

**MTOTO-BEBE: Promoting Access to and use of Pre-and-Postnatal care information by
Harnessing Social Capital Through Inclusive Mobile Application Development in Ilorin
Nigeria**

by

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mental models, participatory design, information architecture, mHealth, Human-computer
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Abstract

One of 21 Nigerian women still die from avoidable maternal death. Yet, one of the most critical interventions for safe motherhood is ensuring that women (even in the most remote areas) have access to and are well informed of antenatal and postnatal care information and services. As the price of mobile devices plummet, more people around the globe and particularly in Low-and-Medium Income Countries (LMIC) now have access to smart mobile devices. However, majority of this population are disadvantaged by their levels of literacy as most applications are designed with the assumption that users possess the ability to read and write in certain languages and that users possess cognitive skills like language processing, visual organization and visual memory, speed of cognitive processing, divided attention and perceived self-efficacy are considered essential for realizing interactions on many mobile interfaces. In this dissertation, we include Ilorin women as co-designers in the design and development of Moto-bebe, a mobile application that provides greater access to ante- and post-natal care information. The study is divided into three phases. In phase I, through literature review, conducting and analyzing data collected from surveys and interviews, we learnt about the current eco-system of maternal care available to Ilorin women and how these group of women used mobile technology. The ubiquitous property of mobile technology and its penetration makes them a viable candidate as 47% of women owned a smart phone and 33% more had access to an android powered device as shared device with spouse or family. In phase II, we implored HCI and HCI4D techniques including open card-sort, think aloud protocol and participatory design to learn about the structures of social capital that exist amongst Ilorin women and to identify dominant mental models of this population around maternal care. Ilorin women expected chronological organization of information from birth till after delivery. In the absence of access to adequate healthcare, Ilorin women looked to

other women in their communities for ante-natal and post-natal care information. This point of contact for this population in case of an emergency is a family or friend that lives in the same community. Armed with these findings, we designed the interface for mtoto-bebe and in phase III, we evaluate the efficacy of the application. Using general assistant score as the main metric, we found that no/low literate users can benefit from the use of contextual pictorial representations (e.g., icons, illustrations, digital/hand drawn images, gifs etc.) instead of text, as all participants easily completed the assigned task and 20% needing minimal mediation to identify specific images, or transitions.

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Table of Contents

Abstract.....	2
Acknowledgments.....	3
List of Tables	4
List of Figures	5
List of Abbreviations	8
Chapter I: INTRODUCTION	1
Ilorin, Kwara state, Nigeria.....	2
Background.....	3
Contributions.....	8
Limitations	9
Research Questions.....	10
Chapter II: LITERATURE REVIEW	13
Maternal Mortality	13
Factors that impact healthcare seeking behaviors.....	14
Measuring Social Capital.....	19
SCAT and A-SCAT	21
mHealth interventions in sub-Sahara Africa.....	23
HCI4D and ICT4D.....	24
Designing usability techniques and study.....	26
Designing User Interface for Novice Users	28
Moses Project.....	28
VideoKheti.....	29

KrishiPustak	30
Information Architecture	31
Card sorting.....	32
Analyzing Card sorting with Mixed Method.....	32
Participatory Based Design.....	33
Chapter III: MTOTO-BEBE SYSTEM AND INTERFACE DESIGN	34
Personas	36
Implementation Details and Tools	37
Interface Design.....	38
Add post page	39
Save page	40
List Post page.....	41
System backend	42
Summary	42
Chapter IV: METHOD	44
Research Questions.....	45
Phase I.....	45
Phase II.....	50
Phase III	55
Summary	58
Chapter IV: FINDINGS	59
Phase I.....	60
Healthcare eco-system of Ilorin.....	61

Primary Health care	62
Secondary Health care	63
Tertiary Health care	63
Access to and use of ante- and post-natal care services.....	64
Ante- and Post-natal experiences of currently pregnant women	64
Ante- and Post-natal experiences of recently pregnant women.....	65
Ante- and post-natal experiences of skilled and unskilled birth attendants.....	66
Use of technology	67
Phase II.....	68
Identifying images with meaning.....	71
Grouping images into categories	72
Organization of Clusters	74
Social Capital	76
Phase III	77
Activity one.....	81
Activity two	82
Summary	83
Chapter VI: DISSCUSSION	85
Use of ante- and post-natal care services.....	85
Accessing ante- and post-natal care information.....	86
Use of technology to provide access to ante- and post-natal care	87
Mobile application that eliminates the barrier of illiteracy.....	87
Leveraging Social Capital.....	87

Communal influence as co-designers	88
Mental models.....	89
Information architecture.....	90
Mtoto-bebe Interface.....	92
Chapter VII: CONCLUSION AND FUTURE WORK	96
References	97

List of Tables

Table 1 (Weaknesses and strengths of existing interventions)	23
Table 2 (Distribution of participants by category and location)	46
Table 3 (Distribution of participants by level of education and location)	50
Table 4 (Data organization for Qualitative Analysis).....	53
Table 5 (Data organization for Quantitative Analysis).....	54
Table 6 (Distribution of participants by category and phone ownership)	66
Table 7 (Card description)	70
Table 8 (Final categories)	73
Table 9 (Card placement table).....	75
Table 10 (General assistance score).....	77

List of Figures

Figure 1 (Map of Nigeria with Ilorin highlighted).....	3
Figure 2 (Social capital and healthcare service utilization)	17
Figure 3 (Social capital survey questions).....	20
Figure 4 (mHealth and country income group).....	21
Figure 5 (MOSES project interface).....	28
Figure 6 (VideoKheti interface).....	29
Figure 7 (krishiPustak interface).....	30
Figure 8 (Mtoto-bebe home page)	38
Figure 9a (Mtoto-Bebe video recorder)	39
Figure 9b (Mtoto-bebe Audio Recorder)	39
Figure 10a (Once audio recorded is stopped)	40
Figure 10b (After video recorder is stopped).....	40
Figure 10c (Mtoto-bebe save page)	40
Figure 11a (Mtoto-bebe labor/delivery page).....	41
Figure 11b (Mtoto-bebe antenatal page).....	41
Figure 12 (Low fidelity prototype and cards).....	52
Figure 13 (Distribution of healthcare centers in Ilorin)	61
Figure 14a (Base case).....	71
Figure 14b (50% confidence).....	71
Figure 14c (75% confidence).....	71
Figure 15 (Participant arranging clusters on low fidelity prototype).....	74
Figure 16 (participant interacting with Mtoto-bebe application).....	76

Figure 17 (Home page)	80
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List of Abbreviations

ANC	Antenatal Care
PNC	Postnatal Care
SBA	skilled Birth Attendant
uSBA	Unskilled Birth Attendant
PHC	Primary Healthcare Center
CP	Currently Pregnant
BL3Y	Being Pregnant in the Last three Years
MMR	Maternal Mortality Rate
LMIC	Low- and Medium- Income Countries
WHO	World Health Organization
SCAT	Social Capital Assessment Tool
HCI4D	Human Computer Interaction for Development
ICT4D	Information Technology for Development

CHAPTER I: INTRODUCTION

One of the most critical interventions for safe motherhood is to ensure that proper care is provided by skilled professionals during pregnancy and that women, in the absence of skilled professional are well-informed about pregnancy, possible complications and safe approaches for overcoming them. Nigeria is Africa's largest nation by population (Okoli, Abdullahi, et al., 2021). Maternal health has been a general concern in the country because of the high maternal mortality rate which is currently 980 deaths per 100,000 live births (Izugbara, Wekesah, & Adedini, 2016). Across the country, 9.2 million women and girls get pregnant each year and face a lifetime risk of 1 in 13 maternal deaths (Izugbara, Wekesah, & Adedini, 2016). Nigeria accounts for about 14% of maternal mortality rate globally which makes her the second largest contributor to maternal mortality with estimated annual maternal deaths of 67,000 (Izugbara, Wekesah, & Adedini, 2016). One Nigerian woman dies every 13 minutes from preventable causes related to pregnancy and childbirth complications (Izugbara, Wekesah, & Adedini, 2016). For each death, 30 to 50 women face the chance of experiencing lifelong conditions and disabilities such as obstetric fistula (Macro, 2014). Obstetric fistula is a condition in which a hole is developed in the birth canal as result of childbirth. Overwhelming evidence exists that these causes of maternal mortality can be averted if a woman gets adequate care by the way of antenatal care from the day she is confirmed pregnant until the day of her delivery and postnatal care through post-partum which is 42 days after delivery (WHO, 2016). Providing women with access to information of possible complications that could arise during pregnancy and ways to remedy and /or avoid these complications can have a positive impact on maternal mortality for Ilorin women. This dissertation harmonizes strategies, challenges and lessons learnt from existing mHealth projects in emerging economies to design a holistic approach for addressing maternal health issues and designing mHealth interventions for Ilorin

women. We do this through the development of MTOTO-BEBE, a mobile application that provides Ilorin women with access to ante- and post-natal care information and enables women to leverage the social capital that exists within their community by accessing and sharing stories of motherhood.

Ilorin, Kwara state, Nigeria

Kwara state is in the north central region according to the geo-political grouping of Nigeria. It is one of the 36 states of the country. It is bordered by Niger state to the North, Kogi state to the west and Oyo, Osun and Ekiti states to the south. The primary ethnic group is Yoruba but there are also significant Nupe, Bariba and Fulani minorities reinforcing the vast diversity of Nigeria (Beenish, et al., 2016). Ilorin is the capital of Kwara state with a population of 1,055,500. Ilorin is divided into three local government areas: Ilorin east, Ilorin west and Ilorin south with populations of 280,000 493,000 and 285,500, respectively (NPC, 2014). Maternal mortality ratio in the state is 980 deaths per 100,000 live births which is higher than the national average of 917 (NURHI, 2017). Ilorin is mostly rural, with a few urban neighborhoods (towns). Across the state, there are 740 health facilities spread out over the 16 Local Government Areas. Seventy-eight percent (575) of these facilities serve as primary healthcare facilities, 22% (164) serve as secondary healthcare facilities, and only one represents a tertiary healthcare facility. Primary healthcare centers (PHC) are the most popular and easiest form of health service accessible to Ilorin women. See Figure 1. PHCs are community clinics with less than 5 inpatient beds, no medical equipment, about 3-5 nurses on duty, and on some occasions, a doctor on duty. They were set up to provide basic outpatient care but end up doing much more because most Ilorin women cannot afford and/or do not have access to better healthcare (Babalola, & Fatusi, 2009). Most primary healthcare PHCs are run by the government or nonprofit organizations and therefore, are underfunded, understaffed and

in a dilapidated state. The major causes of maternal mortality in the state include hemorrhage, sepsis, eclampsia, obstructed labor, and complications of induced abortion (NDHS, 2018).



Figure 1: map of Nigeria with Ilorin highlighted

Background

A skilled birth attendant, according to WHO, is defined as “an accredited health professional -such as a midwife, doctor or nurse who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth and the immediate postnatal period, and in the identification, management and referrals of complications in mothers and newborns” (WHO, ICM, & FIGO, 2004). The assistance of skilled birth attendants during childbirth is imperative to guarantee a successful delivery. Poor access to this service by pregnant women is evident as only about 66% of deliveries occur in the presence of skilled birth attendant and only 61% at healthcare facilities (Izugbara, Wekesah, & Adedini, 2016). It’s important to note that there are disparities between access to attended birth for women in urban and rural parts of Nigeria. While 66% of Nigerian women deliver in the presence of a skilled birth attendant, only

29% of women in remote/rural parts of the country deliver in the presence of a skilled birth attendant and 26% at healthcare facilities (Moshood, 2016). There are a lot of primary healthcare facilities in Kwara state, however, these facilities have no equipment, are understaffed and poorly managed. Because of this, the overall healthcare experience of an average rural Ilorin woman is one of dissatisfaction. According to Filbly, McConville, & Portela (2016), Nigerian women living in rural communities tend to prefer traditional/unskilled birth attendants to skilled birth attendants. Filbly, McConville, & Portela (2016) noted that women felt more care and compassion was delivered from traditional/unskilled birth attendants. Traditional/unskilled birth attendants were usually members of the community in which they served as midwives, which gives them an edge in that they are able to relate with their patients on a more personal level compared to SBAs. This kind of bond and connection that exists within communities and their interactions can be explained, measured, and analyzed through social capital.

