Changing data practices for community health workers: Introducing digital data collection in West Bengal, India

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ABSTRACT

In this paper, we present our findings on the experiences of West Bengal Community Health Workers (CHWs) in transitioning from paper to tablet- and mobile-based data collection. Through qualitative interviews, usability testing and timed observations, we found that efficiency and quality of data collected were comparable between the use of tablet devices and traditional paper methods, but data collection performed on smaller mobile phone interfaces was less efficient compared to paper. There was no significant difference in the quality of data collected across all three modes. In terms of work practices, we found that while initial interactions with CHWs suggested positive feelings about switching to digital devices, in their actual practices they retained and preferred the use of paper, and had workarounds to circumvent the digital data collection process. While there were foreseeable challenges around individual user experience, such as device familiarity, and application interface flexibility, the more compelling challenge in transitioning CHWs to digital data collection was organizational. The agency of CHWs within organizations, the levels of training with both data practices and devices themselves, and the sense of comfort that the data collectors felt with the overall project emerge as important factors of attention for implementers of new data management practices.

CCS CONCEPTS

• Human computer interaction (HCI) → HCI design and evaluation methods • Computing methodologies→ User studies.

KEYWORDS

ODK, Maternal Child Health (MCH), India, Pregnancy, Information Management, Android, Tablets

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1 INTRODUCTION

In many parts of the world with health provider shortages, Community Health Workers (CHWs) play a central role in health care provision and often serve as the sole interface between patients and health services [1, 2]. CHWs typically have limited formal training, and resource-strapped health care systems struggle to provide CHWs with the right tools and incentives to be effective.

Research has shown that in settings where the CHWs are the main interface to the formal health system, these providers face significant stress in their line of work. Problems consistently cited include difficult work conditions, inconsistent access to medical supplies and training, communities' resistance to their counsel, and lack of career growth [3, 4, 5, 6, 7].

CHWs tend to operate in rural or low-income urban neighborhoods, are frequently from the communities in which they work, and often have minimal formal education [8]. As liaisons between these communities and the formal health system, CHWs have increasingly taken on the roles of gathering and communicating population health data, particularly through digital means. This has resulted in a range of efforts to get CHWs familiar with utilizing devices such as mobiles, tablets, and custom-made devices in conducting data collection work [9]. In this paper, we focus on the technology-aided data collection aspect of community health work. We present a case study of CHWs in rural West Bengal in East India, and explore the challenges and opportunities of introducing a digital data collection system into their existing workflow. It is worth noting that these health workers are involved in maternal and child health (MCH) data gathering, which has shown slow progress in this region of India [10], particularly among rural communities [11, 12].

Introducing CHWs to digital data collection poses challenges, as is true with any major workplace practice change. But CHWs are somewhat unique in that their practices are a lot less regulated than regular clinicians or nurses. They also tend to have lower education and they typically lack organized labor options or longer-term contracting, making them susceptible to variable work practices being imposed upon them. This can lead to serious consequences, both for the professional work of community health management, and specifically in the case of digital data

collection, in the quality of data emerging from their newly instituted practices [6, 13].

This paper builds on the findings of several key studies of digital data collection in low-resource settings with an evaluation of challenges of interface comfort and data integrity situated within the context of the daily workflow management by CHWs working for a grassroots health care organization working on MCH issues. Our work took place in a real-world setting in which the data collection in the process of this research was part of public health practices. We documented the issues in performing digital data collection, ranging from common user experience challenges relating to training and comfort with touchscreens, to structural issues such as CHWs' agency within organizations they work in. From a two-year field project with the CHWs, we assessed data collection accuracy and user experiences through qualitative interviews, a quantitative usability experiment, and semi-structured survey conducted on digital devices and paper.

2 RELATED WORK

There is a large body of literature examining the role of mobile devices in CHW programs [9]. Such work proposes that technology has the potential to assist both CHW workflows and the data eventuating from their community interactions, and that even with limited or no prior technology training, digital technologies simplify data collection at both the point of care and at the aggregative administrative levels [14] and reduce data falsification [15]. As such, there is a growing expectation for the use of phones and tablets with mobile device capabilities in community health work [16]. Studies of mobile-based data collection by CHWs have also shown that being able to use mobile devices in general may influence how empowered CHWs are to use these devices in their work [17]. DeRenzi et al. identified six CHW workflows that mobile device implementation could improve — data collection, training, communication, decision support, oversight, and promotion of healthy behaviors. They specifically noted the lack of work evaluating such interventions [18]. Electronic forms for mobile data collection by health workers have been evaluated for accuracy in other studies in a lab setting [19] or even for user experience in the field for certain tasks [20] in addition to general studies that evaluate multiple mobile textual interfaces for low-literate users [21].

In the field of Information and Communication Technologies and Development (ICTD), an important early thread in the work on digitization of paper records came through the use of camera-equipped mobile phones (CAMs). One such CAM study examined the use of mobile devices for data collection in the microfinance sector and found that mobile phones can be an effective platform for rural computing applications [22]. The study also started the conversation on the trainability of rural workers with limited literacy for the purposes of data collection. Around the same time, personal digital assistants (PDAs) were seen as having a role in improving data quality from various regions of the world through simplified survey management [23]. One such study explored the use of PDAs to collect data for a standardized pediatric care module in Tanzania [24]. The results showed promising possibilities — using devices for data collection was easy for people with no prior device experience; and from a data perspective, it reduced deviations by assisting CHWs through a pre-programmed logic. In addition to assisting with data collection, research suggests that mobile technology can be used to increase CHW performance adherence. De Renzi et al. demonstrated how web- and voice-based feedback offered CHWs the opportunity to view individualized performance metrics and compare their data with other CHWs [25]. This feedback system showed an increase in CHW performance adherence, measured as increased client visits [26]. In other words, there is much work to show that when digital practices are incorporated properly into the practices of community health work, they are likely to make health delivery processes more efficient.

