INFANTS GROWTH AND DEVELOPMENT MONITORING: A PROTOTYPE MOBILE APPLICATION – A CASE FOR BOTSWANA HEALTH CARE SERVICES

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ABSTRACT
The government of Botswana offers free weighing, immunization, growth and development monitoring to all infants from birth until five years. Infant are issued Child Welfare Cards for data collection. This card has to be brought to a health facility whenever the infant is brought in for weighing, immunization or any other health services. The guardian is responsible for the safe keeping of the card, and the data collected. In addition to the usual paper-based system problems, there is no system in place to manage this process and the data collected. This paper presents a prototype mobile application with a database backend to manage such a process. The system has three components; a data collection component, an analysis component, and interactive charts (based on WHO Child Growth Standards 2006) for parents to visualize growth of their kids. We explore different technology stacks suitable to ensure security, confidentiality and reliability, as well as addressing infrastructure constraints especially in rural areas. Our initial results show that this system is feasible and offers a convenient data collection and processing tool for infant growth and development monitoring in Botswana. This system can work in remote areas with poor internet connectivity, is easy to use, and it enhances centralized child weight data collection. The collected data could be used for national decision making. In addition it is aligned to the Botswana National E-government strategy 2011-2016 whose mission is to provide universal access to services through the use of strategies and technologies for efficient and effective delivery.

KEY WORDS
Health Informatics, mobile applications, Infants development monitoring

1. Introduction
Botswana has an established system for monitoring growth and development of children under the age of five years. This system has three core components:
   a) Children are weighed monthly and their height and head circumference are measured
   b) Children are immunized against some diseases using a recommended schedule. At times, the government runs emergency immunizations
   c) Children development is monitored

This process is important to every child as it can show growth deficiencies in children, allowing for problems in child development to be detected early so that corrective measures could be employed. It also protects children against diseases thus reducing the Infant Mortality Rate (IMR) and Under Five Mortality Rate (U5MR) in line with Botswana’s commitment as signatory to the Child Survival [1].

Mobile phones are ubiquitous, cheap, and reliable and people know how to use them. Botswana has one of the highest mobile market penetration rates in Africa, approaching 170%. At the end of 2013, mobile penetration rates at the National level ranged from 75% in Botswana. And, today’s smartphones, with their powerful computing capabilities, large screens and memory, encourage the use of mobile application, including health and health care applications [12]. Studies have shown that there are over 7000 mobile health applications [6]. Mobile phones have also been shown to be faster, and reduce costs as compared to paper based methods in clinical trials. Some studies [13] have shown that the use of mobile devices can improve data collection time and the data quality in health care systems in developing countries. In South Africa, mobile phones have been used as a data collection tool for monitoring community health workers delivering care, as well as the topics addressed in each client encounter with improved quality of delivery and enhanced decision making support as compared to paper based system [11].
This paper forms the basis of developing a mobile application for child growth monitoring. In this paper, two methods are compared, we developed two prototypes of the system using two different platforms: CommCare, and a custom built Android mobile application. The research compares the two methods in relation to creating a data collection tool. 

The rest of the paper is organized as follows: Section 2 is The Background of the study, Section 3 is a discussion of the prototype mobile application’s implementation, and section 4 is the evaluation and analysis, in section 5 we conclude the paper.

2. Background

In Botswana, at birth, every child is issued a Child Welfare Card. The card contains information about the child at birth, as well as information about the mother. The card is kept by the parent/guardian. Every time the child is taken to a health facility, the card has to be brought along so that any important information is recorded in it. There is an established schedule for child weighing, for immunization and for development checking. The information collected is also recorded in the card. Without the Child Welfare Card, health personnel are unable to weight, immunize or do development checking of a child. This card also allows for weight, height graph plotting so the health personnel and the parent can visualize how the child is developing. The main aim of immunization is for the prevention of vaccine preventable childhood diseases. Table 1 shows immunization schedule for Botswana – Taken from Botswana Child Welfare Card (MH 1040/Rev. 07).