Social capital can be defined as “resources embedded in a social structure which are accessed and/or mobilized in purposeful actions” (Lin, 1999). Social capital can be measured using Adapted Social Capital Assessment Tool (A-SCAT). A-SCAT measures emotional support, informational support, and instrumental support, it also puts into consideration the literacy level of its target population (LMICs) in its design and therefore applicable in a wide range of developing country settings. Social capital plays a pivotal role in designing for and engaging historically marginalized populations. WHO identified social capital as a key determinant of the commission’s framework and emphasizes its role in creating health equity and wellbeing of individual communities (WHO, 2016). Social capital can impact health care seeking behavior and utilization both positively and negatively (Story, 2014). Taking civic participation (a mechanism for structural social capital) for example, civic participation can affect health care use through

formally organized activities that address community issues and on the contrary, civic participation can reduce utilization of health care services by formation of strong bonding capital which can reduce individual freedom to make appropriate decisions. Social capital is a complex structure with multifaceted concepts so therefore, measuring it is complicated and cannot be done by simple proxies (Story, 2014; Agampodi, Agampodi, Glozier, & Siribaddana, 2015; Harpham, Grant, & Thomas, 2002). Measuring and analyzing the types of social capital that's predominant in Ilorin uncovered nuances like the communal influence wielded by traditional rulers and religious leaders in determining what ICT interventions is adopted by the women in their communities. The role elder women in the community played in providing maternal information and even delivery in some cases to younger women in the community.

According to the International Telecommunication Union, over 85% of the world's population is now covered by a commercial wireless signal (WHO, 2011). In Low- and Medium-Income Countries (LMICs) also referred to as the global south, the penetration of mobile phone networks surpasses other infrastructure such as paved roads and electricity (Forenbacher et al., 2019). As these networks become more sophisticated and mobile phones become cheaper and more powerful, the way health services and information are accessed, delivered, and managed is transforming. Apart from health services, Information and Communication Technology (ICT) has also transformed how people send and receive money and manage emergency response amongst other things. Unfortunately, user interface design as well as user study research are almost exclusively tailored for the global north (High income countries). This means that system designers inspire to take full advantage of available resources like internet connectivity and bandwidth as well as put into consideration whatever constraints or bottlenecks exist in the global north setting like differences in spoken languages. There is a huge discrepancy in the number of spoken

languages in the global south, compared to the global north. When designing for the global north, designers need to consider at most six languages, in the global south context however, there are over 500 spoken languages in Nigeria alone (Forenbacher et al., 2019). Assumptions around system and interface design and conducting user studies needs to be reconsidered by researchers. There has been a growing community of researchers in the domain of Human-Computer Interaction for International Development (HCI4D) focused on leveraging the amplification of mobile technology to specifically design usable ICT interventions for (Low- and Medium-Income Countries) LMIC populations (Whitt-Glover, & Kumanyika, 2008; Cuendet, Medhi, Bali, & Cutrell, 2013; Thies, 2015; Chetty, & Grinter, 2007; Tomlinson et al., 2013; Musoke, 2002; Kumar et al., 2013).

The challenges in providing ICT services for the global south can be broadly divided into resource constraint and usability constraint. Resource constraint includes challenges like device availability, power availability, and network connection, while usability constraint includes literacy, differences in cognitive abilities, differences in mental models and cultural/traditional norms which directly influences day-to-day life (Norman 1995). Some of these challenges exist in global north context as well; however, they are always more pronounced in LMIC contexts.

The greatest challenge around resource constraint is internet coverage and cost. ICT4D researchers are working on ways around this constraint. Projects like (Heimerl et al 2013), and more recently google loon (Nagpal, & Samdani, 2017) have worked on extending connectivity by creating alternative networking infrastructure to extend internet to remote areas. Another alternative or complementary approach is Open Data Kit (ODK) 1 & 2 which is an application development framework designed to work in network constrained environments with extended periods of disconnected operation (Brunette, 2017). At the core of usability constraint is lack of formal

education (illiteracy). Over 750 million people in the world are completely non-literate and even more have great difficulty reading text (Thies, 2015). Projects have explored a combination of modalities for input and output. Like the use of an automatic speech recognizer for input in specific dialects (Cuendet, Medhi, Bali, & Cutrell, 2013), audio delivered step-by-step instructions (Smyth, Etherton, & Best, 2010), and other modalities like speech-to-text, text-to-speech, no scroll menu, screen reader, linear versus hierarchical menu, hand gestures etc. (Thies, 2015).

Furthermore, researchers are increasingly investigating how non-literacy goes beyond inability to read text but is correlated with cognitive abilities (Thies, 2015). Cognitive skills like language processing, visual organization and visual memory, speed of cognitive processing, divided attention and perceived self-efficacy are considered essential for realizing interactions on ICTs (Thies, 2015). However, novice users (little and non-literate users) do not particularly excel in the above-mentioned skills. This suggests that designing a usable interface for novice users requires more than just technical solutions. To adequately capture and understand the mental models and cognitive abilities of populations which are apparently shaped by day-to-day life as this population lacks formal western training, research needs to be done to understand the underlining determinants and expectations of novice users and take into account their epistemologies and ways of acquiring and sharing information (that may be different from Western epistemologies) before designing for them.

Most of these above-mentioned studies are being conducted in Asia (India) and South America. There's a dearth of research that addresses Africa and more specifically, Nigeria. Although the challenges and concerns identified in India are arguably consistent across LMICs, every region has their unique context which stems from cultural norms and ways of life. Therefore, to bridge this digital divide, research must be conducted in different communities to reach a

globally acceptable standard. In this dissertation, I focused on user constraints and explored how a “usable” mobile solution can be leveraged to address maternal mortality in Ilorin. Other strong and emerging trends in HCI4D reviewed were the use of Participatory based design in an HCI4D context. Participatory design is an import aspect of designing for no/low literate users. Community based participatory design is a collaborative approach to research that equitably involves all partners in the research process for the betterment of the targeted community and harnesses the unique strengths of all collaborating partners (Harrington, Erete & Piper 2019; Le Dante, & Fox 2015).

Contributions

In this dissertation we explored emerging trends in HCI4D and ICT4D research (such as designing with mediated use in mind, providing voice over description of buttons, developing ASR etc.) and investigated how they could inform interface design for no/low literate Ilorin women. Also, we identified persistent challenges in conducting user studies and designing usable interfaces for this population. Then, we combine the knowledge acquired from the above investigations to design and evaluate the efficacy of an application called Mtoto-bebe. Mtoto-bebe is a mobile application that provides Ilorin women with access to ante- and post-natal care information and enables women to leverage the social capital that exists within their community by accessing and sharing stories of motherhood. Unlike previous ICT4D interventions designed for no/low literate users in LMIC context like VideoKheti (Medhi-Thies et al., 2014) that presents a descriptive functionality of each button on its interface to users, Mtoto-bebe’s interface focuses on leveraging the cognitive abilities of this population in the use of pictures/images over words for input and output. Although Mtoto-bebe does not provide functionalities like giving audio descriptive feedback of what each button on its user interface does, the application is designed to leverage

built-in accessibility APIs (e.g., screen reader) provided by Android and iOS mobile operating systems.

Card sorting is a user-centered design method to elicit a target population's underlying mental models about a particular information domain (Righi, et al., 2013). There are two types of card sorting. Close card sorting is when a researcher predetermines group labels so that the participant can sort within these labeled or named groups. In comparison, open card sorting is when researchers give participants the liberty to create groups on an ad-hoc basis as they sort cards (Paul, 2014). Card sorting provides a window into the user's mind to discover how she organizes information accordingly (Rosenfeld, & Morville, 2002). Card sorting typical conducted with word, however, in this dissertation I present a novel approach which used images instead of words in conducting card sorting.

Additionally, previous interventions that addressed maternal mortality in sub-Saharan Africa and available to use by pregnant women focus on emergency response (Abiye, RESCUER,). Unlike these interventions Mtoto-bebe address the most critical aspect of maternal mortality which is ante-natal and post-natal care. In the design of Mtoto-bebe I measure and leverages existing social capital that exists in Ilorin thus provide women with context rich “evidence-based” information. Measure, leveraging and relating social capital to healthcare utilization and outcome is novel in that it has not been before used researched/studied in Nigeria.

Limitations

Over 256,000 women still die from preventable maternal causes in sub-Saharan Africa alone therefore more work needs to be done to generalize the findings of this study outside of Ilorin, and furthermore, outside of Nigeria. Although evidence suggests most findings are representative of

our target population (Ilorin women), three percent of participants in phase II of study revealed a completely unique orientation of content organization. These women expressed a right to left orientation of organization as in Arabic or Hebrew. Further probe revealed that there were women in Ilorin who were Almajiranci educated. More research needs to be done in understanding how significantly different this orientation is, if there is a significantly large enough number of Ilorin women with this right to left orientation, and how to include this niche population in design assumptions and principles.

Research Questions

The following research questions guided the scope of this dissertation:

1. In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria?
2. In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin?
3. what mental models exists around antenatal and postnatal care for Ilorin women?
4. How can these mental models inform the design process of a mobile application Mtoto-bebe for Ilorin women with no/low literacy?
5. How usable is the Mtoto-bebe application by Ilorin women?

To answer these questions, the dissertation was divided in three phases:

Phase I: This phase attempted to answer research questions one: in the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria? And research question two: In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin. The goal of this phase was to get aquatinted and familiar

with our target population, which is Ilorin women and their birth attendants (both skilled and unskilled). During this phase, relationships were cultivated with the department of Primary Healthcare in the state, the research team also got acquainted with Ilorin women as well as both community and religious leaders. The studies conducted in this phase revealed the structure of the healthcare eco-system in Ilorin particularly as it pertains to maternity; the types of ante- and post-natal care services and information that Ilorin women had access to and used; and finally, how Ilorin women used technology in their day-to-day life and/or for healthcare, including the kinds of phones that are popular, how they owned and shared devices and what they typically used their devices for.

Phase II: In phase II, I began to answer research question three What are the best practices for designing mobile applications for people with little or no literacy who live in rural/remote areas? and research question four How do these best practices inform the expansion of MTOTO-BEBE to include women in Ilorin, Nigeria, through the design and implementation of an infrastructure to support knowledge sharing? Designing adoptable and intuitively usable applications for no/low literacy users especially in LMIC contexts, requires an in-depth understanding of the target population. In this phase, we leveraged HCI and HCI4D techniques like community based participatory design and Card sorting to learn the mental models that exist among Ilorin women around maternal health and their user interface navigation. Findings from the study revealed the information architecture that became the core design of how maternal care information was structured in the current version of MTOTO-BEBE. Furthermore, In phase I, we found that in the absence of access to antenatal and postnatal care information, Ilorin women turned to one another (family and friends) and elderly women in their communities for support and information around safe delivery. This suggests that there exists social capital that could be leveraged in both design

and dissemination of an adoptable intervention. Therefore, we investigated and measured the social capital that existed amongst this population using Low- and medium-income countries Social Capital Assessment Tool for Maternal Health (LSCAT-MH) a social capital assessment tool tailored towards maternal care in LMIC context (Agampodi, Agampodi, Glozler, Lelwala, Sirisena, & Siribaddana, 2015). To the best of our knowledge, this is the first mention of social capital in relations to healthcare and more specifically maternal care in Nigeria. As described in the literature review, we focus on two aspects of social capital, cognitive components, and structural components.

Phase III: In this phase, the usability of MTOTO-BEBE application interface was iteratively tested. As different versions were deployed, I evaluated how easily users were able to complete tasks, aspects of the interface that overloaded users, and whether the system functionality matched the user requirements.

In the following chapters, I discuss the methodology used in conducting research, settings, participants, and data collection. Then, I present my findings and discussion from all phases of the study.