A second body of related work is on digital data collection, and projects that occurred when consumer mobile devices were just beginning to expand in computing capability. Open Data Kit (ODK) [27] was one such project that allowed for an open framework to enable data collection. ODK has led not only to a series of academic testbeds using text entry, scan functionalities [28], and sensing [29], but also to a number of real-world deployments and creation of commercial products in this broader space [30]. ICTD projects have used ODK within various domains including microfinance, mapping [31] and health care management, ranging from outreach to clinical practice [32, 33] and general workflow management [34].

In the field of health informatics, and particularly in industrialized nations with high-resource health facilities, the use of health technology and information systems has been studied closely [35]. The implementation of health technologies for data collection has been shown to improve health outcomes and care quality [36] and reduce complications as a result of human error [37]. One common finding relevant to our work of implementing digital data collection systems in low-resource settings is that organizational management is, in many cases, the defining factor for successful technology adoption [38]. Nembhard et al. identified six key considerations for successful technology implementation — create opportunities for experimentation and adoption, frame for learning, promote organizational identification, use transformational leadership, measure performance and development, and reward implementation efforts [39].

Empirical results on real-world mobile use in clinical effectiveness, particularly for CHWs in low- and middle-income countries, has been relatively spotty, and research is inconclusive about the actual effectiveness of mobile use at increasing either the outreach of CHWs or the quality of data coming back from the field [40, 41].

Despite much work on digital means of information management, paper is, in many cases, still preferred. A study by Ghosh et al. [42] highlighted the benefits of paper — including its conduciveness to easy inscriptions with a physical trace, which offers persistent visual feedback. Paper offers visibility and transparency without additional exertion by the user, and is a known and trusted medium. One perspective is also that it is unlikely that automation of workflows will help an already flawed CHW system [15]. Ramachandran et al. argued that ICTs are more useful to CHWs as a means of persuasion and motivation rather than the tasks that they are meant to automate [43]. Multiple studies touch upon such organizational and social factors that affect adoption and effectiveness of mobile data collection and information dissemination to provide design recommendations [15, 19, 20, 44] or general policy implications [45]. We take a deep dive into such issues, specifically in the context of data collection of complex information through qualitative interviews and observations.

3 WORK SETTING

Our implementation involved creating and deploying a digital data collection tool to be used by CHWs, and to collect primary data on usability and data quality.

3.1 Organizations

The research presented here was conducted as a partnership between the University of Michigan — represented by researchers from pediatric neurology, biostatistics, and human–computer interaction — and iKure, a grassroots health care group operating in West Bengal. iKure manages a network of community health providers throughout the state. It provides medical consultations and gathers health information, and does its outreach primarily in communities that do not have immediate access to institutional health facilities. The two organizations had intersecting goals. The Michigan group was seeking to document the prevalence of health risk in a low-resource community in the context of maternal and child health. iKure, which works with MCH data in West Bengal, India, was interested in exploring the feasibility of incorporating digital tools for health data collection as part of their work.

A mobile-based digital collection tool was built for the project, but the quality of data was not compromised for the experiment with the technical artifact. Separate checks and balances were designed for the integrity of data for the health risk study, the results of which have not been published.

We worked primarily in six locations around West Bengal, detailed in Table 1. All of these locations exist within a 2- to 4-hour driving distance from the metropolitan city of Kolkata.

Location	Institutional health facility access
Bhowanipore	Disconnected by riverbed, nearest hospital through single vehicle dirt road in Debra
Bhai Nagar	Access to temporary clinic with two government nurses, nearest hospital in Debra
Jagannathpur	Local clinic
Godapiasal	CSR health camps in town, access to government hospital by bicycle
Chengail	Community training hospital
Midnapore	Clinics, one medical college plus full-fledged hospital

Table 1: Locations and Access to Health Facilities

3.2 Tools

From a clinical perspective, the goal of our work was to examine the viability of digital data entry for MCH community health programs. Our team decided to use two survey instruments, a pregnancy baseline survey and the Ages and Stages Questionnaire (ASQ), in the usability studies because these tools are frequently used for clinical purposes in India. CHWs would normally administer the questionnaires to assess the health of pregnant women and to document child development every 2 months between 12 months and 24 months.

The pregnancy baseline survey consisted of 42 questions inquiring about pregnant women's demographic information, reproductive history, antenatal care, delivery plans, and health status. The survey was broadly divided into two modules: general demographic questions and specific pregnancy-related questions. The latter module included questions regarding health care experiences during pregnancy, blood test measurements, and post-delivery information, which add a longitudinal component to the data collection process. The ASQ was a series of evidence-based health surveys that have been used in a variety of studies within the U.S. and India, and have been integrated into clinical practice [46]. ASQ surveys, when administered on paper, are supposed to be administered exactly as printed, with a very specific flow and logic that CHWs are expected to follow precisely.

We used the ODK form-building tools to design and implement these surveys for the CHWs to use on Android tablets and smartphones. We found the ODK suite to be most desirable for this research study because the survey forms — once downloaded onto the ODK Collect application — run completely offline, which was necessary given the unreliable connectivity in rural West Bengal.

Seven child development surveys (one for each 2-month stage between 12 months and 24 months) were created directly from the third edition of the Ages and Stages Questionnaire (ASQ-3) materials. Questions were grouped and color-coded according to performance-related activities the ASQ desired to assess in the children: communication skills, gross motor skills, fine motor skills, problem-solving and personal–social skills.

The scoring scheme classified children as "at-risk" or "normal" in terms of proper growth and development. Although these surveys had been tested in an Indian context, the researchers realized from creating the mobile versions of these surveys that familiarizing CHWs with these forms would be rather challenging. The child development surveys had more complex terms and grammatical constructions, and were lengthier than the pregnancy baseline survey.

ODK forms were built in Excel. In developing the surveys, it was important to ensure that the content was understandable to the CHWs (linguistically appropriate and containing basic terminology) and that the survey question flow matched the users' current understanding of how to collect patient data. The survey language was iteratively tailored between site visits to improve the navigability of these forms when the CHWs tested them on the mobile devices.