Table 1 - Immunization Schedule in Botswana

<table>
<thead>
<tr>
<th>Age</th>
<th>Vaccine</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Birth</td>
<td>B.C.G and Hepatitis B</td>
</tr>
<tr>
<td>At 2, 3, 4 months,</td>
<td>Pentavalent DPT-HepB-HIB, Pneumococcal (PCV13), Rotavirus (Rotarix), Polio</td>
</tr>
<tr>
<td>1 dose in each month.</td>
<td></td>
</tr>
<tr>
<td>At 9 months</td>
<td>Measles</td>
</tr>
<tr>
<td>At 18 months</td>
<td>DT</td>
</tr>
</tbody>
</table>

Table 2 below shows development monitoring in Botswana – Taken from Botswana Child Welfare Card (MH 1040/Rev. 07).

Table 2 - Child development checking schedule

<table>
<thead>
<tr>
<th>Age</th>
<th>What to check, YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 months</td>
<td>Supports own weight on forearms, opens</td>
</tr>
<tr>
<td></td>
<td>hands spontaneously, smiles</td>
</tr>
<tr>
<td></td>
<td>appropriately, coos laughs</td>
</tr>
<tr>
<td>6 months</td>
<td>Supports own weight on forearms, opens</td>
</tr>
<tr>
<td></td>
<td>hands spontaneously, smiles</td>
</tr>
<tr>
<td></td>
<td>appropriately, coos laughs</td>
</tr>
</tbody>
</table>

The current process has been effective for the past years. However, with the current surge in technology, this process could be enhanced to solve some deficiencies it has. These deficiencies include:

- Since it’s a paper-based system, it inherits all problems associated with manual paper based systems.
- Data cannot be aggregated nor compared as there is no central data store.
- Data collected in the process cannot be used to inform policy and guide high level decision making.
- The system is prone to abuse as some parents can skip visiting health facilities and enter records to the child welfare card.

This research investigates the feasibility of using a mobile application as a data collection tool in child development monitoring. The idea is that during a child’s visit to a health facility, health personnel would use a mobile application to record data and optionally enter it manually into a Child Welfare Card. The data collected will mainly be used to monitor the child. However, the data should also be available to be used for nationwide monitoring of growth of children through the use of relevant reports. There are many child growth monitoring mobile applications that have been developed. However, these applications are for the use of the parent, and not by the health personnel. And they mainly entail entering the age, weight, length, and head circumference of the child in to application, then the application plots the relevant growth charts. As a result, the data collected is of use only to the parent, and not to the health facilities. Some of these applications are only available for IPhone and IPad [8, 9], but there are others for Android [10].

In Indonesia, Barnett et al [7] used a mobile growth monitoring phone application parallel with the existing national paper based growth monitoring system over a period of twelve (12) months to compare the two. The mobile application significantly improved the classifications of the growth monitoring status, improved
the timeliness of the data submission, and increased the users’ responsiveness to providing feedback and arranging follow up sessions. However, the comparisons were only made in well selected sites.

In this research, we developed two Android based mobile application prototypes that could be used as data collection tools in child development. We also compare the complexity of developing the mobile application using two platforms: CommCare, and custom built android mobile application. CommCare is an easily customizable, open source mobile development platform that supports frontline workers in low-resourced communities [0]. We used CommCare to create, edit and deploy an Android mobile application for child development monitoring. We also developed a custom Android mobile application. The core features of the mobile application are:

+ It should allow health personnel to register a new child. We created a register child form. It contains text fields, date field, photo field (interaction with device camera). We also included parents/guardian registration in this form.
+ It should allow searching for a child by surname or birth certificate number.
+ It should allow child weight data to be captured. Date should be picked automatically using today's date.
+ Optionally allow for picture to be taken.
+ It should allow child information to be edited.
+ It should allow child immunization information to be recorded.
+ It should allow child development to be recorded.
+ User management capabilities as they could be many health personnel using the system.

