrition. We provide three main contributions: i) The first instance of a formal case study of the CommCare system, studied over three months of deployment in rural India. ii) Demonstration of actual data-management gains achieved through the CommCare system compared to an existing paper-based record-management system. These gains are measured in terms of data quality, completeness and timeliness for 836 patient cases over a three-month period of unsupervised use. iii) A discussion of user experience of the CommCare application and potential benefits in decision making assessed through in-depth end-user interviews with health workers and decision makers respectively.

In addition, we observed two secondary findings related to the use of mobile phones. First, we found that in spite of infrastructural challenges with electricity and connectivity, the rural health workers showed a strong preference for the CommCare system because of the social respect and social power they earned in the local community from the use of this system. And second, we saw that user motivation for non-work and entertainment-related activities on the mobile phone was so strong that it helped trump complexities in the user interface, such as native text input, even for low-literate, novice users. We conclude with recommendations for mobile-phone deployments for resource-constrained settings based on lessons learned.

RELATED WORK

An extensive body of work in the past two decades has used mobile devices such as PDAs, phones and tablets to improve the efficiency and effectiveness of data collection in the developing world. The largest number of efforts in this area has been in using PDAs as the platform for data collection for: malaria monitoring in Gambia [13]; clinical research in Gabon [23]; tuberculosis records in Peru [3]; sexual behavior surveys in Peru, [2]; infant health in Tanzania [9, 29]; respiratory health in Kenya [10]; tobacco surveys in India [15]; and others (SATELLIFE [14], DataDyne EpiSurveyor [28], EpiHandy [12]). More recently, a number of the efforts for mobile data collection and digitization in the developing world have been based on higher-end phones, most notably Open Data Kit [16], a modular, extensible open-source suite of tools on the Android platform. Another study looks at the use of a

mobile smartphone application built on the Android platform that uses computer vision to capture data from paper forms [8]. Research studies have also tried to build seamless integration across paper and digital forms by using camera-enabled phones [25]. While the prices of PDAs and smartphones are falling, they still remain expensive and are not quite robust for many resource-constrained settings in the developing world.

Recently, there has been some work using prototype digital slate devices for data collection and digitizing in rural microfinance [27]. And, using low-cost mobile phones, there have been some recent efforts in malaria monitoring in Kenya [24] and monitoring infant mortality in Mali [19]. However, to our knowledge there has been no formal research of these latter efforts documented in the academic literature. Researchers have conducted quantitative evaluations of data entry accuracy on low-cost mobile phones using electronic forms, SMS, and voice interfaces among rural health workers. However, unlike ours this is not a in-the-wild study and also does not offer a qualitative assessment of user experience issues [26]. Two studies looked at the iterative design process along with hardware and software issues for the CommCare application in Tanzania using low cost Java-enabled phones [4, 22]. These studies provide some preliminary discussion of potential gains in data entry time compared to paper-based record keeping, but they offer no real objective evidence. In another study of CommCare in Tanzania [32], anecdotal evidence and focus groups suggest that health workers benefited from the use of CommCare, but again, the study was not rigorous in nature. We complement these studies by presenting observations and findings from a three-month unsupervised field deployment of CommCare in rural India. We show clear benefits in the efficiency of data management compared to an existing paper-based record management system, and we also offer a detailed qualitative assessment of user experience issues reported by health workers during the three-month deployment.

PROBLEM DESCRIPTION

This paper describes an attempt to replace the paper-based record management process used by the non-profit Non-Government Organization (NGO) Real Medicine Foundation (RMF) in rural central India with the CommCare system. Since January 2010, RMF has been working to eradicate child malnutrition in five districts in the state of Madhya Pradesh. RMF trained 60 community health workers, whom they refer to as Community Nutrition Educators (CNEs—see Figure 1). CNEs' major tasks include identifying children with Severe Acute Malnutrition (SAM) and Moderate Acute Malnutrition (MAM), counseling families of malnourished children, and referring SAM children to government treatment facilities called Nutritional Rehabilitation Centres (NRCs). RMF's program to eradicate malnutrition, which runs until mid-2013, aims to halve the incidences of acute malnutrition in target villages in Madhya Pradesh.

