

Design Principles for mHealth Application Development in Rural Parts of Developing Countries: The Case of Noncommunicable Diseases in Kenya

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Abstract—In this article, we first derive design principles for mHealth application development for rural parts of developing countries based on scientific literature and field studies. The design principles are then instantiated in a design science project focused on treating noncommunicable diseases (NCDs) in rural parts of Kenya. Designing and implementing mobile health (mHealth) applications is a difficult task, and even more so when done in application domains such as rural parts of developing countries or low-resource communities. The resulting mHealth application assists community health workers (CHWs) in the recording of diabetic and hypertensive patients' vital measurements. Additionally, in-person disease support communities for the patients and CHWs were formed, enhanced by an SMS-based community messaging feature to assist in increasing health-seeking behavior. The study's contribution is both the development of a functioning mobile application and collaborative socio-technical support community for patients as well as the development and instantiation of design principles for designing mHealth applications for rural parts of developing countries.

Index Terms—Electronic medical records, health information management, information systems, medical information systems, mobile applications, rural areas, user centered design.

I INTRODUCTION

DESIGNING and implementing mHealth applications is no easy task: Hevner and Chatterjee [1] note that information systems are composed of inherently mutable and adaptable hardware, software, and human interfaces that provide many unique and challenging design problems (DPs) that call for new and creative ideas. Furthermore, successful mHealth interventions do not work as “magic bullets” but are part of “assemblages”—people and things that are brought together to accomplish particular goals [2]. Moreover, in developing countries, many additional challenges exist, such as lack of access to smartphones [3], limited network connectivity, or heterogeneous

use of mobile phones, such as sharing phones between family members [4], which have to be taken into consideration when designing mHealth applications.

There is a lack of guidance for developing mHealth applications for developing countries [5], [6]. While DPs exist for mHealth applications that target patients on an individual level (e.g., [7]), such DPs are not tailored to the context of rural parts of developing countries and do not take into account low-resource constraints and existing social structures. For instance, the DPs proposed by Lienhard *et al.* [7] assume that patients have access to a smartphone, which is not a given in many developing countries. We build on this research gap and seek to answer the following research question: *What are design principles for mHealth application development that target populations in rural parts of developing countries?*

To find a way to address these challenges, we choose to follow a Design Science Research (DSR) approach to develop a mHealth application that enables community health workers (CHWs) in rural parts of Kenya to improve health services for their patients. The following section explains the methodical procedure that was employed in this article in more detail.

The United Nations (UN) has identified the good health and well-being for all as one of the sustainable development goals to be achieved by 2030 [8], as residents of developing countries still suffer from many eradicable diseases and preventable health issues. Noncommunicable diseases (NCDs) such as cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes have become a major concern in low- and middle-income countries, and the prevalence of NCDs in these countries is rising disproportionately to the rest of the world [9], [10]. Kenya is no different: The mortality and morbidity from NCDs are rapidly increasing as well [11]. In 2012, NCDs accounted for more than 50% of total hospital admissions [9], and it is also reported that 27% of all deaths in Kenya are accounted for by NCDs [11]. Hence, the Kenya Ministry of Health compiled a comprehensive strategy—the NCD Strategy Kenya 2015–2020 [9]—to combat the rise of NCDs.

Yet, access to primary healthcare professionals (doctors, nurses, clinicians, or pharmacists) to receive treatment for these diseases is severely limited. In Kenya, the patient-to-doctor ratio is 10 000 people per 1.5 doctors, and the country is also still far off from the recommended 44.5 nurses per 10 000 people [12]. To bridge the gap between the primary healthcare system

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and underserved population, community healthcare workers (CHWs) are deployed. CHWs are voluntary health workers with limited standardized training outside the formal nursing or medical curricula and deliver a range of basic health, promotional, educational, and mobilization services within their communities [13]. They serve as ground-level healthcare workers in the local community and are trusted in the community since they are accustomed to the local cultural customs and languages.

To better document service delivery and assist the CHWs with their work, the Kenya Ministry of Health has developed certain hardcopy logbooks that CHWs must use when conducting visits to patients. However, these logbooks are unsatisfactory to CHWs for two reasons. First, the fact that hardcopy books are used poses several challenges, and replacing them with mobile health (mHealth) applications has proven to be far easier to transport [14]–[16], yield fewer data entry errors [15], [17], and to be cost-efficient [15], [16]. Second, most mHealth applications for CHWs, including the ones in Kenya, do not target NCDs [18], [19] or related measurements pertaining to NCDs to better keep track of patients' health.

So far, the focus of mHealth research has focused on patients at the individual level [20]. Such approaches have shown promising results, especially in developed countries, and also in urban areas of developing countries. However, mHealth approaches that target patients in rural areas of developing countries have been less effective [20]. Therefore, in recent years, for healthcare delivery in rural areas, the attention of the scientific community has broadened toward developing mHealth applications that target community healthcare workers (CHWs) as a sustainable solution [20]. The existing evidence indicates that interventions, which include both CHWs and mHealth tools, are effective [6]. CHWs are integral to providing healthcare in rural settings, where infrastructure obstacles, such as transportation, prevent access to professional healthcare facilities [20]. Furthermore, CHWs can help illiterate patients to interpret and implement health information effectively [6].

II METHOD

DSR has proven to be a valuable paradigm, and its general acceptance as a legitimate approach to information systems research is increasing [1], [21]. Hevner and Chatterjee [1] note that the fundamental principle of DSR is that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact. Thus, for a unique application domain like the Kenyan healthcare system where practicality and workaround solutions prevail, conducting research with the practicality in mind—a fundamental principle of DSR—has potential.

Hevner and Chatterjee [1] state that technology has been defined as “practical implementations of intelligence” and argue that technology needs to be useful, rather than being an end in itself. The goal of the project was to produce a functioning solution that supports CHWs and to identify and verify more general DPs throughout the iterations of the development process. To increase the rigor and generalizability of the study, the research project was conducted in three

different communities and counties in rural parts of Kenya: Gikambura (Kiambu county), Limuru (Kiambu county), and Tuala (Kajiado county).

Throughout our research, we followed the guidelines for DSR, as described by Hevner *et al.* [22]. The DSR approach consists of rigor, relevance, and design cycles. The rigor cycle provides knowledge from the academic literature to the research project and is achieved by appropriately applying existing theory and methods [1], [22], [23]. The design cycle is at the center of any DSR project [22]. In each design cycle, artifacts are designed and evaluated [22]. The goal of the project was to establish a mHealth supported health care service that is highly desirable for patients. The researchers' insights derived from the evaluations are used to inform the design of pursuing design cycles. Finally, the relevance cycle establishes an application context for the DSR project [22].

Fig. 1 depicts how relevance, rigor, and design cycles were instantiated in our research. We started our research project with a rigor cycle in which we reviewed the scientific literature on the Kenyan healthcare system, NCDs, as well as mHealth solutions and DPs for mHealth development in developing countries. In the pursuing relevance cycle, we derived insights on how patients with NCDs live in Kenya by interviewing healthcare professionals and joining them during house visits. Building upon this, we developed DPs and instantiated them in three design cycles. Each of the cycles is described in more detail in the following sections.

III BACKGROUND

In the following section, due to the unique application domain, background on the Kenyan healthcare system and CHWs is provided. The prevalence of diseases in Kenya is also discussed.

A. Kenyan Healthcare System

Shifting from a highly centralized form of government that had been in place since the country's independence in 1963, Kenya introduced a devolved/decentralized system of government consisting of a central government and 47 semiautonomous county governments [24]. This new structure naturally affected healthcare management and delivery. While the central Kenyan Ministry of Health remains responsible for policymaking and other regulatory matters, county governments are responsible for the allocation and management of healthcare resources and service provision [25]. This devolved organizational structure has many contextual and practical implications for healthcare delivery across the counties.

Across Kenya's 47 counties, public healthcare delivery is structured in a four-tier hierarchical structure. Community services are located on the lowest organizational level (Tier 1), and primary care services are located on the second level (Tier 2). Secondary and tertiary referral services are the highest tiers of care (Tiers 3 and 4) [26], [27]. This article addresses the bottom, ground-level part of Kenyan healthcare and is thus concerned with Tier 1 and Tier 2, i.e., community health services and primary care services, respectively.

