Using Mobile Phones in a Real-time Biosurveillance Program: Lessons from the frontlines in Sri Lanka and India

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Abstract

The Real-Time Biosurveillance Program (RTBP) is a multi-partner research initiative to study the potential for new Information and Communication Technologies (ICTs) to improve early detection and notification of disease outbreaks in Sri Lanka and India. A key component of this project involves frontline data reporting using mobile phones to overcome problems of Internet-access in remote locations. This paper provides a brief overview of applications available for mobile phone-based data reporting, describes a formative evaluation framework used in the study, and discusses initial findings related to technology acceptance among frontline health workers operating in a developing country.

1. Introduction

The Real-Time Biosurveillance Program (RTBP) is a multi-partner research initiative to study the potential for new Information and Communication Technologies (ICTs) to improve early detection and notification of infectious disease outbreaks in Sri Lanka and India.

Under the current systems in Sri Lanka and India, patient data from regional and community health centres is gathered using paper-based forms and procedures. These forms are then sent to regional health officials where data analysis is carried out by qualified staff to identify potential disease outbreaks. Notifications are then issued from the regional health administrations to local authorities, again using paper-based reporting methods. Under the present system it can take up to 30 days for information to move through these various steps, leading to delays in both outbreak detection and notification.

Leading experts in the field of biosurveillance and health informatics have argued that improvements in disease detection and notification can be achieved by introducing more efficient means of gathering, analyzing, and reporting on data from multiple locations [1]. The introduction of new information and communication technologies (ICTs) is regarded as a central means to achieve these efficiency gains. The primary research objective of the Real-time Biosurveillance Program (RTBP) is to examine these claims more closely by producing evidence to indicate in what ways and to what extent the introduction of new ICTs might achieve efficiency gains when integrated with existing disease surveillance and detection systems.

The RTBP project is a pilot study that involves digitizing current paper-based procedures using advanced ICT components. A key step in this process is introducing an efficient and cost-effective means of digitizing patient data at front line health centres. Once in digital form, patient data can be transmitted immediately to a central server where rapid analysis can take place using statistical data mining software developed by the Auton Lab at Carnegie Mellon University [2]. Results of this analysis are then made available on an ongoing basis to regional and local health officials as electronic notifications accessible through a variety of means, including mobile phones.

2. Digitizing patient data with mobile phones

The first step in a real-time biosurveillance system is to collect and report patient data in order to conduct epidemiological analysis. Mobile phones present an opportunity to both digitize and transmit patient data using existing commercial wireless data service in a relatively cost-effective manner.

The use of commercial wireless services to support health care initiatives in developing countries is gaining recognition within an emerging field known as "mHealth" [3]. In fact, several notable open source software platforms have been introduced in recent years to capitalize on potential of the mobile phone as cost-effective means for collecting and reporting data from the field, including Episurveyor and FrontlineSMS. In comparing across platforms, the technical design of these applications generally involves three basic considerations:

- Access to the application: (native or download)
- Data entry method: device keypad, camera, voice, touchscreen
- Data transmission: voice, SMS, packet access (i.e., Internet) using GPRS or 3G wireless link

The m-HealthSurvey is a customized application designed to operate on a mobile phone and was developed by indian Institute of technology Madras's Rural Technology and Business Incubator (RTBI) as a means of collecting real-time patient disease, syndrome, and demographic data for rapid detection of disease outbreaks.

While the research team is aware of other initiatives using mobile phones specifically for disease surveillance, such as e-MICI [4], the decision to develop the mHealthSurvey was based on the need to assure interoperability with other components of the biosurveillance system and to install and operate it on any low cost Java-enabled mobile phone. The application is now being pilot tested with frontline healthcare workers in both India and Sri Lanka as part of the Real-time Biosurveillance Project.

2.1 The m-HealthSurvey application

The mHealthSurvey application developed for RTBP involves three basic steps: (1) downloading and customizing the application for the frontline healthcare worker by creating a simple user profile; (2) digitizing patient data; (3) transmitting that patient data using General Packet Radio Service (GPRS), which is a wireless data service deployed as a standard feature in many mobile phones. Patient data is transmitted by GPRS over the mobile operator's network to an Internet gateway, where it then goes to a central database for storage and analysis.