Existing paper-based system

Each CNE covers ten villages and visits each village two times every month. During each village visit, the CNE conducts community capacity-building sessions on malnutrition, proper breastfeeding practices, sanitation and hygiene, locally available nutritious foods, and available government treatment services. Following the community session, the CNE identifies children with SAM and MAM utilizing the MUAC measurement (mid-upper arm circumference, a common test for malnutrition), provides further counseling to families with malnourished children, and refers SAM and MAM children to the NRCs or anganwadi workers (AWWs), government-commissioned community health workers, for treatment.

CNEs record their activities in two paper formats: First, there is a daily visit form that tracks individual children, community and household training sessions held, referrals made, and follow-ups with children in their homes. Second, there is a weekly report summarizing all of their activities from the daily visit forms. These weekly reports track the following indicators at the village level: number of new SAM and new MAM children identified; number of SAM children improved to MAM; number of MAM children improved to normal; number of referrals to NRCs; number of children who actually went to an NRC; number of family counseling sessions; number of community counseling sessions; and total individuals present at counseling sessions. In addition to the daily visit form and the weekly report, there is a MUAC register where every CNE records child-specific MUAC data (for SAM and MAM children), but this data does not make it to the weekly report.

At the district level, each CNE reports to a District Coordinator (DC). The DC is responsible for spot checks of CNEs, following up with children currently receiving treatment at NRCs, and conducting weekly meetings to collect the weekly reports from the CNEs. Each DC then collates these weekly reports into monthly district reports, which are submitted to the Program Manager at monthly meetings for entry into Microsoft Excel for the digital MIS (management information system) at a central location.

Limitations in the paper-based system

The current paper-based system employed by RMF has several limitations.

- *Low granularity of data and loss of data at the backend:* There is no persistent aggregate record of medical and malnutrition history per child. Child-specific data recorded by the CNEs in their MUAC registers does not make it into the aggregated weekly record. The lack of individual patient data prevents RMF from tracking the health of individual children, evaluating performance of CNEs, and determining the success of its program over time.
- *Low process efficiency:* As seen above, there are multiple points of entry of the same data by the CNEs on multiple

forms. Copying and compiling data can introduce errors. There is a lag of about one to two months from collection of data to analysis by RMF management. Given the lag time from collection to entry and analysis, RMF's ability to respond to increased pockets of malnutrition is also limited.

- *Limited utility of the data for end use – one-way data:* Once the aggregation is done on the central MIS, the CNEs and DCs do not receive any feedback for follow-up action in the field. According to RMF, the aggregated digitized data stored in the MIS was mostly for archival purposes and was not actively used for decision support.
- *Limited accountability:* CNEs function independently with little oversight from RMF. There was no way to hold CNEs accountable due to absenteeism in the field. Additionally, the spot checks were poorly managed by the DCs in order to maintain good interpersonal relationships with individual CNEs.
- *Challenges in centralized data entry:* Finally, locating qualified data-entry staff in RMF's remote rural districts is challenging. Entry of aggregated data collected from just 60 CNEs takes RMF data-entry staff over a month's time.

SOLUTION DESIGN PROCESS

Design considerations

A meaningful solution to these problems would improve the quality of child malnutrition data. Gains in data accuracy, completeness, and timeliness of updates could be achieved through local digitization of information. Entering malnutrition data digitally during a household visit and having it immediately processed and reported to the database would remove the need for physical transport of paper forms and remove redundant data entry. It would also improve accuracy, as data would be digitized at the point of entry, unlike in the current approach where a data-entry officer transcribes and digitizes the data collected by CNEs. Furthermore, digital recording of child-specific information would improve the granularity of data.

In addition, immediate, local digital data entry could allow for the automated calculation of several outcome variables such as the change of SAM to MAM, the total number of trainings and counseling sessions, etc. This would automate (or make redundant) the generation of weekly and monthly reports, thus reducing the CNEs' workload and the possibility of any calculation errors.