CHAPTER II: LITERATURE REVIEW

Maternal Mortality

According to the international classification of diseases maternal death is defined as the “death of a woman while pregnant or within 42 days of termination of pregnancy irrespective of duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes” (WHO, 1992). Regions in sub-Saharan Africa still face many challenges around providing adequate healthcare services for their populations. Access to adequate healthcare is among the factors suggested to be associated with the high maternal mortality rate in the region (Thomas, & Rankin, 2015). Maternal mortality rate (MMR) is the number of maternal deaths during a giving period per 100,000 live births in the same period. Although, the global MMR has fallen by 44% since 2000 when the UN member states pledged to work towards a series of Millennium Development Goals (WHO, 2011), developing countries including Nigeria account for approximately 99% of the global maternal deaths (WHO, 2011). In Kwara state, the MMR is 980 deaths per 100,000 live births (NURHI, 2017). The major causes of maternal mortality in the state includes hemorrhage, sepsis, eclampsia, obstructed labor, and complications of induced abortion, all of which do not have to lead to death if well managed or if preventative measures are taken. Without access to adequate care and services during pregnancy, women will not benefit from the essential preventative measures offered by ante-natal care. The premise of ante-natal care is that every pregnancy is at risk of complications and should be monitored appropriately (WHO, 2016). In Nigeria however, the availability of skilled birth attendants is below 40% (Okoli et al., 2012).

Furthermore, a large portion of maternal and neonatal deaths occur during the first 48 hours after delivery (Babasola, Mabawonku, & Lagunju, 2015) thus, apt post-natal care is also crucial

for women to treat any complications that may arise from delivery as well as provide mothers with critical information on how to care for herself and her child. Safe motherhood recommends that all women receive checkup within 2 days of delivery (WHO, 2016) yet post-natal care (PNC) service utilization in the country is just 42% (Babalola, & Fatusi, 2009).

Factors that impact healthcare seeking behaviors

In developing economies like Nigeria, access to quality healthcare is a privilege as most of the population must travel hundreds of miles on unpaved roads to get to a hospital (with x-rays, MRI etc.). Also, the cost of quality healthcare is exuberant for most of the population as over 50% live below the poverty line (Wekesah, & Izugbara, 2017). Nigeria is the second largest contributor to maternal deaths globally. While this can be attributed to her large population of over 200 million, Nigeria has approximately 3% of the world's population; however, her contribution to maternal death is 14% (Babalola, & Fatusi, 2009). To investigate this, (Babalola, & Fatusi, 2009) examined the determinants of use of maternal health services in Nigeria with focus on individual, household, community and state-level factors (they analyzed predictors such as: education, age at most recent birth, attitude towards family planning, ethnicity, ideal family size and socio-economic status) and identified that 60% of women used ANC at least once during their pregnancy however, WHO standards for safe motherhood recommend at least 4 ANC visits for pregnant women (WHO, 2016), 43.5% had skilled birth attendant at delivery and 42.2% received PNC.

Utilization of ANC services is higher than use of skilled assistance during delivery and use of PNC services. One reason for lower coverage of skilled assistance during delivery is attributed to the unpredictable nature of onset of labor in the face of difficulty in accessing health facilities in poor resource environments (due to poor road networks, limited means of

transportation and high cost of transportation). The poor staffing of health facilities is another factor that discourages women from seeking help (Babalola, & Fatusi, 2009). Also, the role of tradition and religion with regards to comparative efficacy of the medical versus traditional birth attendants may also contribute to failure of use of skilled assistance during delivery (Filby, McConville, & Portela, 2016).

In most rural African communities, both traditional and modern healthcare services coexist; therefore, women may have to choose between the two options (Addai, 2000). Nigerian women (specifically in remote settings) tend to rate unskilled birth attendants (uSBAs) over Skilled birth attendants (SBAs) as they consider them to have more interpersonal communication and relationships. uSBAs are considered more considerate and are said to provide a more compassionate care. Also, uSBAs provide services at a more affordable price or even at for free at times (Filby, McConville, & Portela, 2016). (Filby, McConville, & Portela, 2016) identified some of the challenges that influence quality of service rendered by midwives in developing economies as social inequality, inadequate pay, unsafe working conditions, physical and sexual abuse etc. They added that the presence of some or all these factors leads both skilled and unskilled birth attendants to burnout and moral distress. In Anambra state, Nigeria, they found that deeply embedded gender inequalities predetermined the low social status of the midwifery profession. Furthermore, cultural construct influences the perception of assisting childbirth as inherently “woman’s work” which, by extension, makes it a low skilled labor. Strong perceptions like this led to a constraint in promotion of evidence-based care by midwives in these communities. E.g., in Mozambique, midwives hesitated to promote skin to skin care at birth because the social attitude was newborns require cleansing prior to contact. Filby, McConville, & Portela (2016) also found that in some developing economies like Nigeria, maternal and

childcare training was aimed at highly resourced urban and institutionalized care with medical support, but the reality is that majority of newly qualified midwifery personnel were deployed to Primary healthcare centers (PHCs) in remote rural communities.

The most readily available (in terms of cost) and accessible forms of healthcare services in Ilorin is Primary Health Care. To ensure that Nigeria achieved the Millennium Development Goal 5 (maternal and child mortality), the Nigerian government established the Midwives Service Scheme (MSS). The program is designed to mitigate shortage of birth attendants at the primary healthcare level. Unemployed, new graduates and retired (but physically able) midwives were engaged and deployed to selected Primary healthcare facilities across the country. (Okolio et al., 2012) studied 652 PHC facilities enrolled in the MMS program and found that although there is evidence that use of skilled birth attendants is growing, over 60% of Nigerian women still have unattended home delivery. Less than 50% of women attend the recommended four or more antenatal care visits when pregnant and only about 33% of women attend recommended postnatal care. These poor attitudes towards seeking optimal care are caused by cost of service, distance to health facilities, poor infrastructure, long waiting times at primary healthcare facilities, religious and traditional beliefs.

Social Capital

Social capital can impact health care seeking behavior and utilization both positively and negatively (Story, 2014). WHO emphasizes the role of social capital in creating health equity and wellbeing of individual communities by identifying it as a key determinant of the commission's framework (WHO, 2016). Social capital can be defined as “resources embedded in a social structure which are accessed and/or mobilized in purposeful actions (Lin, 1999). In order to better understand the relationship between social capital and health care utilizations, Bain, &

Hicks (1998) dichotomize the various conceptualizations of social capital into “structural” and “cognitive” forms. The structural components reflect (Bourdieu, 1986) conceptualization of social capital as the extent and intensity of associational links or activity while cognitive social components include perception of support, reciprocity and social trust and reflects the conceptualizations of (Coleman, 1988) and (Putnam, 1993) work. An additional important construct is between “bonding”, “bridging” (horizontal) and “linking” (vertical) social capital (Szreter, & Woolcock 2004). Bonding social capital refers to social cohesion within a group’s structure (i.e. interactions between homogenous members of a community resulting in densely knit social network e.g. family) (De Silva, & Harpham, 2007), bridging capital refers to weak ties between acquaintances (people who are alike in socio-demographic sense) (Story, 2014) while linking capital refers to the type of social capital that links, or cuts across different groups or communities. This is a relationship between people across power and authority gradient (Agampodi, Agampodi, Glozier, & Siribaddana, 2015).

Both (Harpham, Grant, & Thomas, 2002) and (Story, 2014) description of social capital highlights the importance of “bonding” and “bridging” constructs as it emphasizes the role of government and state within social capital. Without bridging capital connecting communities to local government or groups with resources there may be no improvement in any aspect of a community’s well-being. Likewise, without bonding capital between individuals and similar groups, important information channels, support channels and /or other benefits of solidarity will be lost (Harpham, Grant, & Thomas, 2002). While social capital is not a new field of study in sociology, researchers in the USA are starting to link social capital with health and showing that elements of social capital like reciprocity, membership of voluntary organization and social trust have significant impact on life expectancy, maternal and infant mortality rates, heart disease and

violent crime (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997). Figure 2 below shows how the different elements of social capital can interact to increase or decrease health service utilization.

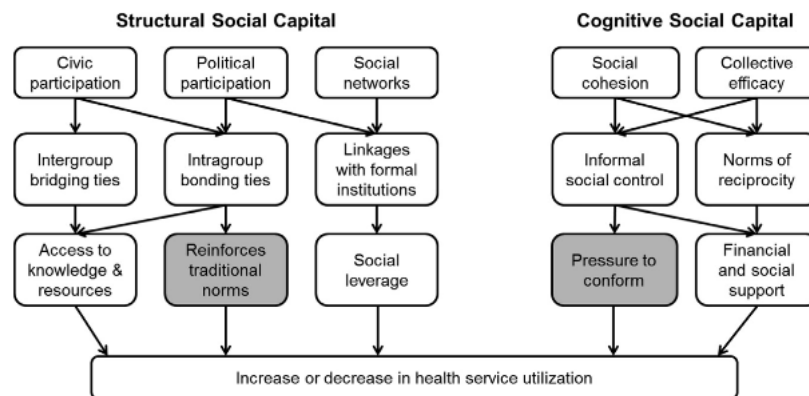


Figure 2: social capital and healthcare service utilization (Story, 2014)

To understand how social capital can impact health service utilization in India, (Story, 2014) identified potential mechanisms such as civil participation, political participation, and social networks for structural social capital. And for cognitive social capital, they identified social cohesion and collective efficacy. As depicted in Figure 2 above, civil participation can affect health care use through formally organized activities that address community issues and on the contrary, civil participation can reduce utilization of health care services by formation of bonding capital which can reduce individual freedom to make appropriate decisions. political partnership has the potential to lead to bridging ties with people of influence. social networks between communities and representatives of formal institutions can also be a form of bridging social capital which is important for leveraging resources, ideas, and information. Social cohesion evokes a sense of mutual trust and solidarity among neighbors. collective efficacy encourages individuals to forgo their own self-interest and act in the interest of the group.

Measuring social capital

Social capital is a complex structure with multifaceted concepts so therefore, measuring it is complicated and cannot be done by simple proxies (Story, 2014; Agampodi, Agampodi, Glozier, & Siribaddana, 2015; Harpham, Grant, & Thomas, 2002). While there is a wealth of research linking social capital with health in developed countries like the USA, little has been done in developing countries (Story, 2014; De Silva et al., 2006; Bisung et al., 2014) and none has been done in Nigeria. Social capital is an ecological characteristic, it is a feature of a social structure and not of individual actors within the structure as expressed in Harpham's definition of social capital. "The degree of connectedness and the quality and quantity of social relations in a given population". De Silva et al., (2006) advocate that individual level social capital variables are better than those measured at ecological level, while (Yip et al., 2007) suggested multilevel modeling as a more appropriate statistical measure to understand the relationship between social capital and health. (Krishna, & Shrader, 1999) developed Social Capital Assessment Tool which is currently the most widely adopted in Low- and medium-income countries (LMICs) context, target individual level variables then aggregate the individual responses to the neighborhood level and then analyze as an ecology rather than individual characteristics.

SCAT and A-SCAT

(Krishna, & Shrader, 1999) developed the Social Capital Assessment Tool (SCAT) a measure of social capital for use in LMICs which combines community profile, organizational profile and household survey. SCAT has been used in a number of countries including Peru, Vietnam and India. Like almost all other social capital measurement tools out there, SCAT is an adaptation of (Sampson, Rudenbush, & Earls, 1997) quantitative measure called "collective

efficacy” which measure social cohesion and informal social control and (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997) which also quantitatively measured social capital by per capita membership in voluntary groups, interpersonal trust and perceived norms of reciprocity. A unique advantage of SCAT is its clear distinction between cognitive and structural components. However, (Harpham, Grant, & Thomas 2002) noted that the household survey part of SCAT was too long (over 60 questions) and failed to successfully incorporate questions designed by (Sampson, Raudenbush, & Earls, 1997) so they designed an adapted version known as “A-SCAT” which had 11 questions on cognitive social capital and 7 questions on structural social capital. Another improvement of A-SCAT over SCAT is the full treatment of the concept. A-SCAT measures emotional support, informational support and instrumental support. A-SCAT also puts into consideration the literacy level of its target population (LMICs) in its design and therefore applicable in a wide range of developing country settings. (Agampodi, Agampodi, Glozier, & Siribaddana, 2015) conducted a systematic review to identify the methods used to measure social capital in LMICs and to evaluate their relative strengths and weaknesses. Their findings support (Story, 2013) in that of the 46 studies they selected finally in the study, only 7 studies were solely conducted in low-income countries and only 3 were conducted in Africa but none in Nigeria. They also found that while SCAT which was developed under the World Bank's social capital initiative was the most cited, most researchers adopted a shortened version or used the adapted version A-SCAT designed by (Harpham, Grant, & Thomas, 2002).