Digitizing patient data is done on the mobile phone using an installed java-based application. The application is a Java 2 Micro Edition (J2ME) Midlet that incorporates MIDP2.0 (Mobile Information Device Profile) and CLDC1.1 (Connected Limited Device Configuration) JSR (Java Specification Request) components. This allows the Midlet to be ported on to any, manufacturer independent, mobile phone that supports the same (MIDP2.0 and CLDC1.1) or higher versions of the JSR that transparently interact with the mobile device display/controls and connectivity, respectively. The midlet has been successfully tested on a number of devices, including a Nokia 3110c, Amoi A636, Gionee v6600, Gionee v6900, Motorola , Sony Ericsson s302c.

2.2 Application access and configuration

Users must first download the application to the mobile phone by entering a pre-defined URL into the phone's Wireless Application Protocol (WAP) browser, which then contacts a server on the Internet using a packet access service such as GPRS (General Packet Radio Service). Once contact is established the user sends a request to the server and retrieves a Java Archive (JAR) file, which is then downloaded and installed on the phone.

After installing the application the first step is executing the *download list* function which retrieves the lookup values from a database that includes pre-defined lists of disease names, sign, symptoms, age-groups, gender names, case-status, location types, and health worker types (Figure 1 (a)). This is usually a onetime step but users are encouraged to execute this function periodically, especially, update the list of disease, signs, and symptoms on their mobile phones.

The next step is a profile registration process (Figure 1(b)) to generate a universal unique identifier for the user from the database to the m-HealthSurvey application. This identifier is then used to tag all records received from this particular user profile. Each mobile phone can carry more than one health worker profile so that several healthcare workers at a health facility can share a single mobile phone.

Next the user must identify the village they work in, which is facilitated through the *location* menu. The health worker selects their jurisdiction type; i.e. the administrative geographic area name; followed by entering the name of that area (Figure 1(c)). For example, location type = "PHI" and the location name = "Kuliyapitiya" would retrieve all the villages belonging to the Kuliyapitiya PHI area.

2.3 Data entry method

After installation and configuration, the application presents the frontline healthcare worker with a series of fields and menus that are completed using the standard keypad on the phone. Patient data is captured with several attributes included on the *health survey* form: case date and time; health worker id; location name; patient first name; patient last name; notes; gender; age-group; disease; symptoms; signs; and case-status (Figure 1(d) and 2(e)).

Date and time are automatically set at the moment a patient record is transmitted, anticipating that health workers are sending real-time data. However, the application does gives users the option of overriding this feature and inserting customized date and time information should there be a delay in submitting the record. Health worker Id, location name, age-group, gender, and status are pre-defined drop-down lists that are initially set through the download list, profile registration, and location defining functions.

The m-HealthSurvey application includes several design features intended to simplify data entry. For example, a pre-defined menu of disease types is incorporated into the application so users need only begin to enter the first few characters of the diagnosis in the appropriate field, which will bring up a list of possible corresponding diseases (Figure 1(e)).

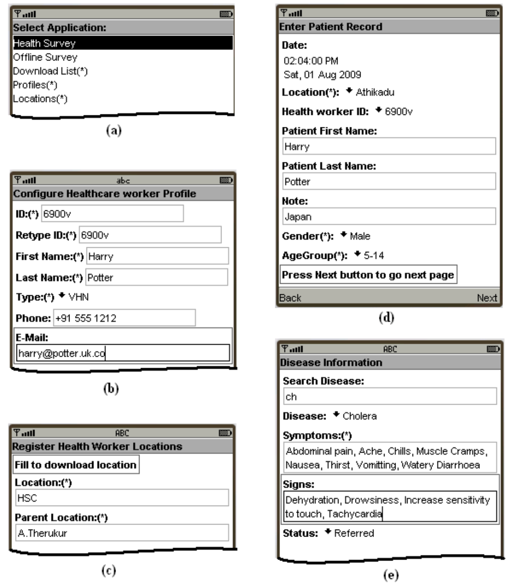

Figure 1. m-HealthSurvey Screens (a) main menu (b) profile (c) location (d) patient record page 1 (e) patient record page 2

2.4 Data transmission

The m-HealthSurvey, client application, communicates data, with the database, through Hyper Text Transfer Protocol (HTTP) Post, Request, and Get functions embedded in a server side PHP hypertext pre-processor application that follows a REST (Representation State Transfer) like architecture. Each record is typically about 2kb in size, and in both Sri Lanka and India the transmission cost per record is less than $0.01(USD), with a more specific estimate placing it at $0.0002 USD per record.