Design Constraints

Given that the digital record-management system would be deployed in the field in rural central India, there were a number of user, device, and system constraints that had to be taken into account:

- *Unsupervised use:* Perhaps the most important constraint is that the digital record-management system had to be functional in remote locations with minimal technical

support and require only moderate training. This simulates a real-world situation where local technical support is challenging to provide in a rural context in a timely manner.

- **Device literacy:** The digital solution needed to be easily usable by the CNEs who do not speak English, have low levels of education in the local language (Hindi), and limited experience with ICTs (e.g., using only voice phone calls on shared mobile handsets).
- **Electrical power infrastructure:** Some of the villages where the CNEs worked had frequent power outages, and electricity was available only up to six hours per day during the summer and monsoon season. Batteries for devices had to charge quickly and efficiently and be robust to variable power (see below).
- **Device cost:** To provide greater access and scalability for non-profit NGOs such as RMF, the cost of the devices would have to be kept low. Building the record-management system on platforms such as smartphones or tablet PCs would be unsustainable.
- **Intermittent connectivity:** For sending data to the remote database, the digital solution would have to be functional at rural locations where connectivity was intermittent.
- **Robustness of device:** Rural areas in central India often are hot and dusty during summers and very wet during the monsoons. Also there tend to be high fluctuations in electrical power with the changing seasons. The device used for the record management system would need to be highly robust to withstand all of these environmental challenges.

Solution: Phone-based CommCare System

Happily, the device that fits the above constraints happens to be very common in rural India: the mobile phone. The CommCare application can run on inexpensive Java-enabled phones and was adapted to the RMF record-management system. The mobile application is complemented by a server-side case management solution called CommCareHQ [7] that allows managers to create, edit and deploy the mobile application, manage and communicate with health workers, and export data submitted by the health workers [39]. CommCareHQ also allows management to enroll, support and track all of their field workers.

The mobile application was designed through a participatory process, which has been previously discussed [22]. The adapted application consisted of audio and image prompts to decrease reliance on text (Figure 2). All text was displayed in Hindi, the local language in rural central India. In addition, the CommCare interface was enabled for native input, so CNEs could enter free form text in Hindi, as required. For this deployment, the device used was a Nokia C2-01, costing ~USD 75.

Figure 2 shows four screenshots of the CommCare mobile application interface in Hindi.
 (a) Nutrition and Health Form: Shows a MUAC value of 12.0, which is categorized as 'मध्यम कुपोषित' (Moderately malnourished). It asks if the child is underweight and if there are any other problems.
 (b) Nutrition and Health Form: Shows a branch of questions for a MAM child, asking if the child needs to go to the Anganwadi center.
 (c) Referral Form: Asks if the child's mother is satisfied with the NRC treatment and if the treatment is complete.
 (d) Family Counselling Form: Shows a counseling session between a health worker and a woman, with questions about family counseling.

Figure 2. CommCare forms. a) Nutrition and Health Form recording MUAC value, b) Nutrition and Health Form displaying the branch of questions for a MAM child, c) Referral Form, d) Family Counselling Form.

The CNEs could monitor malnourished children in CommCare by capturing key pieces of data on MUAC, clinical symptoms, referrals and follow-up care at the NRCs. The mobile application contained five forms, each containing a set of questions controlled with skip logic and data validation that would guide CNEs through their home visit workflow and counseling sessions. The five forms were (See Figure 2): (1) Registration, (2) Nutrition and Health, (3) Referral, (4) Family Counseling, and (5) Group Counseling.

In the Registration form, CNEs registered SAM and MAM children and collected identification information such as name, mother's name, father's name, village, and vaccination history. This is where a CNE added children to her case list in CommCare.

The Nutrition and Health form displayed questions that reminded the CNE of relevant counseling information that needed to be given to the child's caregivers; informed the CNE of the child's nutrition status from a previous visit and actions taken; and compared previous and current nutritional status to indicate improvement (or worsening) of health. The nutrition status was based on the MUAC value and associated clinical symptoms (Figure 2a). If the MUAC entered was less than or equal to 11.5, the form displayed

the branch of questions pertaining to the care required for a SAM child. If the MUAC entered was greater than 11.5 and less than 12.5, the form displayed the branch of questions pertaining to the care required for a MAM child (Figure 2b). A referral to the NRC was triggered if a child was determined to be severely malnourished or displayed signs of edema.