A. Structural ('connectedness')	B. Cognitive (reciprocity, sharing, trust)
(1) Participation in organizations. (2) Institutional linkages (connections to services, facilities and organizations). (3) Frequency of general collective action. (4) Specific collective action (whether people would get together to address named hypothetical situations). (5) Degree of citizenship (whether the respondent has voted/campaigned/taken part in other neighbourhood or city-wide activity). (6) Links to groups with resources (such as local government or aid agencies). (7) Links to parallel groups (namely other communities).	(1) General social support. (2) Emotional support (enabling people to 'feel' things). (3) Instrumental support (enabling people to 'do' things). (4) Informational support (enabling people to 'know' things). (5) Trust. (6) Fellow feeling. ^a (7) Reciprocity and co-operation. (8) Social harmony. (9) Sense of belonging. (10) Perceived fairness (would others in the community take advantage of people). (11) Perceived social responsibility (would others in the community return lost items).

Figure 3: social capital survey questions (Harpham, Grant, & Thomas, 2002)

Mobile Health (mHealth)

The use of Mobile Health (mHealth) has become prevalent with 83% of 112 participating member states of WHO reported the presence of at least one mHealth initiative in their country (WHO, 2016). mHealth is the use of mobile communications for health information and services to improve health outcomes. The use of different applications of mobile phones such as SMS, calls, and apps that offer, seek and receive healthcare services can be defined as mHealth. The Global Observatory for eHealth defines mHealth as medical and public health practices supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices. mHealth depends on the capitalization of mobile phones' core utility of voice and SMS and other more complex utilities like Bluetooth technology, Global Positioning System (GPS) and general packet radio service (GPRS) and its successor like 3G, 4G and more recently 5G. mHealth is divided into the various categories based on type of services rendered (e.g. health call centers, treatment compliance, appointment reminders, community mobilization and health promotion, patient monitoring, decision support system etc.). Across the globe (both developed and developing countries), governments are expressing interest in mHealth as a strategy to strengthening their health systems and achieve the

United Nations Millennium Development Goals and more recently, Sustainable Development Goals (WHO, 2016).

Figure 5 only depicts the presence of mHealth initiatives but does not represent the depth of activity within each country. Although there is a lot of research on and development of mHealth applications (Dombrowski, 2017; Thomas, & Rankin, 2015; Wekesah, & Izubgara, 2017; Babalola, & Fetusi 2009), only a few are able to scale beyond the pilot stage especially in LMICs. Cobb, (2010) identified a possible reason as the difference in the understanding of “scale up” between industry and researchers. While researchers are focused on improved health outcomes, private enterprises are more concerned with growth in market share. Another identified issue is the “black box” nature of most mHealth interventions. Most applications are being developed independently therefore, a patient with two or more conditions will have to make use of completely different numerous applications to monitor and keep track of their health which is unsustainable. Estrin, & Sim, (2010) advocate the criticality for a standardized interface and shared components for realizing the potential of mobile-device-enabled health care delivery and research.

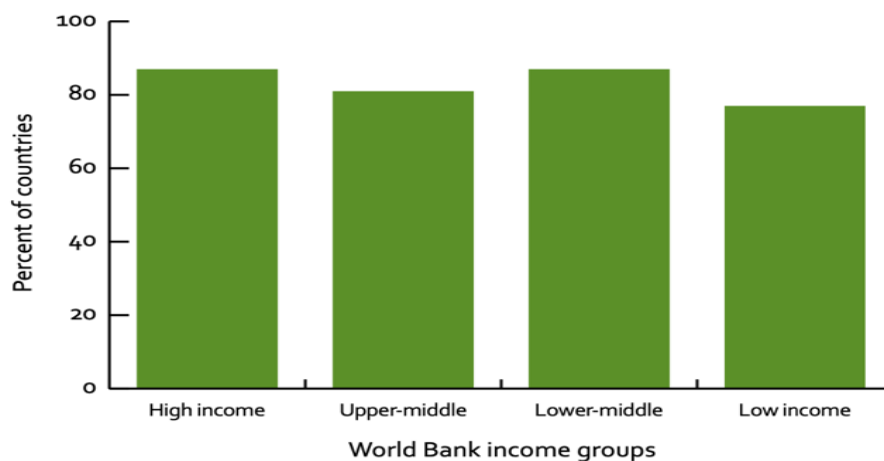


Figure 4: mHealth and country income group (WHO, 2016)

Existing maternal care mHealth interventions in sub-Saharan Africa

Across Africa, ICT is being used to deliver maternal and child health information and services. Interventions from health call centers and appointment reminders to patient records and monitoring (Obasola et al., 2015). In Nigeria, the safe motherhood program (also known as “Abiye”) is an example of use of ICT to mitigate maternal mortality rate. They adopted mobile telephones as a tool to connect pregnant women in remote locations of Ondo state with health extension workers and delivery facilities (Isola, 2013) the extension works provided women with information as needed and transported women to the hospital in emergency cases. Similarly, in Uganda a radio communication system called RESCUER was used by SBAs to partner with public health facilities to deliver health care to pregnant women (Musoke, 20002). Unlike the Abiye project, which leveraged mobile phones, some interventions were PC based. The OpenMRS project in Kaduna state, Nigeria, falls in this category. It is an information system used to support decision-making by health workers by providing information on antenatal visits, labor, child health, immunization, and family planning (Obasola, Mabawonku, & Lagunju, 2015). Another PC based project is Mailafiya project which used intel powered notebooks to collect patients’ data (Obasola, Mabawonku, & Lagunju, 2015).

Women in Nigeria also have access to m4Change2, which is a mobile decision-support application used primarily by health centers to improve the quality of available maternal, neonatal and child health services. Once registered, m4Change2 tracks pregnant women and/or new mothers through the child’s first year of life via electronic forms. Wired Mothers is another mHealth application that links pregnant women and new mothers with health care workers and facilities in Zanzibar (Izugbara, Wekesha, & Adedini, 2015). In Kenya, “Every Child Counts” used SMS to improve child health and empower community health workers. Obasola,

Mabawonku, & Lagunju, (2015) did a system review of mHealth applications in sub-Sahara Africa and identified some challenges faced by intervention during implementation. Charging devices in areas without electricity or poor electricity supply and phone maintenance (getting additional minutes and data) was common (Dombrowski, 2017; Thomas, & Rankin, 2015; Wekesah, & Izubgara, 2017; Babalola, & Fetusi 2009). Other challenges included limited access to phones, poor network coverage, language barriers and prevalence of phone sharing.

	Weakness	Strength
Abiye	Fulltime presence of health workers required	Access to maternal and childcare information Transportation to Hospital in cases of emergency Mobile phone based
Rescuer	Fulltime presence of health workers required	Access to maternal and childcare information No call/text cost Use of walkie talkie
OpenMSR	Language barrier PC based	Digital patient record keeping
M4change2	Language barrier PC based	Digital patient record keeping

Table 1: weaknesses and strengths of existing interventions

HCI4D and ICT4D

Technology adoption remains one of the defining factors in human progress. As the prices of devices plummet, more people across income groups around the globe are getting access to a range of technologies, from mobile phones to PCs. Over 5 billion people have mobile devices, and over half of these devices are smartphones (Pew Research, 2019). In sub-Sahara Africa, access to the internet and use of mobile phones have increased over the last decade (Poushter,

2016). In Nigeria, 71% of the population use mobile phones as their primary platform of communication and access to the internet (Forenbacher, Husnjak, Cvitic, & Jovovic, 2019). Beyond facilitating communications, Information and Communication technologies (ICTs) have transformed the way people send money, manage health, check market prices, engage with government, manage emergency response etc. (Thies, 2015). Therefore, ICT has become a potential platform for delivering services by government and non-government agencies, business, and international development (Bourdieu, 1986; Forenbacher, Husnjak, Cvitic, & Jovovic, 2019; Thies, 2015).

ICT has become a potential platform for delivering services by government and non-government agencies, business, and international development. These trends have given rise to Information Technology for Development (ICT4D) and Human Computer Interaction 4 Development (HCI4D). ICT4D involves designing and deploying computer-based solutions for developing nations (Chetty, & Grinter, 2007). However, designing and deploying ICT in developing countries comes with the challenge of illiteracy among others. Over 750 million people in the world are completely non-literate and even more have great difficulty reading and writing (Thies, 2015). Of the 750 million non-literate people 85% live in developing countries of which 30% are in sub-Sahara Africa. For obvious reasons, User Interface (UI) design for little and no-literate populations should be different because this set of users possess a different set of cognitive skills from typical users. Cognitive skills like language processing, visual organization and visual memory, speed of cognitive processing, divided attention and perceived self-efficacy are considered essential for realizing interactions on ICTs (Thies, 2015). However, novice users (little and non-literate users) do not particularly excel in the above-mentioned skills; therefore, to

understand how researchers and developers can design usable UIs for novice users, Human Computer Interaction for Development (HCI4D) is an emerging field of research.

Designing usability technique and study

Conducting HCI research in LMICs poses a unique set of challenges (Chetty, & Grinter). These challenges stem from factors ranging from exposure to technology and average household income of LMIC populations to difference in characteristics between researchers and the community they work with which arise from variations in ethnicity, age, and other socio-demographic characteristics (Thies, 2015). Although some of these problems are consistent in both developed and developing context, they are usually more pronounced in the developing world context. Thomas, & Rankin, (2015) used a paper prototype to reduce barriers of getting feedback. This decision was made because of the cheaper cost of designing the prototype and level of flexibility that it presented to the respondents, reducing the needs for the researchers to make design assumptions. As such, this dissertation adapted the use of paper prototype as medium to collect data to understand initial usability design and testing. This approach of paper prototyping also reduced the time of study as it eliminates the need to reprogram the interface after every interview and dependence on infrastructure (like electricity to power device or network connection) (Chetty, & Grinter, 2007).

Researchers observed that novice users are prone to often feel intimidated during usability tests for fear of breaking devices and thinking that they are the ones being tested and not the technology (Thies, 2015). Thomas, & Rankin, (2015) had a native (Kenyan) woman conduct the interviews during their study to create a sense of rapport with the women (respondents) and to communicate with participants in their local dialect. As one of the key steps in socially just design, (Dombrowski, 2017) argues that it is imperative to partner with communities in the

design process “to better understand the practices, desires, and goals of the people they are designing for.” Like (Dombrowski, 2017) push to engage community partners in the fight for social justice, we will engage members within the very population that we want to design for and with as relationship brokers. These relationship brokers help us as researchers to build trust within the community. Though the community relationship brokers make salient the sociocultural norms, desires, and goals of a specific vulnerable population, they also make visible the motivations for investigating a particular set of problems that impact a specific vulnerable population. Crucial to this effort of utilizing members of vulnerable populations as community relationship brokers is the need to decrease the power distance between the researcher and the vulnerable population of study.