2.5 Workflow

A typical procedure will involve transcribing patient data from a handwritten record (or "chit") into the phone to create a digital record. While this approach may be relatively simple to implement from an application design standpoint, it presents several drawbacks in terms of efficiency and accuracy when dealing with frontline health care workers. For example, entering data using the telephone keypad is cumbersome and time consuming. Frontline healthcare workers may find it disruptive to current workflow or find that the transcription process introduces unacceptable error rates when healthcare workers are entering data from handwritten forms. One concern is that healthcare workers may be reluctant to adopt this technology if they perceive it to be disruptive to current practices. Adoption and use of the mobile phone for entering patient data at the frontline is essential evaluating the real-time biosurveillance system as a whole and it is therefore essential that potential sources of resistance be addressed by the research team.

For these reasons, it is important at an early stage in the project to understand potential problems associated with digitizing patient records using mobile phones. Having clear understanding of these challenges, can allow the research team to modify the design of the application or introduce other methods (e.g., training, procedural changes) to improve the timeliness and accuracy of the digitization process. The biosurveillance system relies on a sound database of patient records being provided in real or near real-time.

3. Formative Evaluation Framework

Wagner [5] stresses the importance of field testing, noting that "many important characteristics of biosurveillance systems can only be determined once they are deployed, at least partially, in the field" (p. 507). Field testing can be intended as formative or summative in approach, with formative studies aimed at producing insight as to the effectiveness of a component or sub-system and identifying potential improvements to that component. An evaluation framework for field testing of biosurveillance systems will examine the attributes of the system or system components, which can be divided into three general categories:

- Human resources (e.g., frontline healthcare workers, epidemiologists)
- Communications networks (e.g., wireless links, Internet connections)
- Computing resources (e.g., mobile devices, data mining and analytics software)

Whereas communications networks and computing resources will be evaluated based on attributes associated with technical performance, evaluation of the human element of a biosurveillance system must consider the relationship between both social and technical attributes. Among these considerations, *acceptability* is a defining attribute for the human element in a biosurveillance system because it will exert an influence on usage practices among frontline health care workers with "downstream" consequences for data analysis and disease detection components in the system. As such, the key goal of undertaking a formative study at this stage in the project is to better understand to what extent frontline health care workers are willing (and able) to use the mHealth Survey application to enter patient data in real-time, and whether there are certain impediments or barriers to this initial data collection that might be addressed with future modifications to planning, training, and design.

Measures of acceptability have been developed perhaps most notably in the Technology Acceptance Model (TAM), which introduced two theoretical constructs *perceived ease of use* and *perceived usefulness*, to study factors influencing technology acceptance of ICTs by individuals within organizations. TAM has been influential in drawing attention to both social and technical factors in technology acceptance, with research findings suggesting that on, the one hand, "mandatory, compliance-based approaches to introducing new systems appear to be less effective over time than the use of social influence to target positive changes in perceived usefulness". On the other hand, perceived ease of use through system design is also a critical factor for increasing user acceptance, especially if it leads to improvements in workflow that can empirically demonstrated to show users the comparative effectiveness of a new system [6, p. 199].

In addition to the TAM literature, a sector-specific approach to acceptability has also been developed by the US Centers for Disease Control (CDC) and focuses on measures involving various participation rates among health professionals [7]. Wagner writing specifically for the biosurveillance field, adopts the CDC-based approach, and defines acceptability as "the willingness of people and organizations to participate in a surveillance system or to use it" (p. 512).

In evaluating the RTBP, the soco-technical factors identified in the TAM literature have been blended with Wagner's general definition to generate an evaluative framework based on the fundamental principle that willingness to use the system is, among other factors, indicative how frontline health care workers perceive the new technology in terms of ease of use and usefulness in relation to current practices. An assessment of these perceptions can be derived from an intersubjective account based on observations and survey data but can also be obtained from various objective indicators related to usage of the mHealthSurvey by frontline healthcare workers involved in the project.

Wagner identifies a total of 21 objective attributes relevant to the evaluation of biosurveillance systems. For the purpose of the formative evaluation study, the research team selected five attributes based on Wagner's framework, structuring them into a relational set around the key attribute of acceptability:

- acceptability of system or components
- reliability
- data quality
- time latency
- portability

For the purpose of evaluating the RTBP, four attributes related to participation have been identified as indirect indicators of acceptability. *Reliability* is defined as the likelihood that a trained frontline healthcare worker will be capable of using the mHealth Survey to correctly enter patient data application. This was measured by performance testing conducted by the research team as part of a certification exercise.