CNEs could track any open referrals to the NRC in the Referrals form (Figure 2c). In this form, the CNE could track whether the child had been admitted to the NRC and completed treatment. After the treatments were complete, the CNE would close the referral. For ongoing treatment, the CNE could schedule a date to make a follow-up visit. If the treatment was incomplete, the CNE was required to enter a reason before she could close the referral.

The Family and Group Counseling forms (Figure 2d) were built to display nine counseling topics that a CNE might speak about during a home-based family counseling session or a group counseling session at the village health center. The CNE would open the form when she began counseling, enter the number of individuals present and answer “yes” or “no” per topic to indicate whether it was discussed. Each topic was represented by an image to serve as a convenient visual cue to remind her of the topics she may choose to discuss with beneficiaries.

All completed forms in the mobile application were sent to CommCareHQ over a GPRS connection. If connectivity was unavailable, the completed forms were saved locally on the phone and automatically sent when connectivity was restored. RMF staff members and/or RMF’s District Coordinator were able to view the data in real-time through pre-built performance reports on CommCareHQ. They could also monitor CNEs’ performance and track data collected in the forms to make evidence-based decisions for their community health programs and workforce. The pre-built reports included daily form submissions and completions, form completion trends, case activity, etc.

DEPLOYMENT

We deployed the CommCare system with 10 CNEs in Khandwa district in rural Madhya Pradesh for a period of three months from 10 July to 10 Oct 2011. Before deploying we took informed verbal consent from all 10 CNEs and the program coordinator.

During this period the CNEs visited individual households to record child-specific data, information on referrals, and family and nutrition counseling. In addition to the CommCare application, each CNE also recorded data in the paper forms as they had always done. While this might seem inefficient, RMF wanted to be certain that no data was lost during this trial. However, as a result, we were able to generate information contrasting the new digital system with the existing paper-based system. Throughout the study, the CNEs maintained ownership of both the CommCare phones as well as the paper forms.

Participants

Ten female CNEs participated in the deployment of the CommCare system. The median education of the CNEs was grade 8. Their mean age was 35.3 years (sd=5.5), and they had been working as a CNE for an average of 12.4 months (sd=6.8). All participating CNEs spoke at least two languages—Hindi and a local tribal language such as Korku or Neemadi—and were familiar with the Indo-Arabic numeric digits. All of them had mobile phones at home (owned by their husbands), and three of them also had their own personal phones. All participating CNEs had previously used a phone for receiving and occasionally dialling phone voice calls, but only one of them had sent text messages and saved phone numbers to the contact list. All but two of the participants owned television sets in their homes, half of them had some video playback device (typically VCDs), and only one of them owned a computer. Eight of the participants had only one electric socket at home (the remaining two had two sockets); they used a socket-multiplier to power multiple appliances including electric light bulbs, TVs, and mobile phones.

Training

The deployment was initiated by a one-day training session for the CommCare application. Ten CNEs, one DC, and one regional program coordinator of RMF attended it. DC, who was previously trained by one of the authors, led the training. The training included a three-hour demonstration of the CommCare application in groups of five, followed by individual practice for one hour each.

Data collection

We conducted face-to-face interviews with all ten CNEs and the program coordinator at the end of the deployment period. Informed verbal consent was collected before recording the interviews. Respondents could refuse to be audio-recorded, but none did. All CNE interviews were conducted in Hindi, while the program coordinator interview was in English. The CNEs were asked about their experiences while using the CommCare application, as compared to the paper-based system. To complement the interview data, we collected data on quality, completeness, and latency logged onto CommCareHQ. In addition, we also collected paper forms filled out by the CNEs between July and Oct 2011 in order to compare quality and completeness of forms. The time taken between the collection of data and analysis in the paper-based system was self-reported by the program coordinator in his interview.