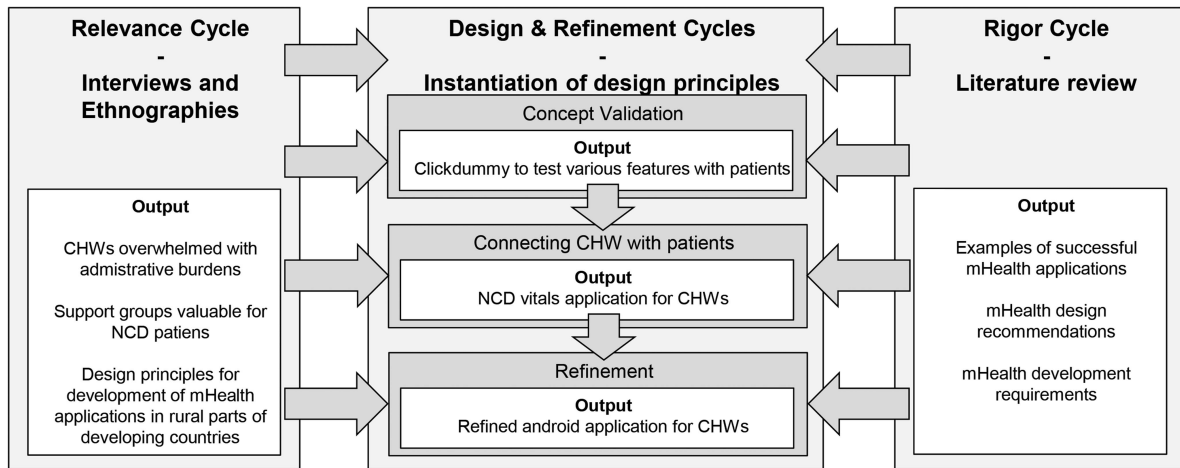


Fig. 1. Research approach.

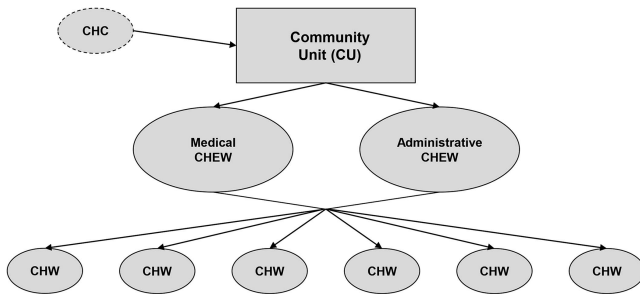


Fig. 2. Organizational structure of community-level healthcare.

The three pilot facilities we cooperated with are classified as Tier 2 facilities. Their services include several fields, such as basic outpatient diagnosis and medication delivery services. The pilot facilities cooperate closely with community-level health services (Tier 1). Such first-level services encompass activities such as personal and domestic hygiene or treatment of minor ailments [26]. These Tier 1 activities are organized on a regional level and carried out by voluntary ground-level healthcare workers, the CHWs, which are recruited and deployed across Kenya. The CHWs are organized into groups called community units (CUs). In total, 8800 CUs exist nationally. Each CU covers a defined geographic area covering a population of approximately 5000 people [27]. The CU is also often referred to as a link facility, as it links CHWs to the health system and community members to the formal health centers.

Within each CU, three key actors with different roles are identified [27]: the Community Health Committee (CHC), the Community Health Extension Worker (CHEW), and the Community Healthcare Workers/Volunteer (CHW). Their relation is set out in Fig. 2.

The CHC serves as the governance body of the CU and consists of representatives from different groups and villages who provide leadership for managing level-1 services. Furthermore, each CU is assigned two CHEWs. CHEWs are health or development workers who support CHWs and CHCs technically through supervision and mentoring and strengthening linkages between

CU and higher health systems [27]. The third role within a CU is a community healthcare worker (CHW). CHWs are community health volunteers who offer promotional, preventative, and basic curative services in the community.

B. Noncommunicable Diseases

The mortality and morbidity from NCDs are rapidly increasing in Kenya [11]. In 2012, NCDs accounted for more than 50% of total hospital admissions and over 55% of hospital deaths in Kenya [9]. It is also reported that 27% of all deaths in Kenya are accounted for by NCDs [11]. Hence, the Kenya Ministry of Health compiled a comprehensive strategy—the NCD Strategy Kenya 2015–2020 [9]—to combat the rise of NCDs.

Four main types of NCDs are identified in Kenya, namely cardiovascular diseases (e.g., heart attacks and strokes), cancers, chronic respiratory diseases (e.g., asthma), and diabetes [9]. These NCDs share major behavioral risk factors such as tobacco use and exposure, an unhealthy diet, physical inactivity, and harmful use of alcohol. This article focuses primarily on cardiovascular diseases (specifically hypertension) and diabetes, as these were identified as the most pressing NCDs to CHWs during the relevance cycle.

IV ELICITATION OF REQUIREMENTS

In order to elicit requirements, a rigor and a relevance cycle were conducted. The rigor cycle aims to provide a solid theoretical foundation as it provides past knowledge to the research project in order to ensure its innovation [28]. This is done by establishing an overview of mHealth research in Kenya and other developing countries, along with an overview of design recommendations for mHealth applications from the scientific literature. In contrast, the relevance cycle explores the application domain: Its main contribution is in finding and providing the requirements for the research artifact [29]. During the relevance cycle, interviews with a variety of stakeholders were conducted at two of the three counties under review (Kiambu and Kajiado) as well as in Kenya's capital Nairobi. As the purpose of the

relevance cycle is to explore the perceptions, opinions, experiences, and responsibilities of CHWs and patients to ultimately determine the application domain, we chose interviews and ethnographies as a research method to obtain initial insights into the field [30].

A. *mHealth Applications in Developing Countries*

Betjeman *et al.* [31] define mHealth concisely as “the use of mobile phone technology for health-related purposes.” The mHealth transformation can be most disruptive in developing countries, which are often characterized by a dysfunctional public health system [32]. The literature on mHealth implementation and usage in developing countries has gained relevance over the past decade, most likely to the ubiquity of mobile phones in these regions [33] and mobile phones’ potential to improve service delivery on a massive scale in marginalized areas where health services are often scarce or absent altogether [34]. Activities conducted with mHealth solutions may assist facilitation of care delivery, medical records charting, patient and health worker education, disease prevention, and patient self-management [18]. When planning and implementing solutions for developing countries, hardware and technology considerations are an essential part of the process [35].

Many mHealth initiatives designed for CHWs in developing countries aim to address issues at the time of contact between CHWs and patients. A conclusion here was that mHealth has the potential to increase patient load—i.e., the number of patients seen—which is generally a signal of a more successful CHW program [18]. However, an increased load of patients results in more stress to the individual worker. It was also found that mHealth can increase contact time with patients and increase the thoroughness of data collection in households, as digital entry fields cannot be skipped as opposed to their paper equivalents [36].

Communication between CHWs and patients has also been a focus of mHealth literature. Especially in rural settings, communication can be improved by reducing the amount of travel time between patients and CHWs [37]–[41] or serve as intervention delivery channel for underserved populations [42]. Through SMS texts, mHealth initiatives were able to assist in medication adherence [37], [41], appointment adherence [41], [43], tracking patients [39], [40], and ease of enrolment of patients into health programs [41].

mHealth has also been used for data collection and surveillance for research-based purposes. The differences in outcomes between several mHealth initiatives and traditional paper-based collection methods have been compared. Studies showed that mHealth solutions led to more efficient and reliable data collection than traditional paper-based methods. This was ascribed to the fact that mHealth solutions are easier to transport [14]–[16], had fewer data entry errors [15]–[17], and were more cost-efficient [15], [16].

B. *Design Recommendations for mHealth Applications From the Scientific Literature*

The field of healthcare offers many opportunities for the use of DSR to design innovations with a goal of improving the

effectiveness and efficiency of healthcare products, services, and delivery [44]. Yet, for developing countries, challenges exist that are unique to the population and environment [45].

One such challenge is social and cultural norms. Social and cultural norms can become barriers to the adoption of mHealth programs and should be accounted for [6], [46]. It has been recognized that successful mHealth interventions do not work as “magic bullets” but are part of “assemblages”—people and things that are brought together to accomplish particular goals [2]. To develop applications that are culturally appropriate, an understanding of how the culture relates to health behavior is essential and needed to inform later development activities [47].

Having identified social and cultural norms, rather than conceiving them as barriers to knock down or overcome, it is instead advisable to figure out ways to work with them [2], [6], [48]. This can be done by establishing partnerships with influential local players, such as local governments and nongovernmental organizations [49]. Such partnerships can be helpful in providing local technical capacity and training [5]. Partnerships have shown to be especially valuable in overcoming infrastructure obstacles in rural parts of developing countries [20].