The data collection was conducted on mobile phones, tablets, and paper. The mobile phones were Micromax Bolts with 4-inch screens, running Android v4.4 (KitKat), and had 512 MB RAM and 4 GB internal memory. These phones retail at approximately US $75 each. The tablets used were iBall Slide 3G 7803Q tablets with 7.85-inch screens, running Android v4.2 (JellyBean) and had 16 GB internal memory. These tablets retail at approximately US $60 each. An important goal was to study the feasibility of mobile data collection on low-end, off-the-shelf commercial devices, which would be affordable in low-resource settings. The ODK forms were built in March 2014.

3.3 Community Health Workers

The majority of pregnant women and children from our sample are served by CHWs as their primary point of contact with the health system. CHWs are typically from the communities in which they work. Their work involves traveling door-to-door in villages, collecting health metrics, spreading health-related messages, facilitating referrals, and in the case of certain infectious diseases — particularly leprosy and tuberculosis — providing medicines and ensuring that the patients take them. The

work is fairly physical in nature because it involves difficult commutes, and the women must carry all materials they would need for their visits, including medicines, basic vitals equipment, and documentation materials such as files and notepads. Data gathered during field visits are relayed back to community health centers located at nodal points. Prior to our field testing, CHWs were required to keep records of conversations, which they did by hand in ruled books with carbon paper, copying each patient's data onto a new page. They did not audio-record their interactions with clients. The typical method was to do shorthand field notes and then do proper write-ups later at home.

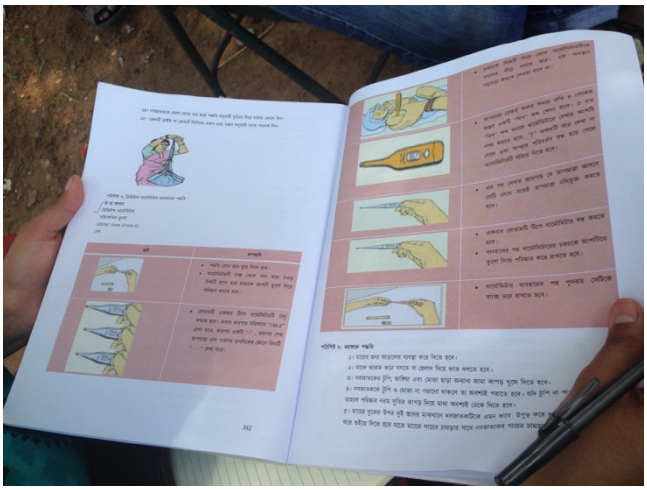

Figure 1: CHWs share instructional materials that help them with performing health screenings in the field (photo credit Jackie Wolf)

iKure employs its own CHWs — who are in some cases Accredited Health Activists (ASHAs). ASHAs are formally trained Community Health Workers through the government of India who receive comprehensive training in health education and promotion [47]. In our sample, ASHAs were distinct from CHWs in that they were trained professionals who had been working extensively in their respective communities for a number of years, and were also required, as part of their work, to undergo regular refresher training provided by the government. iKure' CHWs on the other hand, were community members who had been hired for health care work. For all the CHWs we spoke with, their employment with iKure was the first time they had been formally hired to work in the health care sector (Fig. 1). The CHWs working with iKure in our sample were hired through snowballed connections, and were relatively younger than the ASHAs. The ASHA workers in our study ranged from 27 to 42 years of age. The CHWs were between 18 and 38 years. CHWs had no prior experience with using smartphones, but they all had experience using keypad-based feature phones. All the health workers were given 1 day of training to get accustomed to the smartphone and ODK interface and were able to navigate through the forms several times. The CHWs were required to return the devices for the data collection work when they were not in use; this meant they were not able to "play with" the mobiles to gain comfort with the interface and its affordances, which other studies have suggested offers important learning benefits to technology users in comparable situations [45].

4 RESEARCH DESIGN

Our research design involved primary research with 10 CHWs who were involved in this project. We also interviewed staff members at iKure and ASHA workers. The data collection methods also involved the recruitment of infants and pregnant women for the study.

4.1 Preliminary Interviews

We first conducted qualitative research, which occurred in two phases. The first phase of preliminary interviews was with the iKure management staff, ASHA workers, and CHWs to understand their motivations and concerns in using mobile technology for community health work.

We conducted three interviews with leaders of iKure at their headquarters in Kolkata to gain an understanding of the organizational motivations for technology implementation. Following this, we interviewed seven ASHA workers for an overview of the field setting, because they had been formally designated by the government to work in that region and had an in-depth understanding of the health care concerns for the field sites. The ASHAs' training and experience with rural health care and information management made it easier for them to talk about the ways that technology had become part of their practices. All interviews with ASHAs were semi-structured and oriented toward understanding their practices, routines, and concerns. All interviews were conducted in Bengali, video-recorded, transcribed, and analyzed for key themes. This work took place in May 2015.

4.2 CHW interviews and observations

The second phase of qualitative work involved interviews with CHWs at three field sites — Bhowanipore, Bhai Nagar, and Jagannathpur — which were visited over 3 weeks. Each of the CHWs was an employee of iKure. At the time of our interviews, the CHWs had undergone a day of training in recent weeks to become familiarized with the ODK application. This work took place in June 2015.

We conducted a basic usability test providing design probes and activities to confirm basic understanding of and ability to use the mobile- and tablet-based applications (Fig. 2). CHWs were introduced to the differences between paper and electronic surveys. They were asked to perform sample tasks of registering a patient, completing forms, and more advanced features such as messaging physicians. Each CHW was assigned a task, following which we observed their completion of the task and asked for their impressions of the ease or difficulty of the task.