OBSERVATIONS AND FINDINGS

During the three-month period, CNEs registered a total of 836 children and collected MUAC data 1434 times, i.e. approximately two readings per child. In terms of form submission distribution, 23% of the total submitted forms were Registration forms, 40% were Nutrition and Health forms, 2% were Referrals, 34% were Family Counseling forms, and 1% were Group Counseling forms.

Here we report our observations and findings related to this deployment. We break this down into three main areas: objective measures of data management comparing the existing paper-based system and CommCare; the user experience of the CommCare system for RMF; and finally, the ways in which the system may improve service delivery, resource allocation and overall decision-making for the RMF program.

Data management

The principle driver of this project was the promise of improving the efficiency and accuracy of data management for our NGO partner. To help us understand whether there was any objective improvement, we compared the new CommCare system to the existing paper-based system on measures of latency, data completeness and data quality.

Latency

We define latency as the time it takes for data collected by a CNE in the field to reach the regional program coordinator in digital format. RMF management reported that the latency for the paper-based system is on average 45 days. For the CommCare system, CommCareHQ logged the time when a form was filled and when the form was submitted to the server. Using the CommCare system, the mean latency was eight hours ($sd=3.25$), a dramatic improvement over the existing paper-based system. In addition, we should note that the paper-based system only digitizes and stores the aggregated data in the MIS, while the CommCare system stores *all* data collected by the CNEs on their mobiles.

Data completeness

Data completeness is the extent to which required or expected attributes of the data fields were recorded by the CNEs, i.e. to what extent do CNEs provide all the data they are supposed to? For the paper-based system, we looked at the ratio of fields actually filled to those that were required in the different forms. To estimate data completeness in the paper system, we analysed a representative sample of paper forms by looking at the daily visit forms from five randomly selected CNEs. We needed to reduce this to a manageable amount of data, so we systematically chose forms from every fifth day (this reduced the variance due to weather, holidays, etc.). We found that on an average 67% ($sd=5.8$) of the daily village visit fields were filled.

For the CommCare system, while none of the fields were mandatory, we found that on an average 84% ($sd=4.1$) of the fields in the daily village visit form (which includes counselling) were filled. Hence the CommCare solution collected significantly more data compared to the paper-based system.

Data quality

Data quality pertains to the error rate in transferring data from the daily visit forms to the weekly reporting form per CNE, from the weekly reports to monthly district reports by the DCs, and finally transcriptions of monthly reports into Excel and the MIS. Because we only had access to the

CNEs' forms, we only looked at the first step, the transcription from daily forms to weekly reports. We only consider miscalculation for our analysis. To compute data quality, we first randomly selected five CNEs. Thereafter, for each CNE, we randomly selected cumulative forms for four weeks. Two researchers from the team compared the number of differences between the daily visit and weekly report forms. We found that the error rate was 9.4% ($sd=2.7$) in transferring data, assuming that no errors occur at the point of data entry on the daily visit form.

For the CommCare system, every form was transferred directly to the cloud-based server CommCareHQ. As there is no transfer of data between forms involved, data quality should approach 100%.

User Experience

While objective measures indicate that the CommCare system was an improvement over the paper-based system, we were very interested in how it would be perceived by the CNEs who had to work with it on a daily basis. We identified a number of challenges and benefits of the CommCare system through open coding of the CNE interview data.

Interacting with the phone and managing native text input

Considering that the CNEs had very limited experience with ICTs, we assumed that the complexity of interacting with the phones would pose severe challenges to the use of the CommCare application. Prior to the training session, only one CNE had used her phone for text messaging. Indeed, consistent with related research in mobile interfaces for low-literate users [21], we observed that the CNEs who owned phones had never used their phonebooks; instead they dialled numbers from scratch each time. The experience of the remaining seven CNEs, who used other family members' phones, was limited to knowing that the "green" key was for receiving calls and the "red" key was for cancelling.