Data quality is defined as the accuracy and completeness of patient information as entered by the frontline health care worker using the mHealthSurvey. This was measured against basedline data obtained from official (paper) records that continue to be generated in both countries.

Time latency is defined as the delay between the moment a frontline health care worker receives patient's case data and the time that data is uploaded to the RTBP analytics software. Given the focus of this project as a *real-time* biosurveillance system, latency is a significant concern. Latency is measured by comparing timestamps.

Finally, *portability* is defined as the likely amount of effort that will be required to introduce the system into a new location. This was measured as disruptive impact on existing procedures and practices involving frontline healthcare workers as well as other medical staff indirectly involved in patient records. In terms of acceptability, the measure associated with the portability attribute may be indicative of potential resistance to the introduction of mHealthSurvey into current arrangements. Where it is perceived as highly disruptive, frontline and other health care workers may be less accepting of making changes to accommodate the mobile phone as a means of digitizing patient records.

4. Initial Findings

A group of frontline health workers, 29 in India and 16 in Sri Lanka, were supplied with a mobile phone and the mHealthSurvey application in order to digitize patient records and enter data into the real-time biosurveillance system. Data in India come from four Primary Health Centers and 25 Health Sub centers located in Tamil Nadu province. In Sri Lanka data are collected from a total of seventeen hospitals and clinics from various regions of the country. Health workers in India began submitting case data in June 2009. Due to delays in receiving government clearance the Sri Lankan participants began in submitting data in September 2009.

In Sri Lanka, the dataset was extracted from treatment chits, which are essentially pieces of paper given to each patient upon examination by a senior medical officer at the hospital or clinic. Each chit carries the name, gender, and age of the patient as well as the diagnosed disease, symptoms, signs, and the treatment. Research assistants belonging to a community-based primary Health Care services providing organization, Sarvodaya Suwadana Centers visited each hospital or clinic to obtain the chits and then digitize the health records by entering the data using the mHealthSurvey application. The role of the research assistants in this case were intended mimic the introduction of a new resource person to the clinic or hospital that might accompany the introduction of a real-time biosurveillance system.

The dataset in India was extracted from the OPD registry, where the senior medical officer also documents each patient's identification number, gender, age, and diagnosis on a chit similar to that used in Sri Lanka. However, in this case almost all of the frontline healthcare workers (26 of the 29) submitting data were already working in the health centre. The senior medical officers associated with the health centres or hospitals in either country were not involved in digitizing the health records.

4.1 Real-time vs other-time submission patterns

There was an initial training period of about 4 weeks (W01-W04, Figure 2) during which time the senior medical officers needed to be reminded constantly to record the diagnosis on the chits. This had not been general practice previously and posed an initial challenge for the research team. For those in Sri Lanka Figure 2 shows a gradual increase of data influx rate of

200 per week after the initial training period. Figure 3 shows a learning curve gradient of 100 records per week increase for those in India. These two figures reflect growing familiarity with the application among frontline healthcare workers, suggesting that acceptability levels as indicated in real-time submission patterns may increase over time in conjunction with perceptions around ease of use.

In terms of real-time data submission counts, these varied across countries and appear to be linked to the ability of the frontline health care workers to manage this imposed new responsibility with other existing duties. In the case of Sri Lanka, the research assistants were tasked with this role specifically and appear to have been able to more effectively manage real-time submission of records as noted in Figure 2.

Unlike the research assistants in Sri Lanka, record counts from India suggest that frontline health workers had difficulty coping with real-time submissions as a result of competing demands on their time during peak patient visitations. As such, many of them were required to transcribe and submit patient records after working hours, and in some cases on the weekends. As a result, 86 percent of the data arrived during other time with only 14 percent real-time.

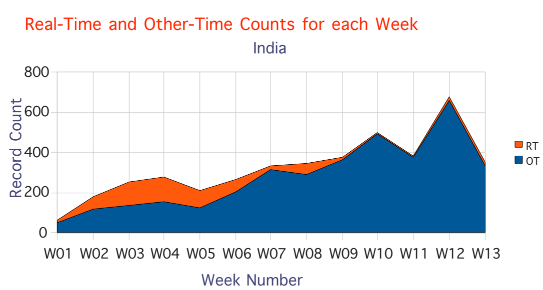

Figure 2. Sri Lanka real-time (OR) and other-time (OT) submission counts by week.