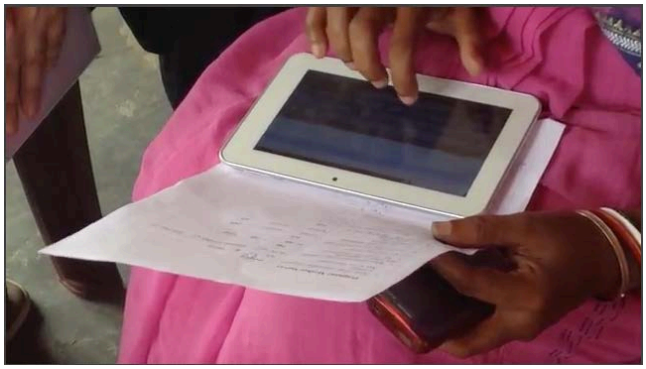

Figure 2: CHWs conducting usability tests after being given written instructions (photo credit Jackie Wolf)

Although there were some minor differences in the tasks tested at each location for logistical convenience, all the CHWs had the same pre-test training with the mobile application, and all were tested on the all the tasks listed in Table 2.

Site	Tasks
Bhowanipore	Paper vs. electronic survey Patient registration Vitals and symptoms recording
Bhai Nagar	Categorizing information into forms Cancel, Save, Next button logic
Jagannathpur	End-to-end test with patient registration Case entry workflow Physician referral logic CHW-physician messaging features

Table 2: Field Visits for Observations in Chronological Order

4.3 Patient Sampling

CHWs were asked to recruit infants and pregnant women in their circles — in this case through the six locations surveyed, during the summer of 2015. All respondents to our survey were restricted to pregnant women in their first, second, or third trimesters, and children ages 12–24 months. These included a total of 279 women and 368 children, for a total of 647 respondents in the study.

All of the pregnant women were offered Nutrimix, a locally produced protein and iron food supplement, as a token of appreciation for their participation. A physician was available at all times for CHWs to consult as part of the study. Interactions with the respondents were conducted in Bengali. None of the interactions with the mothers or children was audio- or video-recorded. In this study, we do not report the outcomes of the extended study, which were used for clinical purposes, but instead focus on a subset of 150 people for timed observations. This work took place between July and November 2015 and was conducted by a total of 10 CHWs spread throughout the locations.

4.4 Timed Observations

The timed observations took place after the completion of more than 200 surveys on mobiles and tablets, to ensure that the respondents were comfortable filling out forms on a device. Each CHW was assigned to 15 data collection tasks. For each task, a CHW completed two or three infant and corresponding adult forms, such that by the end of the test, each individual had seven of one and eight of another form completed. Thus each CHW completed five tablet forms, five mobile forms, and five paper forms. One CHW did one extra form on a tablet. All CHWs had the same Micromax mobile devices or tablets (Table 3). This work took place in November 2015.

Data Collection Type	Forms Collected
Infant ASQ (Mobile)	20
Infant ASQ (Paper)	29
Infant ASQ (Tablet)	21
Adult Pregnancy Baseline (Mobile)	30
Adult Pregnancy Baseline (Paper)	20
Adult Pregnancy Baseline (Tablet)	30

Table 3: Types and Quantities of Data Collection

We conducted two forms of analysis on the timed observations. First, we wanted to see which of the three data collection mediums was the most time efficient. Second, we wanted to see whether there was a difference among the three formats in terms of data quality. We collected the fully completed form in each case to examine the results within the larger set of 647 surveys to analyze the consistency of data quality with the observed cases.

4.5 Second-round User Research

To mitigate potential bias with the qualitative data from CHWs, when both the international researchers and iKure staff were deeply involved in the day-to-day functioning of the work, we conducted a second round of interviews and usability tests with seven of the 10 CHWs who worked on the project, the others having left for other opportunities. This took place in September 2015. During this round of work, only the primary researcher (a local Bengali speaker unaffiliated with iKure) and one local usability tester interacted with the CHWs. Our goal at this point was to revisit the field site to test the veracity of the first round of results and conduct the usability study in a low-pressure environment.

Unlike the observational study in phase 1 (section 4.2 of this paper), which was conducted in the field, during our second visit to the field we conducted a structured usability test using both the child development and pregnancy baseline questionnaires and followed up with interviews. The tasks that were tested included opening the correct form, filling out the form, and saving, editing, and reviewing it.

4.6 Analysis

We used basic descriptive statistics to analyze the results from the timed observations. We compared average (mean) values through a *t*-test, and descriptively present medians in box plots. We used a grounded theory approach to work through our qualitative data and create themes for discussion and theory-building [48]. The transcripts of interviews and observations were read by three coders independently and annotated for themes, which were collated and discussed as a group. Following this, we selected quotes from the interviews that adequately represent these themes.

5 RESULTS

5.1 Timed Performance across modes

While the sample sizes (n=15 for each CHW) are small and do not allow for a deep comparison, we can see in Table 4 that the mobile method was the slowest in average time taken for all the CHWs except CHW 07. Moreover, the ASQ form for children was generally longer than the pregnancy baseline questionnaire.

Looking at the time taken in each mode by the type of form, we found that the differences between the three survey modes was highly significant ($p=.05$) among groups. The box plot in Figure 3 shows that tablets and paper outperformed mobiles for both the pregnancy baseline questionnaire and the ASQ.

The mobile input was the slowest on average for both the pregnancy baseline and children's surveys. We also found that paper and tablets were roughly comparable. While in the mean time taken, tablets performed the best, there was a higher variance in the tablets in terms of time taken to complete both the

pregnancy baseline and the ASQ surveys. The differences between the groups was significant ($p<0.01$).

To examine whether the quality of data is comparable among the three modes of data collection, we ran a series of tests on key variables to see whether there was any distinction among the samples from satisficing behavior by the survey enumerator or any other form of data entry behavior that might cause the data to be compromised.

For this, we compared means among the three data collection types — mobile, paper, and tablet. To do this, three scale variables were selected, two at the start and one at the end of the survey, and their means were compared. Our hypothesis was that if the data were reliable, there should be no significant difference in means among mobile, paper, and tablet (unless there were other variables that caused these differences). The choice of spreading out the selected variables through the survey was to control for any fatigue on the part of the survey administrators that might lead to satisficing toward the end of the survey. Table 5 shows results for the ASQ surveys.