Our preliminary results show that a mobile application could be used as a data collection tool in child development monitoring. It further shows that CommCare offers an easy and cheap alternative to develop a platform for such applications compared to custom Android mobile application development. The main focus of our comparison is: complexity of application development, user management capabilities, data access and analysis, security, and offline operation. The main drawback of our solution is that data is stored in the cloud. For sensitive health care data, clients might not be comfortable with this even though it is secure. In future, the mobile application will be enhanced to include:

a) Data analysis and graph generation for parents.
b) Notifications services through SMS and email
c) Counselling services so that parents with children who have been identified to have some deficiencies on some aspects could be counselled with guidance from the mobile application.
d) Monitoring of health personnel performance.

The research involves personal health details about a child and its mother. Health information is very sensitive, and therefore security is an important part of every mobile health applications. It is important to ensure:

- Data confidentiality: There should be effective and efficient access control mechanisms in place to ensure that the patient’s data is only accessed by authorised personnel.
- Data integrity: The systems should have measures to secure the data, verify that the data has not been changed by unauthorised entity, and verify the origin of the data
- Data Availability: The data should be available to the patient and the other users at all times and from anywhere

3. Prototype Implementation

This section outlines the architecture of our mobile application and discusses implementation on the two platforms.

3.1 Mobile application architecture

Figure 1 shows the components of the prototype mobile application and the relationship between them.

![Mobile App Architecture Diagram](image-url)

Figure 1 - Architecture of the prototype mobile application
The prototype mobile application has seven components:

- A group of data collection forms to be used by health personnel in the field to capture data.
- Mobile application functionality which includes checking for legibility for immunization, sending reminders on missed immunization, checking for legibility for development checking and sending reminders on missed development checking.
- In-device database to store data when there is no Internet connectivity.
- Synchronization service to synchronize the in-device database with the external database when Internet connection becomes available.
- Authentication service to handle login requests.
- External centralized database – for storing all data captured through the mobile application in different health facilities.
- Security service – to secure the data while in transit from the mobile device to the centralized database.

### 3.2 Implementation of the Mobile application features

This section discusses the actual implementation on the two selected platforms.

#### 3.2.1 Initial Setup

CommCare requires a good internet connection as the mobile application is built on the cloud and later downloaded to a mobile device. The developer also needs to create an account in order to use CommCare [2]. For the Android custom mobile application, all the tools had to be installed and configured, including android SDK and android ADT plugin for Eclipse.

#### 3.2.2 Data Collection forms

Data collection forms are to be used by health personnel in the public clinics, in schools and in any other location where weight, immunization and development monitoring could be done.

With CommCare form fields are created using a question bar shown in the figure 2 below:

![CommCare Question bar](image)

**Figure 2 - CommCare Question bar**

All types of fields we required in our application were present, including Text Field, Multimedia, multiple choice, number, and dates. The developer clicks on the type of question they want and then adds properties for that question. Properties include validation rules, display conditions, default values, hint messages and help messages. In addition, multimedia options include audio, video and picture. CommCare allows the developer to edit the XML source code directly if they wish to. In addition, submit button and the Java code that fetches data from the form and populates a database a pre-built into the system.

On the Android custom application development, form creation needs knowledge of XML, getting data from form fields and inserting it into database needs knowledge of Java programming Language, and designing and creating databases needs knowledge of databases.

#### 3.2.3 Logic/Calculations

This is functionality to check if a child is due for immunization and which specific immunization. If a child weight, height and head circumference are entered and the child is due for immunization and/or development checking, extra fields will automatically show requiring information of this. In the future we intend to include optional immunizations schedule as well. At times, the ministry of Health runs emergency immunization; we intend to include this in the future. This system will also cater for those immunizations that are done at schools.

#### 3.2.4 Internal in-device database

When there is no network, the mobile application saves the data in an internal in-device database. This is to allow operation in low resourced areas. CommCare comes pre-built with this feature whereas in the Android custom app, we had to include a SQLite in-device database to store the data.