Furthermore, Esmaeilzadeh, & Sambasivan, (2017) introduce a framework for designing technologies for emerging markets that emphasizes design interactions that minimize text input, increase tappability and add visual richness. While this is fine and dandy in the context of designing technologies, researchers need to be mindful that when working with vulnerable populations in which issues of illiteracy may arise, it is necessary to use these same techniques to collect data. Just as participants expressed the need to use easy to understand written or spoken language when collecting data (Harrington, Erete, & Piper, 2019), we advocate for the use of non-textual data collection techniques. For example, one might read survey questions to participants and record their responses rather than having participants read and provide a written response. Other issues that should be considered in the design of user studies and techniques are participant response bias, “demand characteristics”, lack of ICT exposure, social peer pressure, gender differences (women are not used to being the center of attention or speaking in front of

men in some cultures) and safety of research team. (Thies, 2015; Chetty, & Grinter, 2007; Twimm, 1997; Squires, 2009).

Designing User Interface for Novice Users

In designing UI for novice users, certain challenges must be taken into consideration. A consistent one across all HCI4D studies is lack of formal education and inability to read text (Thies, 2015). Illiteracy in sub-Saharan Africa is over 65% and among the lower-middle class population in these countries even the literate fall under the “novice user” classification (Eshet-Alkalai, & Chajut, 2010). Another barrier is infrastructure constraint in power and connectivity (WHO, 2016; Thomas, & Rankin, 2015), poverty and other financial limitations like acquiring and maintaining hardware (Cuendet, Mehdi, Bali, & Cutrell, 2013) is another. Variation in spoken languages is another major challenge in designing for the “Global south”. In Nigeria alone, there are over 500 spoken languages and over 2100 in Africa (Pew research, 2019). This poses a unique challenge because unlike the “Global South”, in the “Global North” most technology systems are designed with at most 6 languages in mind (Cuendet, Mehdi, Bali, & Cutrell, 2013). To counter these issues, HCI4D researchers have explored ways to combine different modalities to offer different affordances to novice users.

MOSES project

The MOSES project is a mobile interactive computer system that allows users to browse and watch video messages, and to record their own messages for others to see (Smyth, Etherton, & Best, 2010). They used hand drawn icons (by Liberian artists) to represent categories in the MOSES project. In addition to visual, audio is another modality embedded in the MOSES project to replace text. The system had an audio instruction step-by-step user guide, greetings,

and prompt. The step-by-step instructional system was designed according to the principle of rehearsal. Also, all audio was delivered by an animated agent named Moses (a common male name in Liberia), the animated agent is used to give the system a sense of personality which in retrospect made the system more familiar to novice user and reduced the issue of lack of familiarity to ICT. MOSES was designed as a kiosk to allow user to transfer their existing idea of trust and risk (Palava hut is a ubiquitous village gathering place that represents the symbol of community disclosure).



Figure 5: MOSES project interface (Smyth, Etherton, & Best, 2010)

VideoKheti

VideoKheti is a mobile system that helps local farmers in rural India find and watch agricultural extension videos in their own language and dialect (Cuendet, Mehdi, Bali, & Cutrell, 2013). They also used hand drawn icons, In the result from the usability analysis, (Cuendet, Mehdi, Bali, & Cutrell, 2013) noted that compared to actual pictures, hand drawn icons did not lead to as much confusion. VideoKheti used modalities such as speech and touch interaction to replace text. Developing and training a full-fledged automatic speech recognizer (ASR) is

expensive and time consuming especially when application scale-up is put into consideration (because of the diversity in language and dialect in most LMIC settings). Therefore, they made use of SALAAM an ASR developed by (Qiao, & Rosenfeld, 2010) which makes it easier and cheaper to create ASRs. SALAAM allows small-vocabulary recognition by using the acoustic model of any existing ASR and performing cross-language phoneme mapping between the language of the ASR and the target language. Although cheap and easier to use, SALAAM is limited as it only works for a maximum of 100 words and only allows one vocabulary item to be recognized at a time.



Figure 6: VideoKheti interface (Cuendet, Mehdi, Bali, & Cutrell, 2013)

KrishiPustak

(Medhi-Thies et al., 2014) developed an audio-visual social networking application called KrishiPustak for low literate farming population in India. This application was then deployed to this population over a period of four months. The application depended on the use of mediation, where the research team selected members of the community as mediators and trained them on how to use the system. Users had to come to the mediators to use the application. They found that mediators made about 10% of the post. They also found that 30% of posts were made by

someone other than the person signed in, which suggested that the mediators were the once physically making post on behave of users.

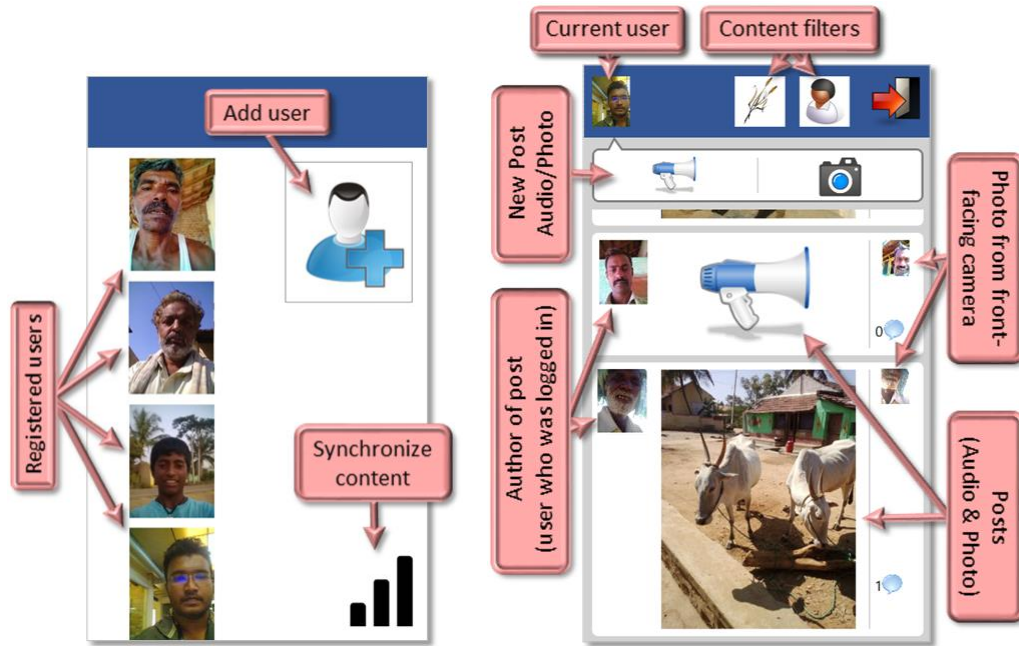


Figure 7: krishiPustak interface (Medhi-Thies et al., 2014)

Information Architecture

Information architecture (IA) is the classification and organization of information within a knowledge domain (Rosenfeld, & Morville, 2002). IA helps to organize information by understanding the purpose of the information, the context in which information will be used, and the mental model of the users. In visualization, IA is used in the design of knowledge visualization and to describe data models that drive intuitive visualization interfaces. IA is used in different types of information design and in user-centered design applications (Rosenfeld, & Morville, 2002). IA enables efficient navigation of applications by effectively organizing, structuring, and labeling content on an application (Rosenfeld, & Morville, 2002).

Card Sorting

Card sorting is a user-centered design method to elicit a target population's underlying mental models about a particular information domain (Righi, et al., 2013). There are two types of card sorting. Close card sorting is when a researcher predetermines group labels so that the participant can sort within these labeled or named groups. In comparison, open card sorting is when researchers give participants the liberty to create groups on an ad-hoc basis as they sort cards (Paul, 2014). Card sorting provides a window into the user's mind to discover how she organizes information accordingly (Rosenfeld, & Morville, 2002).

Analyzing Card-sorting with Mixed Methods

Analyzing data collected from open card-sorting can be challenging in that its ad-hoc characteristic allows for multiple topics and mental models to emerge. The use of mixed methods can be beneficial in capturing rich details that could be unidentified by just qualitative or quantitative methods. Although qualitative analysis methods can provide in-depth and valuable interpretable design insight, they cannot be automated, they are not exactly repeatable, and they do not scale well as number of participants increase. And while quantitative methods can be automated, are repeatable and scale, they are often difficult to interpret and do not provide deep insight as qualitative methods do (Paul, 2014). In addition to mixed methods, visualization techniques can help to make sense of data collected from card-sorting (Paul, 2014).

Participatory Based Design

Participatory design is an important aspect of designing for no/low literate users. Community based participatory design is a collaborative approach to research that equitable involves all partners in the research process for the betterment of the targeted community and

harnesses the unique strengths of all collaborating partners (Harrington, Erete, & Piper, 2019), (Le Dantec, & Fox, 2015). Situating individuals as co-creators and collaborative partners allows the target population who will be directly impacted by the technological intervention to play an active role in the design process and the way problems are defined.

CHAPTER III: MTOTO-BEBE SYSTEM AND INTERFFACE DESIGN

Regions in sub-Saharan Africa face many challenges around adequate healthcare services for their populations. Women who live in rural areas face a high mortality rate due to lack of access to skilled healthcare professionals and state of the art healthcare facilities. Yet, one of the most critical interventions for safe motherhood is ensuring that women in rural areas have access to and are aware of pre- and post-natal information and care. Mtoto-Bebe is a mobile application that provides women in low resource settings access to ante-natal and post-natal care information.

Mtoto-bebe design was informed by suggestions from 1) literature centered on designing mobile applications for users living in developing economies with little or no literacy; 2) literature on conducting user field studies in developing regions; and 3) analysis of data we collected from interviews, questionnaires, and usability assessment from Ilorin women who interacted with both low-fidelity prototype and functional prototype.

Armed with these insights from the literature and our research, we developed a functional software prototype for Mtoto-bebe. Two important things to consider are that 1) Mtoto-bebe is designed for low/non-literate women living in developing regions like Ilorin and 2) While the goal is for the app to also provide advice and information from “expert” sources (e.g., medical doctors, obstetricians, etc.), this version of Mtoto-bebe focuses on leveraging the social capital and expertise that already exists amongst these women as it relates to ante-natal and post-natal information.

As stated in the literature review, there are existing ICT interventions that address maternal and newborn care in sub-Sahara Africa. Some of the intervention afore mentioned

include, the Abiye project which adopted mobile telephones as a tool to connect pregnant women in remote locations of Ondo state with health extension workers and delivery facilities (Isola, 2013) the extension works provided women with information as needed and referred/transported women to the hospital in emergency cases. The RESCUER project is another intervention. RESCUER is very much like abiye expect instead of mobile phones, the means of communication was walkie talkie (cite). Like the abiye project, mtoto-bebe provides pregnant women and new mothers information on antenatal care and postnatal care. However, unlike both projects, ante- and post-natal care information is readily available on the mtoto-bebe application and does not require the full-time presence of a health worker.

Other interventions available to Nigerian women, mothers and healthcare providers include openMRS, m4Change2, and Mailafiya project. openMSR is an information system used to support decision-making by health workers by providing information on antenatal visits, labor, child health, immunization, and family planning. m4Change2 is a mobile decision-support application used primarily by health centers to improve the quality of available maternal, neonatal and child health services. Once registered, m4Change2 tracks pregnant women and/or new mothers through the child's first year of life via electronic forms. A major weakness of these interventions is language barrier, in other to use them healthcare worker must be able to read and write English. Also, the healthcare worker needs to speak the language the of the patient to collect their information as most patient in rural communities do not speak English and health care workers do not always the same language as the community they serve. Furthermore, both openMSR and m4Change2 are PC based. Studies suggests that LMIC populations prefer and are more likely to use/have access to mobile phones. Unlike these projects, Mtoto-bebe is a mobile based application optimized to work devices popular amongst the population it serves. Mtoto-

bebe is designed to be usable by women and healthcare workers independent of the language they speak.

Personas

Like every other aspect of this dissertation, stakeholder involvement and participatory design drove the development of the personas. As opposed to developing personas from just demographic data, we developed personas that were behaviorally driven and domain specific. we used data collected from phase I of this work.