Given this, we predicted that the native text input of the device (in Hindi) would present an enormous challenge. Hindi text input on mobile phones, with its vowels, complex vowel modifiers and conjuncts, is far more complex than entering Latin text (e.g., using multi-tap). Indeed, it is known to pose challenges even for relatively educated and advanced mobile phone users [18]. While the CNEs interacted with the device individually for one hour each during the training session, we were sceptical that they would take to native input when left on their own.

Our initial assumptions were trumped when we observed that eight of the ten CNEs took only a week of regular usage and practice to "comfortably" enter names in free-form Hindi text. Interviews revealed that five of the ten CNEs had independently, or with their husband's assistance, created learning sheets in their notebook that mapped phone keys to individual Hindi alphabets (see Fig. 3). For example, numeric key "2" mapped to the vowel

sounds (a, aa) and “4” mapped to the consonants (ka, kha). They used these sheets to memorize the mapping of the Hindi text input to the phone keypad. Three of the CNEs remarked that they would practice native text input every day after coming back from the field in the first week. We suspect much of this motivation may have stemmed from various non-work-related usages of the phone (see below).

User motivations associated with non-instrumental usage

In order to maintain prepaid talk time for GPRS transfer of data, all CNEs were requested to use the phones for personal calls only in case of emergency. However, interviews revealed that six of the ten CNEs had used their phones to receive non-work calls and to give “missed” calls to a family member. A missed call is when a phone user dials a receiver’s number and disconnects before the call is received. It is usually a request to the receiver to call back the caller [11].

Two of the CNEs with teenaged children allowed them to watch entertainment media on their phones such as Bollywood music videos (or “video songs”), short comedy clips or funny advertisements as are typically found on YouTube, and short clips of popular film dialogs. This media content had been procured offline via Bluetooth transfer from the children’s friends or “mobile shops” that sell prepaid mobile talk-time credit.

One CNE who frequently watched entertainment media on the phone with her children said:

CommCare system is very nice; we get better video phones for our work. My husband’s phone is black-and-white (basic handset) where you can’t watch film videos.

Another CNE used her phone to regularly give “missed” calls to her sister:

My husband’s phone never used to have enough balance (talk-time credit) for me to even give a missed call to my sister. Now I use the

CommCare phone to do that; she is married into a rich family and always has balance to call me back.

We suspect all these instances of non-work related usage of the CommCare phone were an indirect motivation for the CNEs to learn the challenging native text input within a week’s time. The CNEs thought that the CommCare phones would be “taken away” if they failed to learn how to use them. Other technologies without these secondary usages (e.g., dedicated PDAs) would certainly not have engendered such passion. This finding is consistent with related work that discusses how sufficient user motivation towards non-instrumental and entertainment-related usage goals turn UI barriers into mere speed bumps [30].

Working around challenges due to infrastructure

Based on the CNEs’ reports, the Nokia C2-01 handsets worked out quite well for the challenging infrastructural conditions in the field. It took only 1.5 hours to fully charge the battery, and CNEs would keep the handsets charging during the night when electricity was available. Before leaving for work in the mornings, they ensured that the phone battery was fully charged. If the phone was low on battery while in the field, it was convenient to charge it for short periods at any patient’s house where electricity was available.

Network connectivity was intermittent in the remote villages where the CNEs worked. But wherever connectivity was unavailable, the completed forms were saved locally on the phone and were automatically sent when connectivity was restored. As a result, CNEs never had to think about network connectivity. This seemed to be an important feature in the CommCare system, which made data reporting in areas with intermittent connectivity possible.

Social respect and power associated with technology use

In the paper-based system, child-specific data did not make it to the central MIS, whereas in the CommCare system, the individual child information was digitized and made available on the CommCareHQ. During household visits, three of the ten CNEs told patients’ parents that their child’s information would “appear” on a computer in New Delhi (capital of India, where RMF’s head office is located). When interviewed, CNEs reported that this apparently made the parents very proud. Parents also started being more attentive at the counselling sessions. Nine of the ten CNEs agreed that the CommCare system had helped them earn social respect and recognition from the community. One CNE remarked:

Earlier Lali’s dad used to be drunk whenever I went to their house for counselling. Now after knowing that someone in Delhi is viewing his daughter’s information, he stays away from drinking before my visit and also carefully listens to what I say.