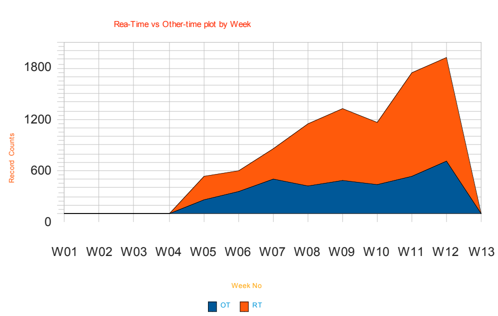

Figure 3. India real-time (OR) and other-time (OT) submission counts by week.

4.2 Corrupt and clean records

While the research assistants in the Sri Lanka may have achieved higher levels of real-time submission of records, they are also relatively inexperienced health workers compared with their Indian counterparts and face challenges in terms of English language competency and awareness of medical terminology. Insofar as the mHealthSurvey predictive menu is incomplete, the research assistants were sometimes required to guess at incomplete details provided on their chits when transcribing to the mobile phone. This is one possibility for the relatively high error rate in weekly record counts from Sri Lanka as illustrated in Figure 4.

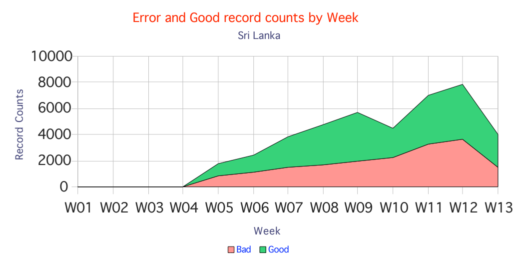

Figure 4. Sri Lanka good and bad record counts by week

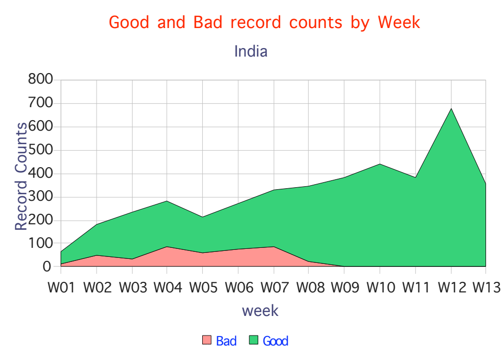

Figure 5. India good and bad record counts by week

On the other hand, the Village Health Nurses (VHNs) in India with 10 or more years of experience may have been submitting relatively few real-time records, but error rates were significantly lower than those found in Sri Lanka. Moreover, as Figure 5 shows, these levels began to subside over time, as the VHNs gained experience with application and when the error rates were drawn to their attention by the research team. In fact, by week 10 of the evaluation, the error rate had declined to almost zero for the remainder of the evaluation period.

4.3 Certification/usability exercise

An m-HealthSurvey Certification Exercise was carried out as part of a formative evaluation of the m-Health Real-Time Biosurveillance Program (RTBP) in an effort to assess the usability and acceptability of the m-HealthSurvey mobile application. The exercise was conducted in summer 2009, with health workers in Sivagangai District, Tamil Nadu, India and in Kurunegala District, Sri Lanka.

The first step of the exercise required participants to demonstrate their ability to establish GPRS connectivity, download the JAR, and configure the JAD for immediate use. The second step had participants enter and submit six health records in various combinations using the mHealthSurvey on a mobile phone.

Observations from the exercise revealed a disparity between the age groups of the health workers using the m-HealthSurvey for RTBP data submission – younger Sarvodaya Suwadana Center health workers, between the age of 18 – 35 in Sri Lanka, were able to complete the exercise easily in the allotted time by themselves without any help. While the older Tamil Nadu Health Department Village Health Nurses, between the age of 30 – 50, but with 10 or more years field experience, were unable to complete the exercise in time and, except for one or two of them, all others required guidance and assistance. This, adoption and usability, disparity of mobile phone applications between older and younger generations is also evident in findings from a study of mobile adoption at the Bottom of the Pyramid (BOP), where "youngsters are more likely than older to adopt mobile phones beyond voice" [8]. Higher levels of reliability in predicted use of the application by younger frontline healthcare workers, however, is tempered by concerns about data quality as noted above.

4.4 Impact on existing procedures

Current records show that over 100 patients visit the hospital and clinic each day in Sri Lanka. The Public Health Center sees the same number of patients; where as the Health Sub Centers may see only 50 patients a week. Given these numbers, the project has set a target of at least 4000 records to arrive from India and the same count from Sri Lanka each week. Figures given above for record submissions clearly show that the project is not achieving this target. In the case of Sri Lanka, concerns about data quality are also in need of attention.