Furthermore, mHealth interventions need to take into account existing local processes if they are to be successful [6]. The inclusion of healthcare workers in the design and piloting of mHealth technologies is helpful for strengthening the effectiveness and diffusion of such tools [6]. Kahn *et al.* [5] suggest that ongoing evaluation of specific initiatives should guide mHealth development. Especially qualitative methodologies can be used to illuminate the subtle aspects of the interconnectedness of technology and people [2].

Above all, the mHealth application must be developed with input from users [50], [51]. In the healthcare context, this typically entails healthcare workers as well as patients. User-centered approaches are necessary to design an application that considers the users’ training and limitations and anticipates possible scenarios that will be encountered [50]. Medhanyie *et al.* [52] suggest conducting several evaluations spread over longer periods.

C. *Requirements Derived From the Scientific Literature*

The goal of the rigor cycle was to find requirements related to the development process of mHealth applications intended for use in rural parts of developing countries. The results discussed in the previous section are synthesized in Table I for reference in pursuing relevance and design cycles.

D. *Interviews and Ethnographies*

The qualitative interview is the most widely used qualitative research method [55] and has been applied extensively in multiple disciplines, including information system research [56], [57]. CHWs in the Gikambura, Limuru (Kiambu County), and Tuala (Kajiado County) communities were visited for the interviews. In line with the relevance cycle conducted in [29], it was decided to interview at least five CHWs at each of the three facilities. However, it was possible to get access to more CHWs, and ultimately 26 CHWs were interviewed (10 in Gikambura, 15 in Tuala, and 1 in Limuru). In total, 12 of the

TABLE I
REQUIREMENTS FOR mHEALTH SOLUTIONS IN KENYA DERIVED FROM THE SCIENTIFIC LITERATURE

Requirement	Description
LRQ1: Identify social and cultural norms. [2, 6, 47, 53]	An understanding of how the culture relates to health behavior is essential and needed to inform later development activities
LRQ2: Establish partnerships with local players [2, 6, 48]	Having identified social and cultural norms, rather than conceiving them as barriers to knock down or overcome, it is instead advisable to figure out ways to work with them.
LRQ3: Integrate healthcare workers into the artifact design [2, 5, 6]	One of the patients' primary contact points with the Kenyan healthcare system are the CHWs. Thus, their involvement in potential solutions should be considered.
LRQ4: Follow a user-centered approach [50, 51]	User-centered approaches are necessary to design an application that considers users' training and limitations and anticipates possible scenarios that will be encountered.
LRQ5: Aim to reduce travel time for CHWs [37-41]	In rural settings, communication can be improved by reducing the amount of travel time between patients and CHWs.
LRQ6: Handle virtual community data sensitively [54]	One of the most salient success factors of virtual communities is that member data is handled sensitively.
LRQ7: Test regularly with end-users [2, 52]	Different evaluation methods can be used to illuminate the subtle aspects of the interconnectedness of technology and people.

CHWs were male and 14 were female. Their average working experience was 3.75 years. Furthermore, we had the opportunity to do ethnographic fieldwork by following four CHWs during house visits to patients' homes and to get an understanding of the daily work of CHWs. Additionally, expert interviews were conducted across the three locations. They include four CHEWs, one subcounty public health officer, one subcounty focal person and two NGO employees overseeing CHW initiatives.

Following up on advice given by several CHWs, we also interviewed two committee members and eight support community members of the Westlands DHC Support Community on the value/benefits that the support community provides to patients.

A semistructured interview guide was developed based on a basic sequence as set out by Whiting [58]. During the interviews and ethnographies, field notes were created. Field notes are helpful to visualize the researcher's thoughts [59] and allow the researcher to maintain and comment upon impressions, environmental contexts, behaviors, and nonverbal cues that may not be adequately captured otherwise [60]. Lofland *et al.* [61] recognize the difficulty of writing extensive field notes in practice and recommend jotting down notes that will serve as a memory aid when full-field notes are constructed. This reconstruction should preferably take place the same day, which was adhered to in this article. The subsequent qualitative content analysis was conducted according to the procedure described by Mayring [62].

E. Results of the Interviews and Ethnographies

CHWs repeatedly emphasized how sparsely populated their district is in certain areas and noted that it can take 1–2 h of travel time between each house (by foot) or 15 min by boda boda.¹ The Tuala CHEWs confirmed this and noted that CHWs can sometimes only visit three households per day, spending 15–30 min traveling by boda boda between houses and staying for 2 h at each household they visit. CHWs are responsible for data collection, surveying, monitoring, and household mapping. All CHWs, CHEWs, and experts confirmed that these activities

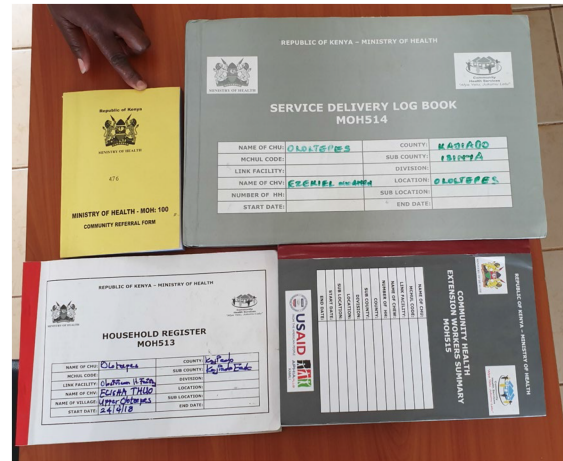


Fig. 3. Logbooks used by CHW and CHEWs.

do make up a significant part of their responsibilities. CHWs confirmed that there are three books that they use when visiting households. These books (see Fig. 3) were observed and photographed at a Tier 1 facility in Tuala during the interview with a CHEW [T01].

Throughout the interviews, CHWs mentioned a number of problems that they experience with the logbooks, which can be broadly categorized as problems with the physical nature of the books themselves and data collected in the books (fields of entry). The first and perhaps most glaring issue was the fact that the logbooks are large, heavy, and impractical to carry between each house. This was especially a problem in a sparsely populated area such as Tuala, where CHWs have to travel great distances either by foot or by boda boda and was brought up by 12 out of the 15 Tuala CHWs. The books getting wet in the rain was also a problem. Other issues with using books include confidentiality—i.e., “that anybody can see what is written down on paper”—and that the pages tear easily. All interviewed CHWs were of the opinion that using a mobile phone is preferable to using the logbooks. The only favorable aspect mentioned regarding the books was that it “looks much more official to

¹Boda bodas are motorcycle taxis which are ubiquitous in Kenya



Fig. 4. Westlands DHC support community.

household members” when collecting data in a big book rather than on a mobile phone.

The required data collected in the books posed several problems to CHWs. Only two questions in the books deal with NCDs and only require the CHW to note if the patient is aware of a chronic illness. Thus, no illness or treatment-specific data is recorded (e.g., blood pressure, blood sugar, etc.) to keep track of patients suffering from these diseases. CHWs’ work in households is much more comprehensive than simply entering binary input and essential additional information is not documented anywhere. Thus, CHWs are encouraged by CHEWs to take separate notebooks along to make notes of service delivery and write down phone numbers of patients to follow up on adherence and other issues.

It quickly became apparent that CHWs undertake much more work than is required of them and that recordkeeping only makes up a part of their routine work. All CHWs and CHEWs we interviewed mentioned that health education is a primary concern when visiting households. Health education provided to community members spanned a wide spectrum of topics (e.g., family planning, nutrition, mother and childcare, and sanitary practices).

From the interviews, it was evident that there are a few key health problems prevalent in both Gikambura and Tuala. To prevent biased results, CHWs were not probed on specific health problems—thus, all issues were brought up by the CHWs themselves. Diabetes and hypertension were the most common health problems mentioned, with both being mentioned by 20 of the 26 interviewees. Other common issues included arthritis and cancer (both mentioned by ten interviewees), and HIV/AIDS being mentioned by eight interviewees.

Several experts mentioned that the concept of patient support communities is very popular in urban parts of Kenya and holds benefits for patients in many respects. Therefore, we visited the Westlands NCD support community, which operates in Nairobi to understand the inner workings of patient support groups and evaluate whether the concept could be transferred to rural parts of the country.

Health-seeking behavior for NCDs like diabetes and hypertension is low in Kenya, and much effort goes into educating patients on these issues. Adherence to treatment is also a problem

due to ignorance, financial reasons, or logistical issues. This is why many NCD support communities in Kenya exist. One of these support communities was started in 2012 by the Westlands NCD Clinic.