All the questions were open ended questions which allowed the interviewer probe further depending on participant response. To identify behavioral patterns of Ilorin women, we asked questions like “how do you use your phone?”, “what applications do you use most on your phone?”, and “what do you like and dislike about these applications?”. Domain specific questions were also asked like “what alternative sources do you have access to for ante-natal and post-natal information?”, “what would you do in a case of a maternal/pregnancy emergency?”, and “what types of ante- and post-natal care services have you used?” Every statement in our persona were generated from user data or observation.

Bimbo is 32 years old has 4 kids. Believes she will have more children if it’s the will of God. She owns an android phone. Bimbo uses her phone for calls and text, mostly calls though. Her husband got her the android powered phone as a birthday gift. Bimbo has friends that are fascinated by android phone and are always trying to show her cool things she could do with the phone other than calls and text. Although bimbo is indifferent about learning these new features as she is mostly busy managing her shop, her friends essentially use her android powered phone to manage their social media accounts as some of them do not own smart phones themselves.

Rukayat is 21 years old, has a baby, and she owns a phone but it's not a smartphone. She is the third and youngest wife of her husband. Her husband, however, owns a smart phone. She shows her husband how to get things done on his phone. She has a Facebook account that she manages on his phone. Rukayat was Almajiranci educated. She speaks Yoruba and Arabic fluently but is barely proficient in English as she did not complete high school.

Aminat is 29 years old, has 3 kids and owns an android powered phone. She uses her phone for more than just calls and text. Aminat is a tailor and uses her phone to send multimedia messages to her clients (e.g., pictures of clothes design for them to choose from). She has social media accounts like Facebook and WhatsApp. She's not afraid to push buttons on her device because her younger sister who lives with her and is also training to be a tailor under her is "tech savvy" and helps her fix her phone whenever she messes up the settings.

Implementation Details and Tools

React Native: is an open-source user interface software framework created by Facebook. It uses native components as its building blocks. It is used to develop cross platform applications by combining the React framework with native platform capabilities. React native runs in a background process that interprets JavaScript directly on the end-device and communicates with native platform via serialized data over asynchronous and batched bridge.

Expo: is framework is a framework and a platform for universal React applications. It is a set of tools and services built around React Native and native platforms that help you develop, build, deploy, and quickly iterate on iOS, Android, and web apps from the same JavaScript/TypeScript codebase.

Redux: is an open-source JavaScript library for managing and centralizing application state.

Redux is a cache/storage to store state of variables. This store can be then accessed by all components through reducer and actions.

Expo Snack: is an open-source platform for running React Native apps in the browser. It dynamically bundles and compiles code and runs it in the Expo Go and on the web.

Cloud Firestore: is a flexible, scalable database for mobile, web, and server development. It keeps your data in sync across client apps through real-time listeners and offers offline support for mobile and web so you can build responsive apps that work regardless of network latency or internet connectivity.

Interface design

Home page

The home page displays chronological organization of maternal health topics from conception to after delivery. These topics are represented by pictures. (The pictures like every other clickable on the interface have a rigid feel to depict them as buttons). Topics represented on the interface include Antenatal, labor/delivery, postnatal and immunization. Clicking on any of these topics navigated the user to a list of posting on that topic. Also at the bottom of page is a button to open the camera for video recording and a button to open the voice recorder for audio recording.

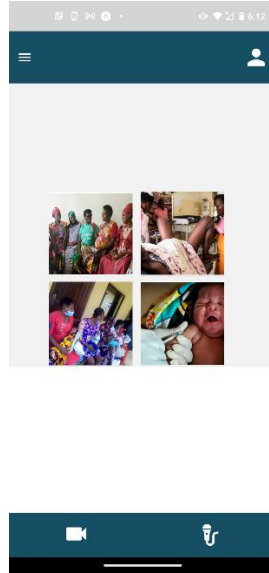


Figure 8: Mtoto-bebe home page

Add post page

Camera: To create a video post, users had to click on the camera icon. The camera view had two buttons, one to start recording and the other to switch between front and back camera of their mobile device. The record button started and recording for as long as the button was pressed down or until the recording hit max duration which was as thirty (30) seconds. Once the recording stopped, the system played back a preview of the recording and displayed two clickable options which essentially prompted user to either keep or discard the recording. If users chose to keep the recording, the system navigated them to a page where they had to choose a category from the four stipulated topics for their posting. And if they decided to discard the recording instead, the system goes to a state where the camera is ready to record.

Audio: to create audio content, users had to click on the microphone icon at the bottom of the home page. This icon is an avatar of a microphone with wired. This icon was selected because it resonated much more with the target population than the conventional audio file icon. The audio

recorder had two buttons, one to start recording and the other to stop recording. Since the file for audio files were much less, we did not cap the length for audio files on the version of the application that was deployed.

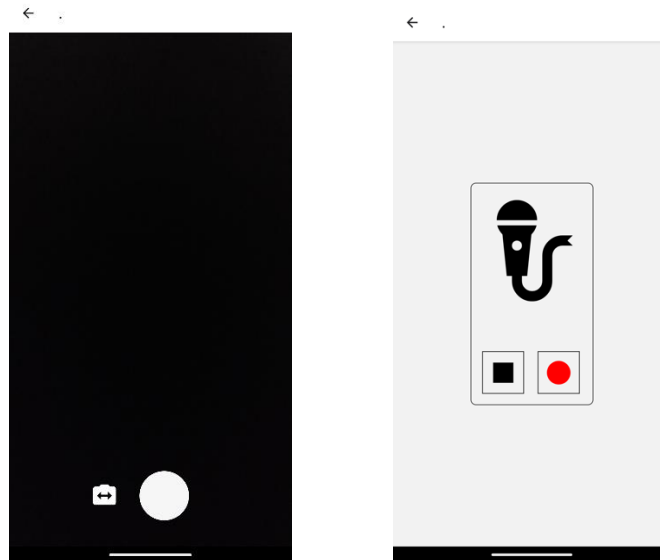


Figure 9: a) Mtoto-Bebe video recorder, b) Mtoto-bebe Audio Recorder

Save page

The categories are represented as a group of radio buttons accompanied with images (avatars). The images are the same as those on the home page and represent the same category respectively in chronological order. There is also a button to upload content below the radio buttons.

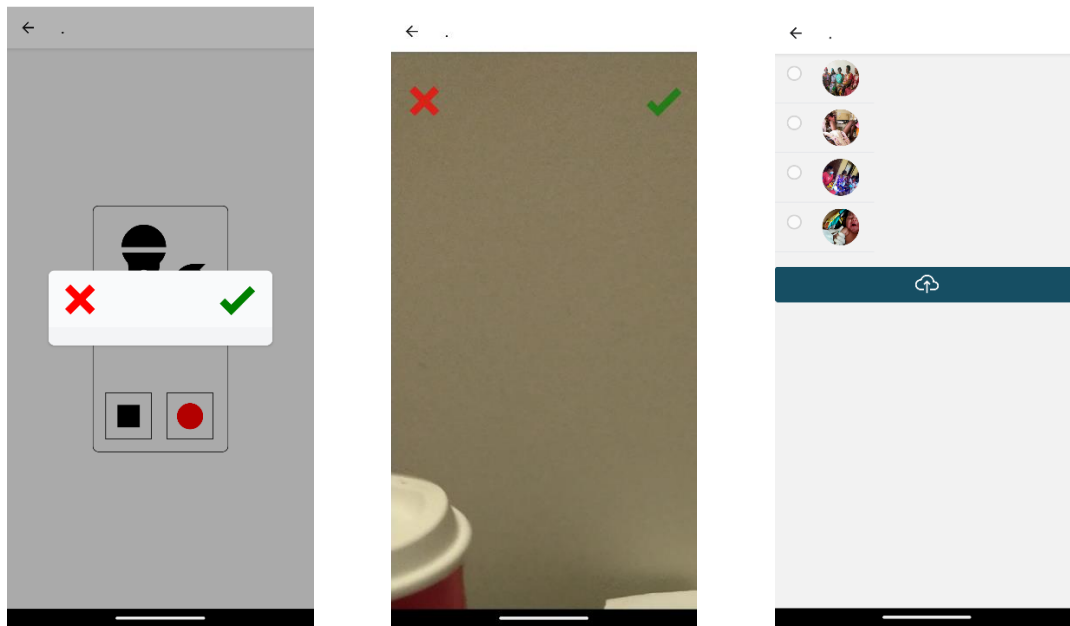


Figure 10: a) once audio recorded is stopped, b) after video recorder is stopped, c) Mtoto-bebe save page

List Post page

For this version, content of this page was based on topic. Instead of having a page that displayed all posting, we restricted posting to be strictly based on category to create a filter. This was done to make it easier for women to find information. Like social networking sites, synchronized posts were displayed on an infinite scroll page and were ordered by timestamp (with most recent post on top). Each post had three components; the name of user who name the post, the picture of user who made the post and the video or audio post. At the top of each post listing page, a picture was placed to remind participants what category they were on as we did not word anywhere on the application. The contents are in a scrollable view, but the picture at the top is fixed.

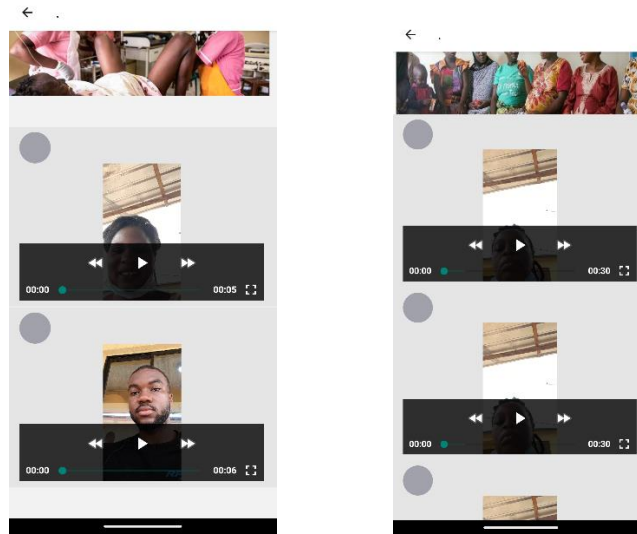


Figure 11: a) Mtoto-bebe labor/delivery page, b) Mtoto-bebe antenatal page

System backend

Internet connectivity and limited bandwidth were major consideration in the design of Mtoto-bebe system. Even though our major focus at this early stage of the application implementation is to design a usable interface we still had to make an application that could work seamless offline and synchronize when connectivity is available. Whenever a new entry was created (be it user registration, posting or comment), the system stored this entry locally, then a background process polled for internet connectivity and incrementally synchronized the local content with a cloud hosted database.

Summary

This chapter explained in the detail the Mtoto-bebe application system. Mtoto-bebe is a mobile application that provides Ilorin women with access to ante- and post-natal care information and enables women to leverage the social capital that exists within their community be accessing and sharing stories of motherhood. Its frontend was developed using react-native

while the backend was developing using a combination of SQLite for offline storage, cloud Firestore for offline and online data storage synchronization, firebase authentication and redux for user authentication and centralized application state management. To deploy the application to Ilorin women for efficacy evaluation, Expo snack and Expo GO were used.

CHAPTER IV: METHOD

This chapter describes the methodologies implemented to investigate the research questions and our work with vulnerable populations. A description of the research design and framework is provided along with details of the study, instrumentations, participants, and sampling. Also, techniques used in data collection from novice and non-literate users are presented along with data analysis in this chapter. The study was primarily divided into three phases: Surveys, prototyping and efficacy. The aim of the survey was to get information and feedback about the current state of affairs as it pertains to maternal and child health in Ilorin while the prototyping phase served as an inclusive design tool, which helped us understand the perspective(s) and expectation(s) of how Ilorin women and birth attendants would interact with MTOTO-BEBE. And finally, efficacy. In the third phase, we measured the usability of the MTOTO-BEBE application. In analyzing data collected from all phases of this dissertation, identifying information like names were not included, and although we went to the same communities, it was not explicitly noted in analysis if the same participant was involved in more than one phase of this research.