#### 3.2.5 External central database

This is a high capacity database allowing for all data from all health facilities in the country to be stored. CommCare has a cloud based data storage integrated with the development platform whereas with the Android custom application, we have an option to use a custom database or a cloud based solution. With sensitive private health data, the client might feel more comfortable with in-house data storage even though cloud services offer better benefits. Developing a synchronization service for an in-house data storage requires knowledge in Java Programming.

#### 3.2.6 Offline Operation and synchronization

We want the mobile application to function where there is no or poor network coverage. When the mobile device detects network, it should synchronize the internal and the
external databases – internal to external. CommCare has this in-built with the development environment, whereas with the custom built Android application we used SQLite for the internal database and MySQL for the external database. When they is a change in the SQLite database, it’s synced with the external database asynchronously when Internet connectivity becomes available. This will allow for data to be transferred from the device to the database server. We defined and implemented the following requirements:

+ We should be able to update an existing entry in the MySQL database server.
+ We should be able to add a new entry
+ We should be able to get a list of updated entries since last synchronization.
+ We should be able to get list of new records since last synchronization.

In the future we plan to add External to Internal database synchronization – MySQL to SQLite synchronization. This will allow children registered in other regions to be attended to in any other region even if there is no internet connection. In addition, records created, deleted and modified in other clinics should be available in all other clinics local in-device data stores. This requires larger storage in the device.

We use Android Sync Adapters framework. This Framework manages and automates data transfers, and coordinates synchronization operations [3].

### 3.2.7 User Management

Three types of user were defined: Administrators, Data Analysts, and Data Capture. These three have different access privileges. Administrators are super users with the capability of creating users, blocking users and deleting user. Data Analysts have access to the data and reports. They can import the data to spreadsheet and do analysis on it. Data Capture are health workers at health facilities who interact with children on a daily basis. In addition, the administrator should be able to monitor usage, who logged in from which device, what time and what did they do. User management functionalities are easy to implement in CommCare than in the custom Android mobile application.

### 3.2.8 Data access and analysis

This allows access to the cumulative data in the central external database. This will also allow for reports to be defined and graphs to be plotted. This component of the system has not yet been implemented.

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### 4. Evaluation and Analysis

Mobile applications offer most of the features required in data collection forms and more. Using different development platforms leads to almost identical products, the difference being the process the developer went through to produce the product.

In our experimental work, CommCare proved to be very easy to use, and suited for use by people with very little programming background. The custom Android mobile application requires someone with knowledge of XML, Java, and databases. During development, CommCare needs good internet connection, but the developed mobile applications can work offline – in areas with poor or no internet connectivity. User management and monitoring is also easy with CommCare compared to Custom Android mobile application development. CommCare also has in-built data management capabilities, relieving the developer of creating that functionality. However, the developer does not have choice of where the data will be stored as it goes to the cloud.

### 5. Conclusion

The use of mobile phones for data collection has higher benefits compared to other data collection methods. Child weight and development monitoring will likely benefit more from such as initiative because:

a) The solution is accessible – Smartphones and cost of data is becoming cheap. In addition, smartphones are becoming more powerful both in processors, RAM, and applications they could run.

b) The solution provides a high quality data collection instrument – it has data validation, it has GPS, multimedia capabilities.

c) The process is traceable – through time logging of events, and other logs.

d) It works where there is poor or no internet.

Developing data collection mobile applications has been made easy by platforms such as CommCare. Here, even non-IT experts can develop, deploy data collection mobile applications with rich features. The time and cost of mobile application development is thus reduced drastically. However, they are some problems to particularly look at:

a) Storing data on the cloud might be viewed by other clients as having little control of own data.

b) The other problem might be device usage and replacement and repair policy. But since the health worker will be using the device for personal use also, they are more likely going to use it with care, protect it against theft. For health care workers, their level of literacy is sufficient to use smartphones without requiring
any detail training. But were need arises, health workers can be trained as capacity building initiatives.

We conclude that platforms such as CommCare offer a relatively cheap, fast ways to develop and deploy data collection tools. This is particularly attractive to resource constrained countries such as Botswana. Our next step is to take the mobile application for testing in the field.

References


[9] Pediatric Growth Chart App