As of December 2018, about 750 patients have signed up to the Westlands NCD support community, and monthly actively contributing members range between 250 and 300 members. As it is not possible to screen this many patients on a single day, the patients are split up into weekly groups of about 60–70 members. This means that a patient comes to the facility once a month on a fixed day (e.g., the first Wednesday of every month). Fig. 4 shows members of the Westlands DHC Support Community on a typical Wednesday waiting to see the doctor and receive their medication.

The support community provides emotional support and advice from fellow peers who are also diagnosed with diabetes or hypertension. As many health conditions in Kenya are still highly stigmatized, the feeling of “not being alone” and discussing personal issues with fellow diabetics or hypertensive patients is appreciated by many patients. Especially since diabetes and hypertension are lifestyle diseases, topics such as nutrition, exercise, and other lifestyle adjustments are discussed among members. Furthermore, the effectiveness of treatment and side effects of medication are also discussed. These discussions can either take place in a formalized way by a peer (or one of the support community committee members) educating fellow patients or simply informally in the queue while patients are waiting to be screened by the doctor. This feeling of support from peers is something that patients often do not get within their communities or even within their families, and knowing that there are fellow patients struggling with the same issues increases health-seeking behavior for their conditions.

F. Insights Derived From Field Research

The goal of the relevance cycle is to find requirements for the research artifact. Due to the context-specificity of this study, the relevance cycle served to augment issues identified in the rigor cycle by conducting field research in Kenya through extensive interviewing of CHWs, patients, and other experts. The requirements derived from the rigor cycle (summarized in

TABLE II
REQUIREMENTS FOR THE MHEALTH APPLICATION DERIVED FROM FIELD RESEARCH

Requirements	Description
FRQ1: Leverage CHWs	Patients primarily have contact with the CHWs when it comes to dealing/discussing their health condition.
FRQ2: Address stigmatization	Lifestyle diseases such as diabetes and hypertension are often stigmatized in the patient's local community.
FRQ3: Easy to learn and to use	An application that supports CHWs should be easy to use during household visits.
FRQ4: Integrate an educational concept	Lack of education leads to non-adherence to medication and treatment, either due to ignorance or other traditional beliefs.
FRQ5: Provide offline functionalities	Mobile network coverage differs significantly in different regions in Kenya (especially in rural areas), causing delays in data uploads.
FRQ6: Identify the real end-user for testing	While most people have access to a mobile phone, phones are sometimes shared in a household.
FRQ7: Provide an authentication mechanism	Confidentiality of personal information is at risk with using hardcopy logbooks.
FRQ8: Align mHealth app with CHW workflows	As CHWs are volunteers, there is a lack of financial and other incentives to do their mandated work properly (plus compensation for the additional work that they do).
FRQ9: Leverage support communities	Support communities can help to provide emotional support and advice for patients from fellow peers.

Table I) were largely confirmed, which is why Table II only lists requirements that were newly discovered during the relevance cycle.

G. Design Principle Development

Based on the requirements derived throughout the rigor and relevance cycles (summarized in Tables I and II), we developed four DPs for mHealth application development in rural parts of developing countries.

Design principle (DP1): Build an understanding of the application domain before building solutions. Healthcare services in developing countries should be tailored to the local context [53]. To be able to build mHealth applications for a specific region, it is essential to understand the social and cultural norms of the target population first (LRQ1). Quite often, certain illnesses are subject to stigmatization (FRQ2), and being aware of those stigmas as well as their real-life implications helps to build socially acceptable applications. McCurdie *et al.* [63] propose a thorough investigation during initial project phases to understand the intended use and goal of the mHealth application by employing research methods such as ethnographies, interviews, and focus groups to explore the field. In this article, DP1 was followed using the ethnographies and interviews described in the relevance cycle (see Sections IV-D and IV-E).

Design principle 2 (DP2): Identify means to build on existing social structures. The importance of integration into existing social structures has also been recognized by other researchers. For instance, Aranda-Jan *et al.* [64] list stakeholder participation and involvement as one of the central elements to successful mHealth development in Africa. Especially in rural parts of developing countries, partnerships with local players (LRQ2) are essential to overcome mobility barriers. A widespread net of healthcare facilities in rural areas makes it difficult and costly for patients and healthcare professionals to meet each other on a

regular basis. One approach to overcome these mobility-related barriers is to leverage established local structures such as CHWs (FRQ1) or support communities (FRQ9). Such structures cannot replace professional medical advice and treatment but can help to augment the reach of medical professionals into rural areas of the country. This can be done by taking over routine activities such as measurement of vital data or by providing emotional support through peer groups.

Design principle 3 (DP3): Integrate the mHealth app into the local healthcare delivery concept. mHealth apps should facilitate both patients' and physicians' routines and should link well with existing processes/services [7]. MHealth apps that do not fit into healthcare delivery workflows risk nonacceptance by patients or service providers (FRQ8). Essential aspects that should be considered during the design phase are that the system needs to be easy to use (FRQ3), should aim to reduce travel time for healthcare workers (LRQ5), and provide offline functionalities (FRQ5). Furthermore, it is advisable to follow a user-centered approach during artifact design (LRQ4) and to integrate healthcare workers into the development process (LRQ3). Moreover, regular tests with end-users are essential to validate design decisions (LRQ7). Quite frequently, patients have relatives that help in monitoring and treating illnesses. It is, therefore, important to determine whether the patient is the real end-user of the mHealth application (FRQ6).

Design principle 4 (DP4): Make the intended healthcare delivery experience tangible for patients. In order to develop effective mHealth tools, it is critical to start with the needs of the intended end-users [65]. In many cases, these needs include educational content (FRQ4) and lifestyle advice related to the illness. Furthermore, sensitive handling of data is essential for patient acceptance of mHealth applications (FRQ6). Redesigning existing healthcare delivery processes to include an mHealth application typically changes the patient experience. To assert

TABLE III
PROPOSED DESIGN PRINCIPLES

Design principles	Referenced requirements
DP1: Build an understanding of the application domain before building solutions.	LRQ1: Identify social and cultural norms. FRQ2: Address stigmatization
DP2: Identify means to build on existing social structures.	FRQ1: Leverage CHWs LRQ2: Establish partnerships with local players FRQ9: Leverage support communities
DP3: Integrate the mHealth app into the local healthcare delivery concept.	LRQ3: Integrate CHWs into the artifact design FRQ3: Easy to learn and to use LRQ4: Follow a user-centered approach LRQ5: Aim to reduce travel time for CHWs FRQ5: Provide offline functionalities FRQ6: Identify the real end-user for testing FRQ8: Align application with CHW workflows LRQ7: Test regularly with end-users
DP4: Make the intended healthcare delivery experience tangible for patients.	FRQ4: Integrate an educational concept LRQ6: Handle virtual community data sensitively LRQ7: Test regularly with end-users

that patients will accept the modified provision process, it is advisable to test how the intended healthcare delivery process will manifest itself to the patient and their social environment. This can be done through regular tests involving end-users (LRQ7), making iterative use of focus groups and other evaluation methods [66]. Table III provides an overview of the proposed DPs and links them to requirements derived from the rigor and relevance cycle.

V FIRST DESIGN CYCLE

Based on the preceding rigor and relevance cycles, the first design cycle was initiated. The information generated through the relevance cycle shows that diabetes and hypertension are prevalent within the communities under review and that there is a lack of proper tracking of vital measurements by the CHWs, accompanied by a lack of health-seeking behavior from patients. Furthermore, the concept of a support community for diabetic and hypertensive patients seems to address these problems well.

A. Suggestion and Development

As an understanding of the application domain (DP1) had already been established through interviews and ethnographies (see Sections IV-D and IV-E), the next step was to develop a solution for NCD patients. Following DP2, it was decided to build on existing social structures by designing an mHealth solution that helps CHWs to deliver patient care but also leverages patient support groups. The foundation for the suggested solution stems from the support community concept as implemented at the Westlands Health Facility. This solution is expanded with the inclusion of CHWs. In pursuing design cycles, the design and development of an application is presented which supports CHWs during their daily household visits. To integrate well with local healthcare delivery concepts (DP3), we were in contact with three healthcare facilities in Gikambura, Tuala, and Mlolongo

throughout the project and conducted pilot tests of our concepts and artifacts with them.

Following DP4, the goal of the first design cycle was to develop a basic concept and verify that patients find it desirable. We started by developing a concept focused on patients who have been diagnosed with diabetes or hypertension. The suggested solution is depicted in Fig. 5 and is discussed below.