Serial No.	Mobile	Paper	Tablet
CHW01 (n=5,5,5)	21:02	14:11	16:56
CHW02 (n=5,5,5)	19:55	17:49	15:21
CHW03 (n=5,5,5)	18:23	17:58	17:37
CHW04 (n=5,5,5)	17:43	14:11	12:22
CHW05 (n=5,5,5)	24:27	17:23	21:58
CHW06 (n=5,5,5)	23:16	19:21	21:30
CHW07 (n=5,5,5)	16:04	16:43	13:38
CHW08 (n=5,4,6)	21:18	20:56	18:03
CHW09 (n=5,5,5)	20:04	13:59	14:28
CHW10 (n=5,5,5)	20:33	17:31	16:30

Table 4: Mean Time Taken by CHW for Forms – both ASQ and Pregnancy Baseline combined (Min)

Timed mobile tests were compared to timed paper and tablet tests.

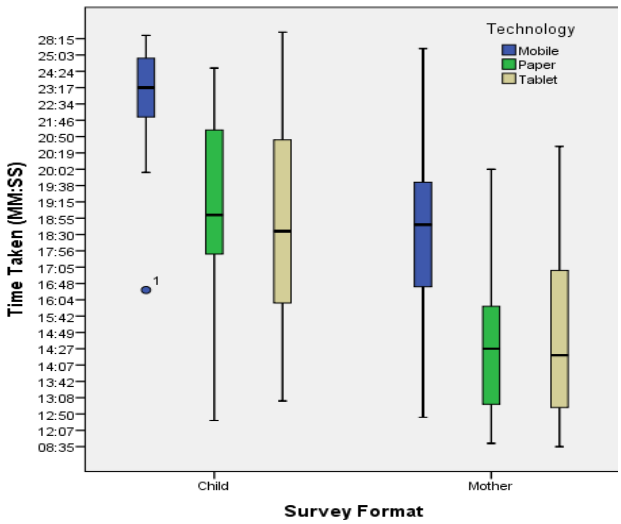

Figure 3: Box plot depicts the differences in median time taken to complete the surveys in various formats (n=150).

5.2 Data integrity

We checked the data for accuracy to study whether working on the tablet or mobile environment led to errors from factors such as interface unfamiliarity or the pressure of working on a new device while being observed. We found no effects. None of the differences among the means of the variables in Table 5 was significant. As we see, gestational age and birth weight are extremely close among all three categories. This is consistent with our hypothesis that birth weights and weeks of gestation would have no differences across large enough samples.

Variable	Mobile (n=318)	Paper (n=30)	Tablet (n=20)
Gestational Age (weeks)	37.9	38.2	38.1
Birth Weight (kg)	2.8	2.7	2.7
Current Head Circumference (cm)	45.2	45.0	45.6

Table 5: Means for Selected Variables Compared by Format (Children's ASQ Forms)

With the sample of pregnant women, we again sought three-scale variables spread through the questionnaire that we could examine for consistency (see Table 6).

Variable	Mobile (n=229)	Paper (n=20)	Tablet (n=30)
Woman's Age (years)	22.0	22.4	21.3
Weight (kg)	49.7	50.1	47.8
Pulse rate (bpm)	81.3	82.5	82.2

Table 6: Means for Selected Variables Compared by Format (Pregnancy Baseline)

We found no significant difference among these variables across the three input formats. We conclude therefore that the quality of data was not inconsistent across the three modes.

5.3 User Experience

When we visited the site in September 2015 to check the progress on ODK usage, we learned that the CHWs still primarily relied on paper forms to take health information on site (Fig. 4). This information would then be input in the mobile forms at a later time or directly input into Excel sheets at the iKure office by a data entry operator working on a desktop computer. We found that the CHWs were concerned about data integrity and preferred the tangible paper-based forms. This was exemplified during the timed tablet- and mobile-based data collection tests, where the seven CHWs universally preferred paper as a means for data collection over tablet and mobile means.

Figure 4: CHWs used paper-based data collection when they had concerns with data integrity (photo credit Sandip Dutta)

5.3.1 Data collection logistics

The health data collected by the CHWs is complex in nature. In parts of the forms, they have to collect contextual data about the patient and note it in text fields. The form has fields for patient information, health history, and many yes-or-no questions about patient health. There are also fields that ask the CHW to mark the current condition of the pregnant women. This makes the forms complex, and the cost of getting something wrong high, thus CHWs preferred paper, validating Ghosh et al.'s [42] findings. Margins on paper forms were used to explain issues; these in turn also became the CHWs' defense for claiming that they had fully reported the issues.

> *If mistake on paper I have to cut and write again and for phone cross it and write. On paper I can see things which are correct and which are incorrect. For phone I can also see but it will take time but for paper I can see it at a glance.* — CHW 3

A related problem was the logistics of typing in English, especially given the CHWs' limited command over the language. CHWs were Bengali speakers, and all the forms were eventually created in Bengali script. However, where text responses (instead of check buttons) were required, these had to be typed in English. Given the limited extent of English literacy, as well as limited awareness of digital artifacts built for English-language users such as position of letters on virtual keypads, we found that CHWs experienced a significant cognitive load in translating this largely contextual data into English — resulting in slow typing tasks (mean time = 18.5 secs for 10 characters) and more spelling errors (mean number of spelling errors = 2.8 errors per CHW per form).

> *Clicking all options are quick in mobile … but in mobile while typing error occurs and after reaching home if you see the errors then you have to go again to the house you went before. English alphabets are main problem while using mobile.* — CHW7

In trials, we found that frequently data had to be repeated multiple times for the CHWs to capture it effectively or correctly because there were no auto-complete or pre-filled terms, units of measure, or dates, further adding to the cognitive load of spelling out terms or means for form validation to check for internal inconsistencies. CHWs typically had significant domestic responsibilities at home, having to redo something done at work was difficult — the entire interaction needed to be captured effectively on the spot.

5.3.2 Training

We found in our preliminary stakeholder interviews and subsequent first-round CHW observations that iKure' focus was on swift training since they had to deal with multiple competing projects where CHWs were expected to serve primary roles. While training was supposed to include some elements of general device familiarity, we found that CHWs were mainly trained with the front-end data collection tasks.