To assist with this study, we had to partner with the primary healthcare department at the ministry of health in Ilorin. They share data and information about healthcare in the state, they also granted us access and gave us a liaison to visit any government operated primary healthcare center in the state. Also, we developed relationships with community leaders because we needed their permission to conduct studies in their communities. Also, these community leaders wielded power to determine what interventions members of their community could adopt. Therefore, including them in the development process from the beginning was strategic.

Research Questions

1. In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria?
2. In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin?
3. What mental models exist around antenatal and postnatal care for Ilorin women?
4. How can these mental models inform the design process of a mobile application Mtoto-bebe for Ilorin women with no/low literacy?
5. How usable is the Mtoto-bebe application by Ilorin women?

There are several factors to consider when designing research methodology and techniques for novice and non-literate users. We categorized our target population into groups to address the unique challenges faced by the different stakeholder that interacts together to form maternal and child healthcare eco-system in Ilorin.

Phase I: Use of technology by Ilorin women and their healthcare ecosystem

Setting

Primary Health Care Centers: were a good place to meet pregnant women and skilled birth attendants. In addition to meeting and recruiting participants, this location was selected because it gave the research team opportunity to experience firsthand what it is like to attend ante-natal and post-natal care sessions in Ilorin. There are 127 primary healthcare centers in the Ilorin, with help from the primary health care department of the state (Kwara state, Nigeria), we selected 5 primary healthcare facilities in the state as venue for this study. We visited selected primary healthcare centers (PHCs) across Ilorin including, Ajikobi primary health center, Oke-erin, Oke-ogun, Okelele and Omoda. These PHCs all had less than 5 in-patient beds, they

provided basic outpatient care and maternal care. Also, they had weekly ante-natal and post-natal group sessions. They generally had 3-5 nurses on duty and occasionally, a medical doctor which is poor considering the fact that these health centers are meant to service over 10,000 people. Without recommendations from other mothers, it was difficult to randomly identify women who are not currently pregnant but have been pregnant in the last 3 years. Therefore, we decided to select a children's specialist hospital, the only of its kind in the heart of Ilorin, as another venue to recruit participants.

Participants

To capture and address the unique difference between the stakeholders that will interact with MTOTO-BEBE, we grouped the participants of this study into categories. The categories include:

- Birth Attendants:
 - Skilled birth attendant (SBAs): these are healthcare providers who had some degree of formal educations or training in pre- and post-natal care (i.e. college, technical school, nursing school).
 - Unskilled birth attendant (uSBAs): these are people that act as birth attendants but have no formal education or training in pre- and post-natal care.
 - Atypical Service Providers (ASPs): This refers to a group identified by (Thomas, & Rankin, 2015) as entities that may have no technical training in maternal health but have a wealth of societal capital and provide information and/or services but not for monetary gain.
- Women
 - Pregnant women (CPs): these are women who are currently pregnant.

- Non-pregnant (BL3Ys): this category is for women who are not currently pregnant but have been pregnant in the last 3 years.

	Ajikobi	Oko-erin	Oke-ogun	Okelele	Omoda	Total
SBA	1	2	4	1	2	10
uSBA	0	0	2	1	1	4
CP	0	6	6	5	7	24
BL3Y	0	4	6	3	6	19
Total	1	12	18	10	16	57

Table 2: Distribution of participants by category and location

Data Collection

The instrumentation for this phase of study was initially developed by (Thomas, & Rankin, 2015) for a similar study conducted in Laare, Kenya. The questionnaire was designed through an agile process that included consultation with mHealth experts, healthcare providers and other researchers. For this new study in Nigeria, the research team benefited from the finding/results of (Thomas, & Rankin, 2015) in disseminating the instruments in both digital and analog format and working with already existing organizations and government initiatives.

Surveys: there were 3 versions of the questionnaire namely survey A (for currently pregnant women), survey B (for women not currently pregnant but were pregnant in the last three years), and survey C (for both skilled and unskilled birth attendants) to specifically address and preserve the unique perspective of the different stakeholders. Each version consisted of two parts: the first part addressed access to and use of ante-and post-natal services. While the second part addressed access to and use of technology. The questionnaires are attached in the appendix section.

RQ1: In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria?

To inform the design and development of MTOTO-BEBE, we must gain insight to how Ilorin women access and use mobile technology. As stated above, our participants were divided into categories to capture the differences if any in the use of mobile phones by birth attendants versus mothers. In addition to understanding the primary use of mobile phones by women in Ilorin, we also wanted to investigate if and how mobile technology has been used in the past to access healthcare services and information. For all surveys, we asked participant about their access to and use of technology, especially internet, and mobile phones. Finally, respondents were asked respondents about their primary use of mobile phone, how they maintain their mobile phones (e.g., charging, additional minutes, etc.), and whether the mobile phone was a personal device, or one used by entire family (shared).

RQ2: In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin?

To design an intervention that can achieve our goal of mitigating maternal mortality by bridging the gap between skilled birth attendants and pregnant women in Ilorin, we needed to first learn about the healthcare ecosystem in the community, ante- and post-natal services available to women and how these women access information as it pertains to ante-natal and post-natal care.

We asked the SBAs about the institutions that provided them formal training, the type and duration of training they had received, and the types of ante- and post-natal services they provided. We also asked them to identify available resources for finding information about ante-

and post-natal care and any difficulties with acquiring access to said resources, as well as difficulties they encounter providing ante- and post-natal services to Ilorin. Finally, we asked them if there were services, they would like to be able to provide that are not currently available to Ilorin women. For the uSBAs as well, we asked how they acquired their knowledge of maternal care, furthermore, we asked them about resources they used to access ante- and post-natal care information and difficulties they encounter trying to access said resources, and any difficulties they encounter providing ante- and post-natal care. We also asked uSBAs about services they would like to provide that are not already available to women in their community.

We asked BL3Ys and CPs about their use of pre- and post-natal services. In particular, we focused on asking them which services they used and how often they used said service(s), their use of pre-natal vitamins, and difficulties encountered trying to access pre- and post-natal services and information. Furthermore, we asked them about resources they utilized when they have questions about pregnancy, labor, delivery, and newborn and infant care.

Interviews: (Thomas, & Rankin, 2015) stated that in order to have a mobile health intervention that will be adopted and used by women in rural communities of LMICs, researchers must leverage and include community and religious leaders (a.k.a. atypical service providers) as co-designers and advocate in that they wield their influence to determine which ante- and post-natal services will be adopted in the community. Therefore, as part of our approach to capture a holistic picture of the healthcare eco-system in Ilorin, we interviewed some participants that fall under this group of atypical healthcare providers. In addition to community and religious leaders, some community members have gone on to become respected Doctors or senior staff in both government and non-government agencies. These people are highly respected, have the ears of the community and religious leaders, and have a good understanding of how members of their

community think and approach healthcare. They have knowledge of what will be accepted and how to present “western information” in a relatable manner to their communities. The questionnaire meant for SBAs was used as a guideline to drive the conversation during interviews with atypical service providers.

Data Analysis

To analyze data collected from respondents’ response to questionnaires and interview transcripts,

first, we prepared interview transcripts for analysis by transcribing audio contents to written and consolidating them with all field notes. Then we prepared questionnaire response for analysis by transcribing hardcopy written responses into digital forms. The next step involved a detailed study of resulting data from both means of collection in which common themes were identified and extracted. Next was codifying of data in a process where we categorize findings and compare themes, topics and other ideas for cross-comparison and validation. Finally, we do a quantitative analysis of the codified data to get numeric and statistical results that can then be directly translated to inform design choices and future work.

Phase II: Prototyping

RQ3: What mental models exists around antenatal and postnatal care for Ilorin women?

and RQ4: How can these mental models inform the design process of a mobile application Mtoto-bebe for Ilorin women with no/low literacy?

Participants

In total we interviewed 36 women---10 from Ero-Omo, 10 from Oke-Adini, 10 from Basin/Okelele and 6 from Fate. Of the 36 women interviewed, 6 were unskilled birth attendants. Participants' ages ranged from 18 to 49 years old. All participants were 18 years old or older and gave both verbal or written IRB consent before the study was conducted. The population included women who were currently pregnant, women who had been pregnant in the last 3 years, and elderly women who had experience with maternal care and wielded some social capital in their community. The highest education level of women was secondary school certificate, which is the equivalent of a high school diploma. Two of the participants did not attend traditional secondary school but were Almajiranci educated (a form of Arabic and Islamic studies practiced mainly in northern Nigeria as an alternative to traditional education). Of the six birth attendants, three were college educated (Table 3).

	<i>Okelele/Basin</i>	<i>Oke-Adini</i>	<i>Fate</i>	<i>Ero-omo</i>
No literacy	5	3	0	1
Low literacy (high school)	5	7	3	9
Literate (college)	0	0	3	0

Table 3: distribution of participants by level of education and location

Settings

With help from statisticians and public health officers at the Kwara State Primary Health Care Development Agency (PHCDA), a department in the Ilorin Ministry of Health, four locations (Ero-Omo, Basin/Okelele, Oke-Adini and Fate) were selected for this study. These locations were strategic as they were densely populated and represented a broad cross-section of Ilorin women. Among other factors, religion was also taken into consideration as Ilorin had a strong Christian and Muslim presence which could lead to challenges during dissemination. Other factors taken into consideration in selecting the locations was to recruit a diversity of Ilorin women from

different backgrounds, including level of education, urban versus rural living, marital status and proximity to the primary healthcare center.

At Ero-Omo, the interviews were conducted at a church. The woman leader at the church is a respected member of the community that women sought when they had general questions about maternity and motherhood. The woman leader introduced the research team to a woman who had just given birth 3 months ago. She participated in the study and then recommended another Ilorin woman that she knew, and the list of participants grew organically, indicative of the snowball sampling method (Paul, 2014). Basin and Oke-Adini are commercial streets (market), so one of the market women let the research team use the back of her shop as a venue to conduct the study. At Okelele and Fate, the study was conducted at the local primary healthcare center. Recruiting participants at the health centers was relatively easy as the study took place during the postnatal clinic hours of service. The participants at Fate were mostly healthcare providers (midwives & nurses).

Data collection

Understanding the experiences of a predominantly non-literate (i.e., people with low or no literacy) user is critical for designing interfaces robust enough to meet the specific needs of these populations because they are significantly different from the target users of typical user interfaces. In addition to information gathered from literature review, this study informed a design tailored particularly to our target users (Ilorin women). Therefore, we used open card sort in combination with the prototype activity explained below to investigate and address research questions three and four.

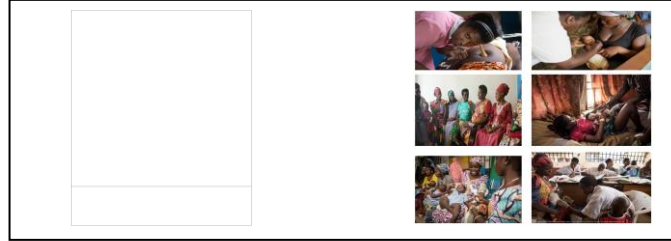


Figure 12: Low fidelity prototype and cards]

We developed a low fidelity mobile phone prototype for MTOTO-BEBE interface. To do this, we developed a large physical prototype of a mobile device emphasizing the screen.

Using the key words of Nigeria, pregnancy and women, a set of 2” x 2” Google images of various people and activities (e.g., a smiling pregnant woman, a woman holding her baby, a doctor giving an exam to a woman, a picture of a smiling male holding a baby, a woman in the hospital, etc.) were generated and printed. We then conducted semi-structured interviews with each woman as she interacted with both the pictures and the physical prototype. A paper prototype with the printed images instead of a software prototype was first used because it is more flexible, allowing each respondent to easily move images on the “screen” without having to pause the study to reprogram (rearrange) the interface. More importantly, using this approach also meant we did not have to make design assumptions about what images participants might select or how they might arrange images on the prototype as a starting point. Instead, participants were giving the freedom to arrange the images in any style or pattern they deem appropriate.

First, participants were asked to identify and describe what a card meant to them.