First, a patient is signed up for the service: She can be recruited either through a CHW or through a fellow patient. The patient is registered at the clinic so that she can meet the clinician/nurse, get acquainted with the facility, and meet fellow support community members. The patient is also assigned a personal CHW, who is responsible for following up with her. The patient then receives a consultation from the clinician/nurse, medication for the month, followed by an interactive educational session with fellow support community members. This visit at the facility with the checkup, procurement of medication, and educational session occurs once per month.

Two weeks after the patient visits the facility, the CHW visits the patient at home. During this visit, the CHW takes the patient's vital measurements and records them. The recorded data is transferred back to the healthcare facility, where the medical professional can view the data and track the patient's treatment. This way, the patient is monitored at least twice a month without having to travel to the facility twice.

In order to leverage the support community concept to its full extent and to integrate community members that live in more rural parts of the region, we decided to implement a virtual community concept. As noted earlier, access and ownership of smartphones are not ubiquitous in Kenya. As opposed to the CHWs, it cannot be assumed that patients have access to a smartphone. Thus, it was decided to provide an SMS-based solution to patients.

An SMS-based community chat for patients was designed, overcoming the known technical and resource limitations, along with a variety of content that could be sent to patients of

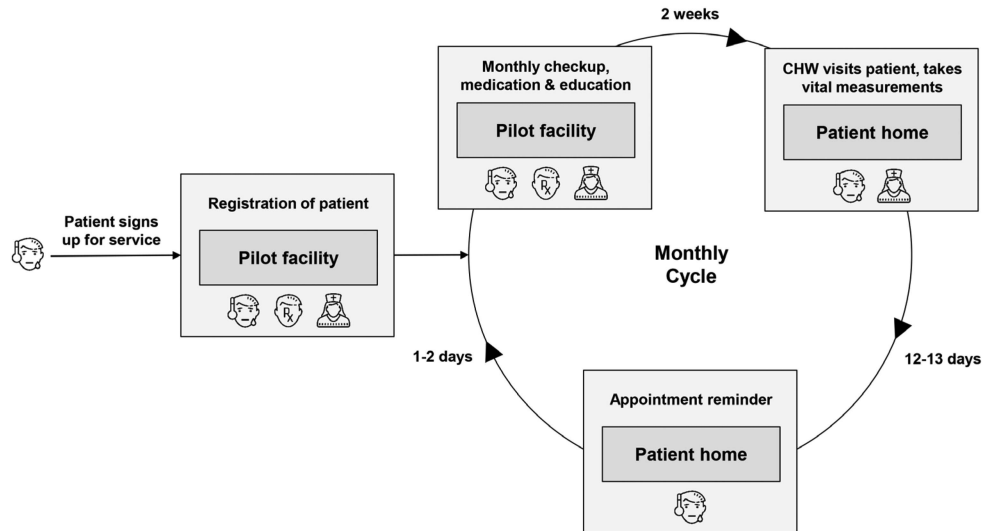


Fig. 5. Overview of the suggested solution.



Fig. 6. Mock-ups of SMS solutions for patients.

the community. Fig. 6 shows some of the mock-ups of the SMS-based messages which we tested with patients. On the left, a sample appointment reminder message is shown; in the middle, an adherence reminder to remind the patient to take her medication; and finally, an example of messages sent in SMS community chat.

B. Evaluation

In order to evaluate the artifact, it was tested with seven patients diagnosed with diabetes and hypertension. The goal of the evaluation was to determine whether the overall concept and the intended experience for the patient, including the community SMS service, appointment, and adherence reminders, are desirable. The participants were recruited at the Gikambura pilot facility. A combination of methods was used to conduct the evaluation with patients. Overall, the evaluation was of qualitative nature as descriptive scenarios with accompanying prototypes were used. As noted by Hevner *et al.* [28], descriptive scenarios

can be useful when evaluating an artifact. This method entails that detailed scenarios around the artifacts are demonstrated to show their utility.

Simple mock-up prototypes displaying a feature phone with SMS messages in a PowerPoint presentation were shown to users, and scenarios around why these SMS are sent were constructed and illustrated to users. While the prototype was not fully interactive—meaning the user did not initiate the action to move from one state to the next in the setting—sample SMS messages were displayed sequentially using PowerPoint animations so that the sequence of the storytelling and prototypes aligned. During the scenario, certain problems were highlighted. Users were asked whether they experienced these problems in their daily lives and whether what was shown with the prototype would solve this problem. For instance, patients were asked if they ever forget to take their daily medication, and, if so, whether a reminder SMS would assist them in adhering to their treatment.

The majority (six) of the seven participants were female. The average age was also high at 75 years. All participants

had been diagnosed with hypertension, one with diabetes, and two mentioned that they suffer from arthritis as well. Most patients (five) reported that they purchase medication about once per month. One patient reported bi-monthly purchasing, while another purchased medication irregularly. It was found that vital measurements usually occur when the patient visits a facility for purchasing medication, meaning that most patients get their vital measurements taken once a month.

The appointment reminders received mixed feedback from participants. Two patients noted that they sometimes forget to go for an appointment. Two patients noted that they do not forget (the next appointment date is often written down on a physical card which patients can keep) and three patients said they do not make appointments. Instead, they usually just visit the facility when their medication is depleted. Nevertheless, the patients indicated that they would still appreciate reminder SMSs, while two noted that they would like reminders but prefer being called.

In terms of adherence, most participants (five) seemed not to experience trouble in remembering to take their medication. One of the remaining patients stated that her family (grandchildren) reminds her, while the last patient took medication very irregularly and was, in general, ignorant about her condition. Nevertheless, three patients still noted that such an SMS reminder “would be appreciated.” All patients indicated that they would like to receive educational content related to their condition. Currently, they receive educational content only in-person at either government or private healthcare facilities or at health education events in the community, which are held at irregular intervals.

The support community concept was also very well-received. All participants indicated that they would find it useful to join such a community, primarily as they can discuss health issues and lifestyle adjustments with their peers. Two participants also indicated that they already discuss their health condition with other people in the community. Another participant indicated that she knows many people in the community with diabetes and hypertension who could join the community. Nevertheless, the SMS virtual community chat received mixed feedback. Four participants liked the concept but were not comfortable sending SMS themselves, two did not grasp the concept fully, and one was excited about the idea.

C. Discussion

From the evaluation, it was seen that the concept of support community meetings for diabetic and hypertensive patients is well-accepted and that the frequency should likely be once a month. The positive reception of the support group concept suggests that having an understanding of the application domain (DP1) building on social structures (DP2) can lead to more desirable mHealth applications.

Finally, we noted that the evaluation method should be adjusted in the next design cycle. Descriptive scenarios (accompanied by mock-ups) proved to be challenging, as some patients struggled to fully grasp concept scenarios, even if they were accompanied by prototypes. It proved to be even more challenging for “organizational scenarios”—e.g., the abstract concept of

a support community—than for SMSs sent, as the SMS could actually be displayed on mock-ups. This learning highlights the importance of making the intended process tangible for patients during evaluations, as proposed in DP4.

VI. SECOND DESIGN CYCLE

Having received an initial validation of the overall concept and the desirability of the patient experience, in the first design cycle, the focus of our research switched to the mHealth application itself for the second design cycle. As almost all CHWs interviewed during the relevance cycle own smartphones—and can operate them well—the goal of the second design cycle was to develop an Android application named “NCD Vitals” and to integrate the mHealth app into the local healthcare delivery concept (DP3). The primary aim of the Android application was to give CHWs an appropriate data collection tool for individual patient vital measurement, which is not currently available using logbooks.

A. Suggestion and Development

Screenshots of several frames of the functional Android application are displayed in Fig. 7. After registering, the CHW needs to log in to access the application. This step is implemented to address the confidentiality issues regarding the medical data of the patients (FRQ6). Once logged in, the home screen (dashboard) is shown. From the dashboard, the CHW has the option to subscribe new patients, view and update patient data, or to synchronize the data on the smartphone with the back-end server. The synchronization feature is important because mobile networks are not available everywhere in Kenya (FRQ5).

Subscribing a new patient can be done via the app by inserting personal data (e.g., name or mobile phone number) using input fields on one of the app’s screens. Once a patient is subscribed to the service, the CHW can view all vital data that has been entered via the app. Furthermore, CHWs can directly add vital data, such as blood pressure or blood sugar levels. This allows CHWs to provide patients’ feedback based on their medical history and to conduct most of their administrative work at the patient’s home.