This created two problems — first, not including advanced ODK functionalities into training meant that the CHWs did not know how to address application-level problems, or make minor alterations to the package. Some ability to make minor amendments to the forms would have been helpful in adding unexpected responses to questions. We found during the second-round user experience tests that none of the seven participants could save the form in the current state, rename the form or go to the start of the form. Only one participant could send the questionnaire to the server, and only two could delete the pregnancy baseline form. All the CHWs at this point had past experience with using ODK on some devices, and yet, working on something outside of the very precise steps one used in an application was challenging.

The more important challenge, however, was that of general device familiarity. None of the CHWs owned a smartphone during the first phase of the test, and one purchased one in the process of the work. CHWs were unfamiliar with the basic functioning of the device. For instance, P2 did not know how to switch the keyboard from alphabets to alphanumeric. Fine gestures, like the tap and hold to move the cursor to a specific location, were unknown to five of the seven CHWs. In the case of errors, all five CHWs deleted all the characters before re-typing them instead of just retyping the erroneous ones.

The limited training with device use led to uncertainty on whether one could recover from errors. We found on multiple occasions that basic touchscreen operations would confound the CHWs, leading either to long-winded solutions or resets. The iKure phones for the project were taken away from the CHWs at the end of each day, and they were allowed to use them only on days when they had data collection tasks. We found that outside of our joint project, the CHWs were going about their regular work using paper, so the only time they entered data on a mobile device was on the days they were working on this project.

Forms like ASQ are carefully designed to have an optimal flow on paper. CHWs had familiarized themselves with the forms and the linear flow of questions in the pregnancy and child questionnaires, but did not have a greater understanding of the form logic. Building expertise with a specific type of data collection was translated as learning and anticipate flow on a form and moving along accordingly. This meant that periods without practice using a specific form led them to fumble during the first few iterations back. Since CHWs also work with different populations and not just mothers and children, remembering the logic and flow of individual forms is not an optimal strategy of technology familiarization.

In fact, when I was continuously using it earlier during the 3 months of the survey, I had gotten used to it with practice and was becoming comfortable. Now I am out of touch using it so I am having problems again. — CHW2

Knowing an application's functions just at the surface level has negative consequences on interface comfort since the individual does not have a deeper understanding of the entire process. We see this with patient matching, which ODK forms do not allow. Once the data are collected and sent to the server they no longer reside on the phone. When the CHWs collect the information from the same women at different junctures, someone in the iKure office has to spend time matching the new data against what were captured previously. This matching is hard, especially if the name is spelled differently in each instance, which is a common problem with typing Indian names in English.

During the usability test, this was logged as a minor error. However, in the health care context, this is a very serious error. From iKure's perspective, this was a major problem because of the lack of patient-matching functionality and the potential of mismatched data records. Training (or ongoing practice) did not give CHWs an intuitive sense of what errors to watch out for, nor did they internalize what errors were more important than others. Consequently, turning to paper collection allowed a material form of verification in which the CHW could hand over to higher authority the work they had done, wherefore checking for errors as a responsibility had been passed on.

5.3.3 Organizational issues

The CHWs working with iKure are typically hired through connections, are relatively younger than the formally trained ASHAs. CHWs are typically from extremely poor families, near or below the poverty line themselves, often heavily dependent on their income. In our early interviews, we found that ASHAs typically had both a deeper understanding of the health care scenario and a more fundamental appreciation of the nature and intent of health information gathering. Lacking an appreciation of the bigger picture impacted both how the CHWs approached the work, and their ability to appreciate their own value in the process. While ASHAs thought of themselves as health professionals providing a service to the community, CHWs saw themselves as employees of a company carrying out data tasks assigned to them.

During the first training session, several of the CHWs had to be reassured that they could not break a tablet by touching it. Even in our second phase of user experience work, the CHWs were extremely cautious with the devices, not doing anything outside of the scripted work of form filling, concerned they may cause damage the devices.

Along with the fear of technology, there was also deference to authority, which we had noted earlier, prompting a second round of user experience research. We found in both rounds of work that whenever interviews or usability tests were conducted in the iKure office, CHWs were wary of authority figures. This is not unusual behavior, since usability tests of any kind can be difficult to participate in when being watched over by one's supervisors. Even outside of those in-office interactions, it was hard to convince the CHWs that we were attempting to understand the functioning of the systems, and disaggregating their employers from our presence. Consequently, even in usability tests that had no iKure representatives in their immediate vicinity, the CHWs were concerned about making mistakes, and whether these may get reported to their employers and the impact that may have on their employment. The refrain of "we are testing the system, not you" was insufficient in this cultural context.

iKure also supported the practice of having paper as a backup. As a company working with larger health corporations or governments involved in health initiatives, their priority was reliable data rather than the means by which data were gathered. Validation of data input in the forms was intermediated by someone at the iKure office. It was verified against information captured in paper forms and then sent to the server to avoid incorrect data. However, the reasoning behind this process was not clearly communicated to the CHWs. This further prevented the CHWs from developing confidence in their data entry abilities and reinforced their reliance on paper forms.

We want both mobile and copy ... I can write in copy at field and can enter all details in mobile at home ... what is very helpful when you use mobile ... I don't have write ... I just have to tap on phone screen ... copy is important as permanent entry as it won't delete and for mobile it's quick to enter the data. — CHW7

From the interviews, it was evident that the CHWs had some intrinsic motivation to use the ODK application and forms. They had a desire to be able to use smartphones and practice English, possibly to help them get hired as ASHAs.

It would be better to use the phone since we are learning to use this new instrument and wish to learn more and use this technology. — CHW4

The patient perceptions of the phone being used also affected CHWs' inclinations to use the ODK application. On one hand, validating Ramachandran et al. [43], phones granted them more authority in the eyes of the patients. However, because the patients were themselves not too familiar with phones, they could not review the data that had been captured to make sure it was correct. One CHW also noted feeling pressured if she took longer to fill out the mobile ODK form in front of the patient.