Figure 3. Native text input learning sheet prepared independently, with phone keys mapped to the Hindi alphabet

Another family thought that they would receive medical help from the headquarters in New Delhi when the “government” officials saw the health status of their child.

The CommCare phones were used in a number of creative ways in the field that we had not anticipated. As noted earlier, CNEs would refer severe and moderate malnourished cases to the government AWW or the NRC for treatment. On one occasion an AWW refused to take up a SAM case for treatment at the NRC because of “lack of resources”. The CNE told her that she could report this interaction between the two of them to higher government officials, using the camera of the CommCare phone. This made the AWW very nervous and she immediately agreed to take up the referral at the NRC.

On a similar occasion where another AWW was reluctant to take up a SAM referral case, the CNE threatened to audio record the conversation using the CommCare phone and report it to the senior government officials. Three of the ten CNEs agreed that the CommCare system gave them the power to hold AWWs accountable with respect to referral activities in the field, unlike the paper-based system. While social respect and power played an important role in this context, we would like to note that this might not generalize to other cultural contexts.

While there were a number of positive experiences associated with the use of the CommCare system, CNEs also reported some challenges.

Problems with unsupervised use

On a few occasions, the CommCare application would not load during registration while a CNE was at a patient’s house, and this embarrassed the CNE. One of the CNEs managed such situations by saying that the phone had “run out of battery”. When this occurred, they were forced to fill out data only in their daily visit forms. The only technical support person they could reach out to was the DC. The DC would often do remote troubleshooting in consultation with CommCare personnel. When the DC was not available, CNEs tried seeking help from local mobile-phone shop owners and photo studio owners with computers. However due to lack of knowledge about the CommCare application, they were turned away from these places. After learning the system and using it for two weeks, two CNEs were unable to use the CommCare application for much of the trial period because of technical glitches in the application that were never resolved (though they continued to use the phones for other, non-work-related purposes).

Transportation issues in spite of robust device

The CNEs travelled to work in crowded public buses or on the back of their husband’s bicycles and motorbikes. According to them, carrying the CommCare phone was easier compared to the bulk of paper forms on most days. When it rained, the CNEs used multi-layered plastic packing to protect the phone during transport. But in spite

of this, they were concerned that water would seep through and spoil their devices. One CNE had to wade through a small river to go to a village where she worked. On one occasion, she slipped and fell into the shallow waters of the river. Her CommCare phone was in her handbag, and it got wet when she fell. But the phone started working fine the next day, “*after drying it under sun*”.

Overall, even though the devices were quite robust for the conditions in the field, CNEs were generally concerned that they might “break” the devices if not transported with care and that they would be held accountable.

Decision support

While the three-month period we studied did not allow sufficient time for RMF management to use the data for any real decision making, our interview with the program coordinator indicated that the CommCare system would significantly impact decision making for RMF’s malnutrition program in the future.

The program coordinator suggested that CommCare provided RMF several advantages over the paper-based system. Case management and tracking of individual children allowed for better analysis of program indicators, including time for recovery from SAM to MAM and MAM to normal, types of referrals to NRCs, and performance of individual CNEs. Although data collected during the pilot was not sufficient to provide an accurate sample size for the program as a whole, data generated by CommCare served as the basis for in-depth analyses.

Remote tracking of program indicators allowed RMF management to remotely access data in real-time through CommCareHQ and to download data ready for analysis using STATA [31] without translation or cleaning. Using data generated by CommCare during the pilot, RMF was able to identify the several indicators not currently available in the paper-based MIS: sex and age distribution of the children; average time for recovery of children, including distribution of recoveries by gender and age; distribution of successful referrals by CNEs, AWWs, villages or individual families; and to distinguish a number of complicated SAM cases (fever, diarrhea, skin rash, cough) from uncomplicated ones.