B. Evaluation

Following DP3, the objective of the evaluation was to validate that the NCD Vitals application fits into the local healthcare delivery concept and whether refinements or augmentations to the app would be necessary. This evaluation phase was once again of qualitative nature and integrated CHWs into the artifact design (LRQ3) using exploratory focus groups (EFGs) [67] to evaluate the artifact after the CHWs had spent some time testing it.

We made use of three EFGs to test the design of the NCD Vitals application. In total, 12 CHWs across our three pilot healthcare facilities (Gikambura, Tuala, and Mlolongo) participated. The 12 recruited CHWs were spread evenly across the facilities, thus with four CHWs at each facility. The application was tested in the field by the CHWs during ten patient house visits in Gikambura and three visits in Tuala. Unfortunately,

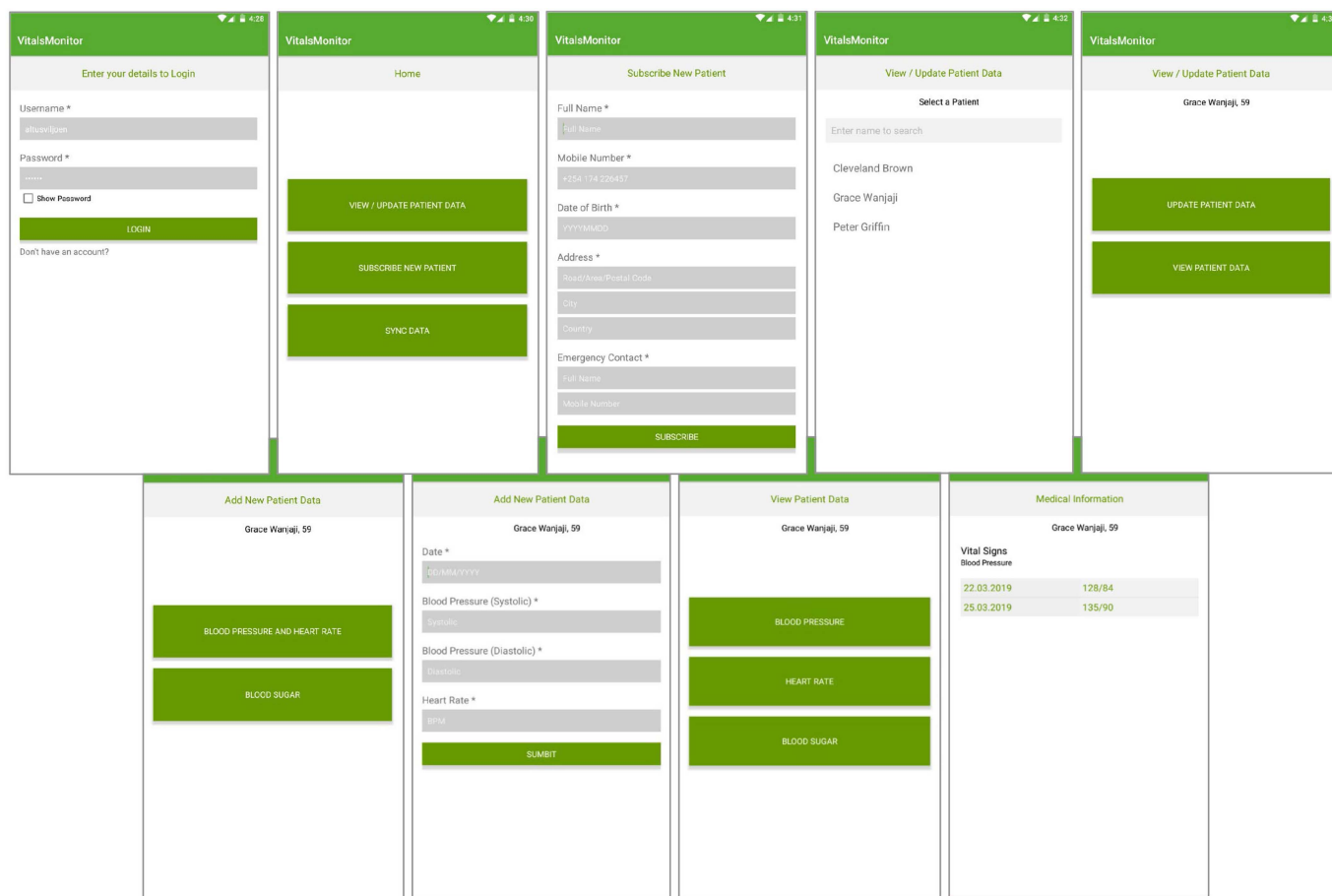


Fig. 7. Selection of screens from the NCD Vitals application.



Fig. 8. Mlolongo CHWs testing the NCD Vitals application (left picture) and house visits with Gikambura CHWs (middle and right).

the Mlolongo CHWs did not have the opportunity to test the application in the field.

The evaluation phase was realized as follows. First, one of the authors met the CHWs at the respective pilot healthcare facilities. The CHWs were explained the idea behind the developed application. This was followed by a run-through of the application by one of the authors so that the CHWs could see how the application works. The application was installed on a dedicated handset (Samsung Galaxy S6 Edge), which was passed around when different CHWs tested the application. Before going out into the field (patients' homes), each CHW

was required to conduct a “mock-testing” of vital sign measurements on a fellow CHW. The CHW was required to register the “patient” in the application, input the measurements, and view the data afterward. The picture on the left in Fig. 8 shows the Mlolongo CHWs testing the application on one another in the Mlolongo pilot facility.

Afterward, house visits were conducted with the CHWs. The Mlolongo CHWs, as noted, did not have the opportunity to test the application in the field. Thus, a focus group was run with them directly after taking each other's vital measurements. Fig. 8 shows two house visits in Gikambura, both with hypertension

patients having their blood pressure checked and their data entered by CHWs into the application.

When analyzing the results, we used the focus group (Gikambura [F01], Tuala [F02], and Mlolongo [F03]) as the unit of analysis, not the individual participants, as Tremblay *et al.* [67] suggest. Generally, the application was very well-received by CHWs across all three facilities. [F01] noted that the application was very easy to use and much more comfortable than carrying a book around. [F01] and [F02] both noted that the data entry and viewing are very simplistic, as “only three things can be entered.” [F01] and [F02] also noted that the app is very suitable for keeping track of patients’ data.

The second theme, interpretation of required data, contains interesting results. During the house visits in Gikambura, upon entering a patient’s date of birth, several patients did not know their date of birth, especially elderly patients. However, they all knew their year of birth by heart (but not necessarily their age). In most households, when the CHW started asking about details of the patient, a family member taking care of the patient immediately went to fetch the ID card of the patient. Interestingly, it was not that elderly patients could not remember their date of births, their ID documents only listed their date of births as 01/01/19xx as, at the time of birth, the exact date was not formally recorded.

In the Mobile Number entry field, a sample number starting with +254 (Kenya’s dialing code) was displayed in the first version of the application. However, it was observed that almost all Kenyans started saying their number with “07 ... pause,” followed by the rest of their number by default. It was interesting to observe that all patients, even illiterate elderly ones, knew their mobile numbers by heart.

The concept of a defined address in both Gikambura and Tuala was also abstract for the CHWs. [F01] suggested changing the input field “address” to “Landmark,” meaning that a close-by landmark such as a school or shopping mall could be entered. It was also established that the third address input field is redundant. The term “Emergency Contact” was also ambiguous to some CHWs. [F02] noted that it should be changed to “Family Member.” The button “Subscribe New Patient” was also sometimes misunderstood. The labels for Blood Pressure “Systolic and Diastolic” were sometimes said to be confusing. While most CHWs were comfortable with these terms, as the training level of CHWs differs, adding understandable terms like “Top Number” and “Bottom Number” when reading a blood pressure reading might be more intuitive for some workers than the official medical term.

Navigation issues were also important to address. After data was submitted (both for registering a new patient and submitting vital measurement data), focus group participants were 1) unsure if the data was successfully entered and 2) confused where to go to view the data, as they had to go back manually to the patient entry. This confusion was experienced by all participants across all facilities.

C. Discussion

This design cycle was very comprehensive, and a lot of data was gathered. An overview of the problems and suggested

solutions is concisely displayed in Table IV. The results of the focus group testing of the NCD Vitals App indicated that the application addressed the challenges with current vital tracking practices. They also provided insightful contextual feedback on the design of the artifact, which was taken into account with the next iteration of development in the succeeding refinement design cycle. Using focus groups also proved to be an effective evaluation method. Overall, the insights derived from this design cycle substantiate that it is worthwhile to integrate mHealth applications into the local healthcare delivery concept (DP3).