In the paper method, the person being interviewed, the villager, is familiar with it and sometimes they go through what we have written and give us a feedback or confirmation that the entry is correct. Most of the people being interviewed is not very comfortable/familiar with the phone so they cannot go through what we do. — CHW4

6 DISCUSSION

The ecosystem of digital data entry for CHWs in West Bengal involves altering existing practices and, in many ways, fundamentally changing the CHW workflow and relationships with communities. CHWs across West Bengal agreed that field visits take long to complete and are physically taxing, particularly given the need to carry around large stacks of paper for data collection. While implementations of digital data collection systems are often driven by the need for better data, we found here that a significant driver and area of concern for CHWs in their successful use of these tools is empowerment.

6.1 Empowerment

We define empowerment based on whether CHWs felt more or less confident in their work with digital data collection. Our results indicate a multitude of factors played a role in CHWs' empowerment (or lack thereof) to use digital devices in their work.

CHWs' beliefs about technology drove expectations about what mobiles and tablets could do for them. In conducting the CHW interviews (section 4.2), we observed how the general use of tablet devices increased the feeling of empowerment among CHWs, as noted by Ramachandran et al. [43]. For instance, CHWs repeatedly stated that one of the potential benefits of the devices was the ability to go back to any record in time and have endless storage spaces, thereby enabling the CHW to better manage their data deliverables to the organization. All 19 health workers (CHWs and ASHAs) that were interviewed indicated very positive views of technology, and we believe this was partly due to their understanding of technology usage as a connection to better employment opportunities.

Results from our timed observations (section 5.1) indicate that tablets were just as efficient as paper-based data collection and that CHWs performed faster on tablets than on mobile devices. The larger interface allowed easier navigation of forms. Although we found higher variance in the time taken for data collection, tablet-based data collection was slightly more time efficient than paper-based collection. An additional factor to consider with paper data collection is the time taken to input the data into a system, such as a server, which was not a factor with the mobile or tablet devices. We also found here that the data accuracy coming from all three mediums in the first round of testing was highly comparable. Data quality was consistent between tablet- and paper-based collection, and seemed to support tablet implementation as the primary method of data collection, to positively impact on CHW workflow.

Despite the high potential for tablet implementation after the first phase of research, the second round of user research revealed that CHWs felt less empowered with tablet-based data collection, for two major reasons. The two themes, presented next, bring forth nuance into our initial determination that tablet-based data collection is the obvious next step for digital data collection in rural settings.

6.2 Organizational Structure and Management

We found that the position of CHWs within the iKure organization significantly impacted their motivation and ability to feel empowered in their adoption of digital data collection. In conducting our second-round user research (section 4.5), we found that an important challenge during this stage of interviewing was the influencing presence of the research team and stakeholders from iKure. This was not due to any intent from the iKure staff to control the CHWs, but likely attributable to a range of issues that we were unable to examine in depth such as the work culture between employees and management, the urban–rural relations between CHWs with limited formal education and the urban officers, or the contractual nature of work that created greater exposure to employment termination. The addition of foreign researchers apparently studying every move during usability tests only added to the nervousness of CHWs.

Power issues were evident during the start of the field trials. The CHWs were deferential in the presence of administrators from iKure during interactions in both Kolkata and in the field. As a result, we found that during early field interviews, after the CHWs had received training, they were uncomfortable holding the devices, particularly when there was a supervisor from the head office on location, irrespective of supervisors' instructions to CHWs to be more comfortable with the devices.

An example of how these factors around the work culture and power relations created biased responses from CHWs was revealed upon conducting our second-round user research. As mentioned, we were surprised to learn that CHWs circumvented the intended workflow of using tablets for data collection. More specifically, all CHWs reverted to using paper for data collection when out in the field, and manually typed the data into the tablets upon returning to the iKure office — essentially doubling their own workload.

We would not have made this observation had we elected to not conduct the second user study — and we, therefore, credit the masking of this issue to CHW power dynamics. However, we believe the core of this issue is rooted in a problem with CHW training, which we discuss in the next section. What this case does highlight is the problem of short-term field research engagements, which are often common in HCI4D or ICTD projects that are constrained by time and a disconnect between the on-the-ground workers and the larger organizations that fund them. This scenario presents a case for deeper engagement of design research in longer-term changes that are made to communities through design innovation.

As it pertains to organizational management, we noticed that user-centered design principles were not a high priority for iKure in designing and implementing technology into CHWs' daily roles. Design-wise, CHWs were not involved in the creation of the ODK application and its interface, and there was significant discussion within the iKure team about whether the application needed to be written in Bengali script. Initially there was an interest to build the tools in English for easier transferability to other non-Bengali speaking states where iKure is active as well as to ensure the standardization of medical terminology. However, CHWs had very limited English-language skill beyond numerical literacy and not sufficiently familiar with medical terminology to collect all necessary data. Herein lies a challenge between designing the most usable product, and ensuring the right compliance with data and terminologies that are essential in a healthcare data collection exercise. Although the question and instructions of the forms were eventually implemented in Bengali, input was still done with a Roman script keypad, thus there were challenges with free-text entry in English, as mentioned. While we expected this to pose challenges, we felt having the forms in a script the CHWs could read would minimize the cognitive overload of working in a language in which one had only basic familiarity.

We found that the frustrations experienced by CHWs in coping with language barriers were significant. As for the rollout of the technology, minimally involving CHWs in the decision-making process to implement technology, and preventing them from using the devices on a regular basis, left them separated from the larger logic of what was driving the organization's design decisions. While this may seem unfamiliar to the Western context, in which new data practices in the health sector often include an involved process of consultation, the separation of such decisions from the implementers is not uncommon in India.

iKure's concerns with safeguarding the devices came from past experience of damage or loss, and that CHWs are hired on contract — with the expectation of a certain among of churn of

employees. Recovering devices from CHWs, who are primarily rural residents, involved a significant effort overhead for the organization. Yet, this process of limiting device access restricted buy-in from the CHWs to use the technology, which Creswell and Sheikh pinpointed as a key element for successful technology adoption [38]. Rollout of the application took place in a top-down fashion, and CHWs were introduced to the technology as though it were a new requirement of their job, rather than an innovative tool that CHWs could use to transform their work and ease their workload.