In addition, CommCareHQ enabled RMF management to remotely monitor staff activities to ensure field visits were happening when they were scheduled, recognize how many SAM and MAM children were identified by CNEs over specific timeframes, and categorize which children had entered the program—their location, whether they had been successfully referred for treatment, and when their next follow-up would take place. CommCareHQ also provided a breakdown of counselling from individual CNEs, which is currently not available in the paper-based system. This included number of family and community counselling sessions held, individuals present per session, and topics covered by the CNE.

In the long term, CommCare should assist RMF operations in three critical ways:

- Respond quickly and more efficiently to field realities, such as increased malnutrition due to migration and seasonal illnesses such as malaria and diarrhea
- Track individual children, including their treatment, complications, and improvement, more efficiently ensuring that the program is correctly treating children and ensuring their continued improved nutritional status
- More effectively monitor staff and adjust trainings and teaching aids in accordance with counselling trends

RECOMMENDATIONS FOR MOBILE PHONE SYSTEMS FOR RESOURCE-CONSTRAINED SETTINGS

Based on our observations from the three-month unsupervised deployment of the CommCare data management system in rural India, we learned some lessons that we believe could be applicable to other mobile phone systems for low-income, novice technology users in similar resource-constrained settings:

Instructional manuals for learning native text input

As noted earlier, health workers managed to find creative ways to learn native text input on the CommCare application, drawing tables in their notebooks that mapped phone keys to individual Hindi alphabets. If mobile phone applications require native text input, we would recommend providing instructional manuals such as phone key-alphabet mapping sheets that end users can practice and learn from. In addition, if resources are available, we recommend providing adequate training to teach complex native text input prior to actual usage.

Local point-of-contact for tech support in resource-constrained settings

The DC, in consultation with CommCare personnel, was the only tech support available for health workers in the field. When the DC was not available, the health workers tried seeking help from local mobile phone-shop owners and photo-studio owners with computers who did not have the technical knowledge to fix glitches in the CommCare application.

For mobile phone deployments in resource-constrained settings such as ours, we recommend providing a dedicated local point-of-contact for technical support. Based on our experience, there are advantages in having a qualified local person do troubleshooting. In addition to being readily available, the local person also tends to be more approachable for such requests. We observed that in spite of multiple field visits from our side, the health workers were quite reluctant in approaching us with problems they faced in using the application; they tended to be very conscious of perceived differences due to socio-economic backgrounds.

Finally, this experience confirms benefits of using low-cost devices for resource-constrained settings. First, end users

tend to be more comfortable using these devices. Previous studies [21] discuss how expensive handsets cause intimidation among users and concern that they might “break” the device and be taken to task for it. Indeed, a typical smartphone could easily cost several multiples of a health worker’s monthly pay! Secondly, mobile phone ownership, particularly of low-cost handsets, has been on the increase even in the rural context in the developing world [22]. With this increase in mobile phones, the number of local shops that do maintenance and repair work for inexpensive handsets is also increasing. While they may not be able to address application-specific problems, these shops can bolster the local technical support setup for simple troubleshooting in the case of emergencies.

CONCLUSION

In this paper we report on a deployment of CommCare, a low-cost mobile phone data-collection and reporting solution intended to enhance the record management system of a nonprofit NGO in rural central India. We conducted a three-month unsupervised deployment of our solution in rural Madhya Pradesh, with ten low-income, low-literate rural health workers. They processed data from 836 rural malnourished children using the solution in spite of infrastructural challenges such as intermittent connectivity and prolonged power outages in the field. We showed clear improvement in data management compared to a paper-based system in terms of data quality, completeness and timeliness measured over the three-month period of unsupervised use. The health workers showed a strong preference for the mobile phone system because of the social respect and social power they earned in the local community from the use of this system. One of our core findings is a demonstration of how low-literate, novice technology users were able to manage challenging native text input on the CommCare application. We believe that learning native text input was motivated by strong user interest in maintaining the mobile phone for non-work and entertainment-related activities.

Achieving data management gains and strong user approval in record-keeping processes has the potential to directly affect the scope for millions of households to steadily receive better healthcare services. Beyond healthcare, mobile phone solutions such as this can be adapted to similar contexts, playing a useful role in single-point digitization and aggregation of data in resource-constrained settings.

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