VII REFINEMENT AND PRELIMINARY EVALUATION

The purpose of this cycle was to build on the insights and address problems discovered during the second design cycle. Most of the required changes were related to the interface of the application, while the overall concept of using an Android application for documenting vital health data was confirmed.

A. Suggestion and Development

Based on the feedback received on the NCD Vitals application during the second design cycle, several design improvements were made. The implementation of the changes mainly occurred on three screens. Fig. 9 displays the reworked version of the interface.

B. Evaluation

In order to validate whether the changes to the artifact address the problems identified in the previous design cycle, an evaluation was conducted once again, this time using confirmatory focus groups (CFGs) [67]. The CFGs consisted of 10 CHWs recruited across the three pilot healthcare facilities (three in Gikambura [F04], four in Tuala [F05], and three in Mlolongo [F06]). We aimed to test with the same CHWs during both design cycles. This was largely achieved, as [F04] and [F05] had only one new tester each, and [F06] none.

The refined application was given to the CHWs on the same handset used for data collection in the previous design cycle. The same process was repeated where they each did mock-testing with one another for entering data into the application. The focus groups were first asked generally about what they liked and what could be improved about using the application, followed by a step-by-step walkthrough of each of the application’s functionalities, i.e., registering a patient, inputting vital measurement data, and viewing the entered patient data.

The CFGs proved to be very effective at validating whether the iterated application is suitable for the application environment. No CHW had significant trouble operating the application. [F04] noted that using the application is easier, more convenient, and better for storage than using the books and is thus preferred to “writing papers,” which were described as tiresome and cumbersome. [F05] and [F06] were also generally very pleased with the simplicity of the application, as it was noted in [F05] to “keep it plain.” Apart from these general insights, the rest of the discussion focused on more specific input fields (i.e., the interface/design of the application).

TABLE IV
SUGGESTED SOLUTIONS FOR NCD VITAL APP PROBLEMS FROM THE SECOND DESIGN CYCLE

Problem	Suggested Solution
Patients often do not know their date of birth.	“Date of Birth” label was changed to “Year of Birth”, with only a 4-digit numerical input possible.
+254 dialing code confuses CHWs when the mobile number has to be entered.	+254 extension was removed and replaced with 07.
The notion of a specific address is too abstract for CHWs, given the layout of the households.	“Address” label was changed to “Landmark”.
CHWs have different ways of entering a date into the application (e.g., date format).	The date entry was removed altogether and use the OS’s date instead. This way, CHWs cannot enter the date incorrectly
Terms “Systolic” and “Diastolic” are confusing to some healthcare workers, especially untrained ones.	The labels “Top Number” and “Bottom Number” were added to the medical terms.
CHWs are unsure if data entered is submitted.	Confirmation of successful data entry clearly displayed, and the application automatically navigates to the previous screen.

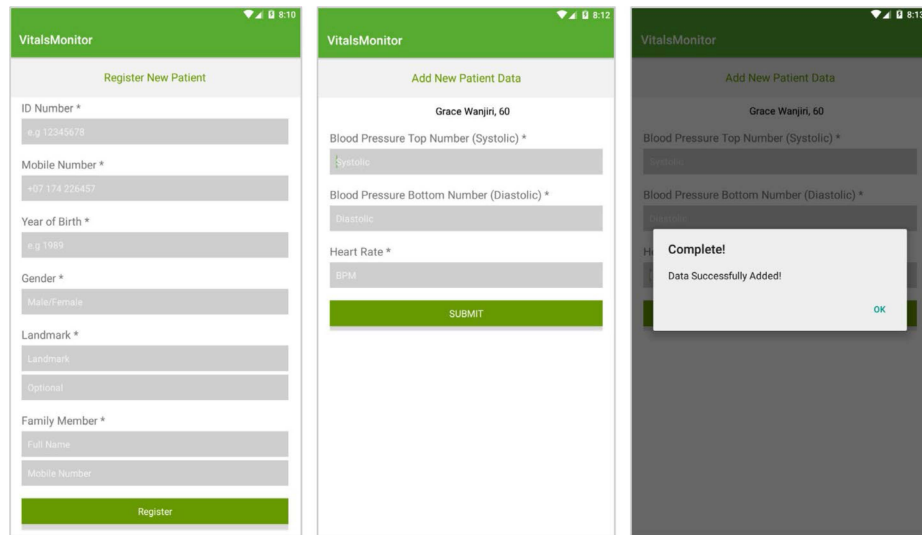


Fig. 9. Selected screens of the reworked NCD Vitals App.

A key learning from conducting focus groups across three facilities was that regional and demographical differences play a role when entering the data, especially when patients are involved. During the house visits, it could clearly be seen that different counties have different ethnic groups and languages, even adjoining ones. For example, while Kikuyu is the largest ethnic group in Kenya, their language is nonexistent in Kajiado County, the neighboring county, where Tuala is situated. Tuala CHWs [F05] emphasized that privacy in their region is essential, and people are unwilling to hand out their data to strangers. In Tuala, a reason for this was noted to be the construction of the Mombasa-Nairobi SGR Railway² through the area, which, according to [F05], led to some community members being compensated by the government and some not. Hence, people are cautious with regard to whom they give their data. While not necessarily regional, [F06] also noted that especially illiterate people are hesitant to give out their data to someone who is

“asking a lot of questions” and prefer to keep their data private. [F05] also mentioned some people having issues with disclosing their age. Thus, a “bracket” (e.g., 45–49 years old) was suggested.

C. Discussion

This cycle managed to validate that the NCD Vitals app would be welcomed by the CHWs. The evaluation results show that cultural diversity is an important factor when developing applications in Kenya. Cultural diversity exists not only on a larger geographical scale but also on very regional levels. Thus, when building an artifact that is intended to be used on a larger scale within Kenya, we advise testing the application in different regions to increase the likelihood that it is acceptable to the different existing cultures within Kenya. We also see this finding as a supportive argument for our second DP (DP2: Identify means to build on existing social structures), as cultural differences between communities are easier to identify and moderate when working together with local players.

²As the name suggests, the Mombasa–Nairobi Standard Gauge Railway (SGR) is a standard-gauge railway that connects Kenya’s largest two cities, Nairobi and Mombasa. It is Kenya’s most expensive infrastructure project since independence from the United Kingdom and was completed in 2017.

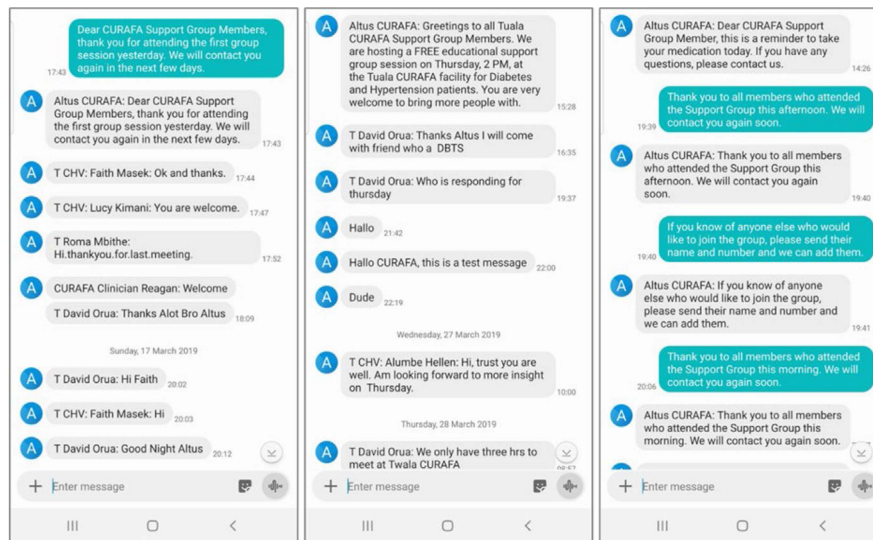


Fig. 10. Examples of SMSs chats with patients.

VIII. FINAL EVALUATION

The final evaluation aimed at establishing whether patients find the support community concept as a whole attractive, and if so, which qualities. Another goal of the final evaluation was to validate that our proposed overall solution consisting of CHWs, the NCD Vitals app, and the support community provides value to the patients. To do this, we followed DP4 by creating a tangible experience of the intended healthcare delivery process for patients.

During the evaluation phase, patients at the three pilot healthcare facilities (16 in Gikambura, 7 in Tuala, and 5 in Mlolongo) were signed up for a virtual community SMS service. SMSs were sent to the support community to evaluate the SMS community chat concept. Furthermore, adherence and appointment reminders were sent out at regular intervals. In Fig. 10, examples of different messages can be seen: general SMS community chat message (left), appointment reminder (middle, top message), and adherence reminder (right).