In light of these concerns, the research team undertook a series of observations and interviews with participants about their knowledge on dealing with issues in relation to lack of diagnosis information in the mobile RMS, about their habits concerning maintenance and upkeep of the mobile phone and practices for seeking technical support when confronting problems with the device or application.

Part of the identified problem in Sri Lanka was that the mHealthSurvey application created a new step in existing procedure, asking the senior medical officers at the hospitals to record the disease and syndrome on a chit for the research assistants. Having observed that medical officers often forgot or ignored this additional request, the research team recently introduced an intermediary step involving a stamp and ink pad which is intended to help remind the medical officer and to facilitate the process by creating a more standardized procedure. The stamp produces a blank form with the required fields that are to be transcribed into the mHealthSurvey application. Because it was introduced relatively late into the study period, the effectiveness of this intervention is not yet known.

The research team also learned that a number of frontline healthcare workers in India had under-reported patient data in an effort to avoid unwanted attention and possibly extra duties from senior health officials.

For accurate epidemiological analysis patient data must be relatively free of errors (ideally, less than 5 per cent of all records per batch). While the India health workers tended to correct many user-instigated errors the problem in Sri Lankan remains a concern. Improved data quality might be achieved through a more comprehensive predictive menu of disease and syndrome incorporated in the mHealthSurvey application. Even when experienced health workers are submitting patient records it was found that local spelling or descriptive conventions may differ for various symptoms. For example, one user might be asked to enter "back pain" and another may enter "backache". This can be avoided if all various disease, symptoms, and signs stored in the mobile phone were linked to predictive menus. The project had considered using the mobile phone dictionary as a predictive text function but this feature is still not standardized across all mobile devices and would compromise the ability to port the m-HealthSurvey J2ME across to different java compliant mobile hand-helds.

In both Sri Lanka and India a major concern for frontline health care workers appears to be the overwhelming patient care rates; thus, facilities in both countries often have to provide care to over 100 patients within a span of 5 hours. In order to reduce disruption to workflow, the research team has looked at the option of bypassing the transcription process and having the medical officers digitize and submit the records directly. This measure might reduce workload and improve real-time data entry as well as data quality. However, the standard mobile phone keypad has proven to be cumbersome method for entering data and remains a potential source of difficulty for frontline healthcare workers.

A less disruptive approach may be to introduce a digitization process that retains current handwriting method but provides a more efficient means of capturing and transmitting patient records. The benchmark for the digitization process of each record is 15 seconds or less—approximately 10 per cent of a patient care time (150 patients in 5 hours would result in spending 2 minutes with each patient and 12 seconds to enter a record), which is an approximate equivalent to the hand writing procedure currently in practice. In order to maintain or improve current workflow against this benchmark may looking beyond the standard keypad for data entry and to introduce a touch screen or other method for digitizing data using the mobile phone's camera for optical data capture [9, 10].

5. Summary

The mobile phone offers an innovative and potentially effective means of digitizing patient records to support real-time biosurveillance programs in developing countries. The Real-Time Biosurveillance Project (RTBP) is piloting the mHealthSurvey application among frontline healthcare workers in India and Sri Lanka as part of an end-to-end biosurveillence system.

The project team has recently concluded a formative evaluation of the digitization process using the evaluative framework based on four indicators of usage and proficiency related to Wagner's acceptability attribute: real-time vs other time submission patterns (latency); corrupt and clean records (quality); results from a certification and testing exercise conducted with frontline healthcare workers (reliability); and observations of and interviews with healthcare workers to determine impact on data collection procedures (portability).

Initial findings suggest that younger healthcare workers are more likely to adopt and use the mHealthSurvey application as compared with older, more mature healthcare workers. However, there appears to be a significant trade-off in terms of data quality between these two groups, with more mature health care workers providing more accurate and comprehensive records than their younger counterparts.

Initial findings also suggest that minimizing impact on current workflow is a key consideration with the introduction of a mobile phone-based data entry system. However, the additional human resources necessary to support this system in the form of a data entry clerk or assistant may offset any efficiency gains or improvements in data quality that would otherwise be achieved with real-time data provision. As such, the research team will continue to examine ways to maintain or improve workflow through modifications to interface design, including bypassing the standard telephone keypad entry in favour of other more experimental methods in optical data capture.

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