6.3 Training

CHW training was limited due to resource shortages, and could be inconsistent depending on whether CHWs were hired as a group and trained together or whether they came in later in the process of a data collection project.

Our interview results indicated that the iKure tablets were many CHWs' first exposure to any form of mobile technology. Many actions, such as typing, swiping, and scrolling on a mobile interface were challenging. CHWs also encountered problems when they clicked on the wrong text (on the text for "Age" instead of the text box), and faced unfamiliar drop-down features.

There were also nonverbal indications that the health workers were unfamiliar with mobile devices: during each test, the women would crowd closely around the device to observe each health worker go through the usability test, and whenever the research team instructed the participant to "swipe," "scroll" or type on the mobile device screen, the health workers surrounding her would make the gestures in the air, either to guide the participant in performing these actions, or to practice scrolling and swiping themselves. In other words, the social elements of learning a new technology are valuable in early technology training, since the CHWs appeared to learn from one another.

We also found that CHWs were uneasy when there was no response (N/A or N/R) because they felt that N/A responses were akin to leaving the form incomplete. They were afraid of being penalized by their supervisors for incomplete work.

Adaptation to the interface took a while, and common errors were created by the lack of exposure to forms through other digital media such as computers or touchscreens. By extension, some of the typical "intuitive" elements such as "forward," "back," "home" and "error" buttons, or features such as auto-correct, were likely to be entirely new to the users. During the first training session, several of the CHWs had to be reassured that they could not break a tablet by touching it. Digital keyboard responsiveness was among one of the early familiarity challenges; many CHWs accidentally deleted entries entirely by going "back" when they were not sure they had typed material in.

CHWs also expressed nervousness about carrying the device by themselves to the field, particularly because they felt a decreased sense of control over errors. As mentioned in 5.3, CHWs preferred paper because they could view corrections and make edits for later consideration, but felt they could not do so using tablets. This, coupled with the fact that CHWs were only given front-end application training demonstrates how CHWs were never provided a comprehensive understanding of how to use these tools confidently in their fieldwork. Furthermore, we observed that iKure did not offer consistent training and that the staff seemed to rarely check in on CHWs to inquire how their work was going. Because of the lack of control CHWs felt as a result of insufficient training, there was an overall sense of disempowerment expressed in using tablets for digital data collection.

In spite of these obstacles, all of the health workers who we interacted with in the study felt that they would be able to manage the technical elements of the data collection once properly trained. We know this to be accurate based on the follow-up timed observations where we found that at least on tablets, CHWs performed at par or better than on paper. Furthermore, we found that the vast majority of the technical familiarity challenges were quickly resolved with some practice. We also found that the familiarity issues with MCH medical jargon, specific in the ASQ forms and the Pregnancy Baseline questionnaires, were sufficiently resolved as CHWs gained familiarity with the terms.

In the second-round study, CHWs had reverted to paper-based data collection while in the field, which we understand was due to CHWs' distrust in the data being safely and completely delivered through the cloud if the devices were used in the field. We believe this distrust could have been a direct result of insufficient training.

On one hand, CHWs could have minimal trust in cloud-based data delivery simply because of their limited understanding of how it works. From conducting our interviews, we learned that CHWs did not have a nuanced understanding of device capacity, network, and storage.

A second reason for mistrust of cloud-based data delivery is the lack of a delivery receipt or a tangible confirmation that the information was saved. Without knowing with confidence whether it was successfully uploaded to the cloud, CHWs felt uneasy using tablets. In comparison, CHWs felt more comfortable using paper and being able to physically submit documentation containing patient health information. Due to insufficient training, however, CHWs were not aware that receipt or confirmation functionality could be built into further versions of the application. From the De Renzi et al. studies [24, 25], we understand that CHWs are willing to utilize a distinct web-based platform to monitor and improve their performance, which suggests that CHWs would not only be willing to learn how to check for delivery confirmation should it become available in an updated version of the ODK application but would also utilize this feature to improve their performance in data collection.

This further demonstrates that consistent and comprehensive training could serve as a vehicle of empowerment in CHWs' use of tablets for data collection.

7 CONCLUSION & LIMITATIONS

iKure's model of engagement with the communities where their healthcare interventions take place is to leverage existing community members rather than bring in external health professionals. This creates new forms of health care access that were previously non-existent in many of the rural settings studied, but also brings new challenges for examination on managing processes that are new for the citizen, the community health worker, and the system that manages it all.

The work presented here is in the limited scope of a Maternal Child Health (MCH) data use scenario. Other scenarios in which the data to be collected are either harder to do without additional aids (visuals) or expertise on part of the CHW (training, awareness of symptoms and follow-up questions), or involve conditions that have a different set of social sanctions (sexually

transmitted diseases) present unique study scenarios. Thus, the results from this study are proposed as relevant primarily to the MCH community.

This project was aimed at sampling pregnancy and early childhood health concerns in rural West Bengal and involved digital technology as data collection tools. The mixed-methods approach of studying the benefits and challenges of collecting the data on mobile devices gives us a look at the ways in which technology impacts community health work. The work also enables contextual understanding of some of the motivations and concerns of CHWs that impact implementation in the short run, but reveals potential consequences for the uptake and use of technology over the long term. Studies of longer duration could help better elucidate acceptability of different data collection methods, along with the quality of data collected.

The study shows that initial concerns of CHWs not being able to navigate technical interfaces can be offset with training. It is reasonable to expect that CHWs can match the speed of data collection on paper without the loss of data quality if training is consistent. However, the study also underlines the perils of building technology without adequately gaining the buy-in of the intended end users. While running projects by fiat may work when organizations can exercise sufficient agency over their employees, such approaches also risk unraveling when new technologies are not implemented or designed for those who use them.

Finally, this work reiterates a growing concern among design professionals that for new technologies to be successful in real-world settings, designers need to step up and dig past participant bias or satisficing responses on the value of technology by their users [49]. Understanding the value of new technology in doing an existing task more efficiently requires examining closely how it affects users beyond the short scope of a usability study and within their ecosystem of practices [50].

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