Once again, explaining the concept of an SMS virtual community chat to patients was too abstract and not tangible enough for the patients. However, once everyone was signed up, and the community messages were sent, patients grasped immediately how the SMS community chat was intended to work.

As noted various times in this article, educational content on diabetes and hypertension are regarded as very valuable by the patients. Thus, the authors were specifically interested in sending out this content. Unfortunately, due to regulatory limitations in Kenya, the authors were not permitted to send out any educational medical information without formal regulatory approval, as the healthcare industry remains very regulated in this regard. However, educational content could still be provided in-person at the pilot healthcare facilities by medical professionals, as the facilities are officially accredited to do so.

Patients were given one week to experience the virtual SMS-support community. After that, support community meetings were scheduled for patients at each of the three pilot healthcare



Fig. 11. Tuala support community educational session.

facilities. CHWs were also invited to attend these meetings. Fig. 11 shows an example of the educational session at Tuala with a clinician leading the session. CHWs were sitting among the patients and were interactively taking part in the discussion. The communication was done in the appropriate local language as not to inhibit patients' understanding, which may have been more limited for some patients should the sessions have been done in English. In Mlolongo, patients arrived one or two at a time and were not patient enough to wait for other patients to arrive to have a proper community session. The Mlolongo sessions are thus excluded from the official results in this subsection.

A. Results

In total, 15 patients and 6 CHWs participated in 4 focus group meetings that took place after the educational sessions. Patients and CHWs were split into two focus groups in Gikambura (five patients and two CHWs [F07] and further five patients and two CHWs [F08]) and two groups in Tuala (three patients and two CHWs [F09]; further two patients and two CHWs [F10]).

A key issue that arose from the focus groups was language. Nine out of ten Gikambura patients [F07, F08] were not able to communicate in English (especially the elderly ones), and a CHW translated all questions and answers into Kikuyu. In

Tuala, the educational session was held in Swahili; three out of five had trouble with English. This has implications for the SMS sent out to patients. CHWs in Gikambura [F07] indicated that communication must be either in Kikuyu or in English, and in Tuala [F10], either Swahili or English. However, in all focus groups, it was indicated that there is usually an interpreter (a family member) in the patient's house who can translate messages.

The support community concept as a whole was very well-received at both facilities, and the sense of community among members was very impressive. One member of the Gikambura focus group [F07] mentioned that educational content could be emailed to him, and he could then print it out and give it to other members to help them. It was also remarkable to see the effort that patients took upon them to attend the session. In [F10], one patient brought a new member along who apparently had to take time off work to attend. CHWs in all focus groups also followed up (calling and household visits) with patients by themselves to encourage them to attend, despite not being asked to do so by the authors. In [F07], this notion of a sense of community was summarized nicely with the quote: "We are a group."

The medical education session was very well-received. Feedback was very much in line with what had been learned from the Westlands DHC Support Community during the relevance cycle. Understanding the cause of diabetes/hypertension, nutritional information, and lifestyle content were cited to be of value [F09, F10]. [F10] also noted that it was appreciated that the clinician took a lot of his time to give a "wide explanation" of the topics. [F10] also noted that there is a lot of misinformation spread about diabetes and hypertension and that sessions like these provide the correct information.

In terms of the SMS sent, the adherence and appointment reminders were desired by all focus groups. For adherence reminders, Gikambura, [F07] asked for reminders once a week [F08] and Tuala, twice a week [F09, F10]. Appointment reminders were desired to be provided 2–3 days before the session, across all facilities. As noted, unfortunately, educational SMSs could not be sent out, but most patients indicated that they would like to receive educational content once a week [F07, F08, F10].

Finally, especially the older patients did not know how to fully use SMS services [F07, F10]. For example, one lady received a message about the support community session but did not know how to reply [F10]. The same concept holds here as with the language issue: There is always someone in the household who can assist.

B Discussion

The final evaluation managed to validate the developed artifacts in the application domain. The SMS solutions for patients and the in-person support community meetings have proven to be desirable with the focus groups. Importantly, it was identified that these solutions are practically implementable, given the technological, financial, and social constraints posed by the environment. The rich evaluation data derived from making

the intended healthcare process tangible for patients serves as supportive evidence for DP4. The next section summarizes the insights obtained through this DSR project and reflects upon the validity of the proposed DPs.

IX CONCLUSION

This DSR study certainly delivered many insights, but especially due to the context-specificness of the study, a discussion and synthesis of the results obtained must be done to position their value in a greater field of knowledge. On a general level, our study contributed to what Gregor refers to as a theory of design and action (type five) [68]. Such theory entails prescriptive statements that specify how people can accomplish something in practice (e.g., construct an artifact or develop a strategy) [68]. Following our four DPs, we built and tested several instantiations of artifacts that help rural communities in Kenya to deal with NCDs. In the following, we discuss how the proposed DPs impacted our project.

DP1: Build an understanding of the application domain before building solutions. When looking back on our development process in the project, our knowledge about Kenya's devolved health system as well as our early experiences with the CHWs and the Westlands NCD support group served as a foundation for developing a solution that is accepted and fostered by the local communities. In developing countries, financial constraints manifest themselves in many aspects of healthcare service delivery. Therefore, local communities often establish less formal structures supported by voluntary CHWs to take care of the medical needs of their community members. CHWs are often a valuable source of advice for patients, as they see them on a regular basis and can discuss their vital data with them. CHWs can also help to address existing stigmas related to diseases in a discrete manner during household visits. Building an understanding of these circumstances in an early stage of the project certainly prevented us from encountering unnecessary pitfalls.

DP2: Identify means to build on existing social structures. We identified two social structures that were of great help to overcome mobility and cost-related barriers: CHWs and support groups. Integrating CHWs and support groups into the healthcare delivery concept is more promising than building an mHealth application directly for the patients. First, many patients do not own smartphones. Instead, many households share one mobile phone or can use a neighbor's mobile phone. Second, in Kenya, many members of the communities are illiterate. This makes it difficult to rely only on text-based channels to communicate with patients. CHWs have received training on NCDs and are in regular contact with trained medical personnel. Furthermore, they are trusted members of the local community and know best how to explain medical information and its implications for daily life in a culturally appropriate manner. Complementary to the CHWs, support groups can provide emotional support for patients and ease access to illness-related information and resources. In order to adapt the successful concept to rural landscapes, we evaluated whether a combination

of in-person meetings enhanced by SMS groups could be used to create a patient experience similar to the support group meetings.

DP3: Integrate the mHealth app into the local healthcare delivery concept. Following a human-centered approach while developing the mHealth app allowed us to iterate quickly and build an application that fits well into existing processes. While following CHWs during household visits, we noticed that network coverage is often insufficient for using mobile data. Thus, it was required that the Android application is also useable offline. Furthermore, household visits typically involve a lot of interaction between the CHW and the residents. In order to allow the CHW to focus on the work at hand, it is thus necessary that the application is designed to fit into the workflow of a patient visit. We also learned that it is not just important that the application fits the CHW's workflow and also that it allows them to do their work faster. A key factor in meeting these goals was the iterative testing and redesign of the artifact together with the CHWs. This helped to implement features that made the application more intuitive to use and improved the alignment of the app with the CHW workflow.

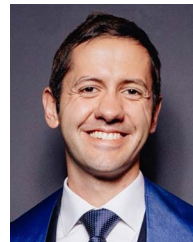
DP4: Make the intended healthcare delivery experience tangible for patients. While it can be difficult to get access to patients for testing mHealth applications, patient feedback during the design process proved to be very valuable to us. Patients are the experts when it comes to their personal situation and how it feels to be the subject of a healthcare process. The patient feedback we received on the overall concept, virtual support communities, as well as medication and appointment reminders helped us create a concept that is desirable for patients. On the other hand, we learned that developers should be aware that patients often have a limited overview of the entirety of the healthcare delivery process. This has implications for user testing. When testing with patients, it is important to find an appropriate evaluation method that allows patients to get a tangible experience of how the process would be for them. In our case, descriptive scenarios were too abstract for the patients. However, testing with actual SMS reminders and the SMS support community helped them to grasp the concept immediately.

The DPs we propose are subject to limitations. First of all, the instantiation of the principles occurred in only three rural regions of Kenya. Furthermore, the developed application focuses on NCDs, which includes a set of diseases that affect a broader population. Future work should evaluate how well the principles generalize to other countries and more niche target groups.

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