Next, they sorted the twenty-six cards into self-selected groups and gave each group a

topic (e.g., breastfeeding, immunization, etc.). When participants used similar descriptions of a particular card, then we marked that card as high ranking and used that card to represent a category icon or a group of pictures. Finally, participants were asked to arrange the groups of pictures on the prototype interface, revealing how they preferred to have information organized on the UI. Every session with participant was video and audio recorded with the video camera focused on the hands of participant as they interacted with the cards and the prototype but not their faces.

Data Analysis

Analyzing data collected from open card-sorting can be challenging in that its ad-hoc characteristic allows for multiple topics and mental models to emerge. Both qualitative and quantitative analyses methods were used to interpret findings.

Participant 1		Participant 2		Participant 3	
Card #	Category	Card #	Category	Card #	Category
3	Antenatal	3	Antenatal	3	Antenatal
11	Antenatal	11	Antenatal	11	Scanning
14	After delivery	14	Immunization	14	Child care
17	Breastfeeding	17	Breastfeeding	17	Breastfeeding

Table 4: Data organization for Qualitative Analysis

For the qualitative analysis, video recordings from field studies were watched and transcribed into a form that could be entered and analyzed in an Excel spreadsheet. To make sense of the different mental models created by participants, each of the 26 cards were arbitrarily assigned a number from 1 to 26, and the number corresponding to a card was recorded in the participant-selected category the card was placed. Table 4 shows the format in which data was recorded.

Topic normalization (Paul, 2014) was used to create an average mental model through a process

of merging similar ad-hoc topics created by participants to form a more representative group (Paul, 2014).

Card A	Card B	P1	P2	P3	Pn	Total
Card1	Card3	1		1	1	3
Card1	Card8		1		1	2
Card1	Card11	1	1		1	3
Card1	Card13	1			1	2

Table 5: Data organization for Quantitative Analysis

In addition to qualitative analysis, applying quantitative analysis techniques like card co-occurrence, can validate and/or present more insight into identified mental models. The goal of using quantitative analysis is to support in-depth qualitative analysis in a scalable and repeatable way. For the quantitative analysis, data was formatted as in Table 5. Card pairs were created by permutating all 26 cards. Card pairs sorted together independent of groups were recorded for each participant. Card pairs that had zero participants were removed from the list. Also, card pairs were only recorded once i.e. (3,26) is the same as (26,3).

Phase III: Efficacy and Effectiveness

RQ5: How usable is MTOTO-BEBE application for Ilorin women?

We wanted to investigate the usability of MTOTO-BEBE interface by Ilorin women. Therefore, specific tasks were designed around navigating the MTOTO-BEBE application for participants to complete. While participants completed the tasks, we also conducted semi-structured interviews to encourage participants think aloud as they completed tasks. Participants were first

asked to respond to t questions about the interface like, what aspect of the screen do you think is clickable? What do you think? What do you want to do first looking at this screen?

Participants

In total we had 10 participants. The participants were either pregnant women or nursing mothers from ages 22 to 36 with an average age of 25 years old. All participants gave verbal or written IRB consent before participating in the study. They all used or had access to an android powered device at the time of the study.

Settings

We went back to locations we visited during phase I and phase II studies. The first participant was recruited on major market street, and through snowball sampling, we recruited other participants as the first respondent introduced us the next and so on.

Data collection

Due to the restrictions imposed by covid-19 pandemic, I was not able to travel to Ilorin to conduct this phase of the study in the person. Therefore, I recruited and trained two people to help conduct the study. One of them was a sociologist in Ilorin. She also holds a master's degree in public health and currently works with an organization that conducts field studies with this population.

Furthermore, Because the application was initially developed with the impression that I would conduct the field studies in the person, special arrangements had to made in deploying the application. an expo snack version of the application was created so that 1) the interviewers could have access to the application through a URL and zero environment setup and 2) the

application can be managed, edited, and updated in real time from halfway around globe if necessary.

First, the interviewer made small talk with participants and ask them some personal questions such as name, age, education level and mobile phone usage and use of social media. Then the interviewer briefly explained the scope of project and the task the participant would have to complete. There were two tasks for each participant to complete, they included 1) create and share a video or audio content in a category of their choice and 2) find and watch a video in a particular category. Once the participant started a task, the interviewer was only allowed to interfere if the participant explicitly asked for help. The Interviewer was also allowed to give a nudge if participants got stuck as they thought aloud.

Each participant was asked to complete the following tasks:

Activity One: Create Content

After participant is comfortable with device, she is asked to create and upload (share) a content about her experience as it pertains to pregnancy and motherhood. There were two provided mediums of delivery which included audio and video. Some participants opted to try out both mediums.

Activity Two: Find Content

A scenario of complication was presented to each participant, and they were asked to try to find resources and information on that subject through the Mtoto-bebe application.

Data analysis

To evaluate the usability of the system, which is the main interest, a general assistant score was computed (Cuendet, Medhi, Bali & Cutrell, 2013). This score was the primary usability metric. For each activity, the weighted sum of the number of prompts in each category was computed. Whenever the interviewer provided help to a participant as they completed a task a score between 1 to 3 was recorded to weigh the help. The help provided by the interviewer was classified into three categories: 1 for simple encouragement, 2 for spoken remainder and 3 for hand holding. High scores indicated difficulty in completing tasks. Videos from the field were watched, and transcribed. For each participant, a general assistance score was computed based on the number of times they asked for help and how much help they got. We also analyzed the difficulty participants expressed and experienced while attempting to complete tasks (e.g., difficulties identifying icons), if and how many participants were able to complete the tasks, and how long it took them to complete the task.

Summary

This chapter explains the methodologies and techniques used in collecting and analyzing data to answer the research questions that guided this dissertation. Some of these techniques included: surveys, interviews, semi-structured interviews, open card sorting, low fidelity prototype, card placement, card co-occurrence, think aloud protocol, general assistance score and some others. First, we conducted surveys and interview to understand the healthcare ecosystem of Ilorin and the use of technology by Ilorin women and birth attendants. Then we used low-fidelity prototype, open card sorting and semi-structured interview to elicit the mental models and visual organization structures that existed among Ilorin women. The data collected from this phase was analyzed using mixed method approach. Then methods, techniques and metric used to evaluate usability of the application developed were also explained.

CHAPTER V: FINDINGS

One of the most critical interventions for safe motherhood is to ensure that proper care is provided by skilled professionals during pregnancy and that women, in the absence of skilled professional are well-informed about pregnancy, possible complications and safe approaches for overcoming them. Yet, 67,000 women die yearly in Nigeria from maternal causes.

Overwhelming evidence exists that these causes of maternal mortality can be averted if a woman gets adequate care by the way of antenatal care from the day she is confirmed pregnant until the day of her delivery and postnatal care through post-partum which is 42 days after delivery (WHO, 2016). Providing women with access to information of possible complications that could arise during pregnancy and ways to remedy and /or avoid these complications can have a positive impact on maternal mortality for Ilorin women. This dissertation harmonizes strategies, challenges and lessons learnt from existing mHealth projects in emerging economies to design a holistic approach for addressing maternal health issues and designing mHealth interventions for Ilorin women. We do this through the development of MTOTO-BEBE, a mobile application that provides Ilorin women with access to ante- and post-natal care information and enables women to leverage the social capital that exists within their community by accessing and sharing stories of motherhood.

To do this, the following research questions are answered

1. In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria?
2. In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin?
3. what mental models exist around antenatal and postnatal care for Ilorin women?

4. How can these mental models inform the design process of a mobile application Mtoto-bebe for Ilorin women with no/low literacy?
5. How usable is the Mtoto-bebe application by Ilorin women?

Phase I

In this phase, I answer research question one: In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria? and research question two: In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin?

I wanted to understand the healthcare ecosystem for Ilorin women, the types of services and information that were available to them, how they used and accessed these services. Additionally, I also wanted to learn about their use of and access to technology. To do this, surveys were administered to Ilorin women. There were three versions of the survey to capture the uniqueness of the different stakeholders identified in this population which included currently pregnant women (CP), women that were not currently pregnant but had been pregnant in the last three years (BL3Y), and skilled/unskilled birth attendants (SBA/uSBA).

We asked the SBAs about the institutions that provided them formal training, the type and duration of training they had received, and the types of ante- and post-natal services they provided. We also asked them to identify available resources for finding information about ante- and post-natal care and any difficulties with acquiring access to said resources, as well as difficulties they encounter providing ante- and post-natal services to Ilorin. Finally, we asked them if there were services, they would like to be able to provide that are not currently available to Ilorin women. For the uSBAs as well, we asked how they acquired their knowledge of

maternal care, furthermore, we asked them about resources they used to access ante- and post-natal care information and difficulties they encounter trying to access said resources, and any difficulties they encounter providing ante- and post-natal care. We also asked uSBAs about services they would like to provide that are not already available to women in their community.

We asked BL3Ys and CPs about their use of pre- and post-natal services. In particular, we focused on asking them which services they used and how often they used said service(s), their use of pre-natal vitamins, and difficulties encountered trying to access pre- and post-natal services and information. Furthermore, we asked them about resources they utilized when they have questions about pregnancy, labor, delivery, and newborn and infant care.

We also interviewed atypical service providers (ASP) a group we identified as co-designers and advocate in that they wield their influence to determine which ante- and post-natal services will be adopted in the community

Healthcare eco-system of Ilorin

The Ilorin healthcare eco-system can be classified in primary, secondary, and tertiary health care. Primary health facilities make up 88% of the health facilities in the state, while secondary and tertiary are 12% and 0.25% respectively (Federal Ministry of Health, Nigeria). The other form of classification is by management which includes two categories; Privately owned/operated and Government owned. Private hospitals are privately owned hospitals/clinics, they are usually expensive as they are profit driven and generally do not provide multiple range of services like the government hospitals. Instead, they are usually specialized. Government owned hospitals on the other hand, are subsidies and therefore more affordable to the public. The relatively cheap cost and broad range of services offered makes them overcrowded. And we

focus mainly on government owned establishment as this is where majority of the participants of this study go.

LGA	Public	Private	Total
Asa	47	25	72
Baruten	55	26	81
Edu	64	19	83
Ekiti	20	5	25
Ilorin East	43	26	69
Ilorin South	41	46	87
Ilorin West	30	39	69
Isin	28	9	37
Kaiama	30	30	60
Moro	39	22	61
Offa	24	24	48
Oke-Ero	31	4	35
Oyun	24	10	34
Pategi	37	6	43

LGA	Primary	Secondary	Tertiary	Total
Asa	45	27	0	72
Baruten	75	6	0	81
Edu	75	8	0	83
Ekiti	21	4	0	25
Ilorin East	46	21	2	69
Ilorin South	45	42	0	87
Ilorin West	36	33	0	69
Isin	33	4	0	37
Kaiama	55	5	0	60
Moro	53	8	0	61
Offa	37	11	0	48
Oke-Ero	31	4	0	35
Oyun	24	10	0	34
Pategi	41	2	0	43

Figure 13: Distribution of healthcare centers in Ilorin (Federal Ministry of Health, Nigeria)

Primary Health care

Primary health care centers/facilities make up 88% of the healthcare facilities in Ilorin (Federal Ministry of Health, Nigeria). This category consists of dispensaries, health posts, clinics, and primary healthcare centers (PHC). PHCs are usually run by the local government and render only basic (first aid) services. As the name implies, they focus on community care (supporting community-based health workers) and homecare for the disabled and elderly. Primary health care is the cheapest way to get health care in Ilorin as all the services are subsidized by the government; however, most people try to avoid them because they are usually

ill-equipped to render any form of service. In Kwara state, there are 575 primary and basic healthcare facilities and 89% of them are public owned. Yet only 73% of births in urban areas of the state are supervised by SBAs. Despite the numerous numbers of facilities, 54% of Kwara women still have unattended births. Faith based clinics are becoming more popular across the state because they are free, and a lot of people look up to their religious leaders/teachers for guidance and advise. The quality of care they render could be considered questionable in that most staff at the facility are church members who volunteer on their free time. One skilled attendant told us faith clinics can be good because its free but can also be dangerous. she said, “they keep women that already have appointment for a cesarean section and promise them natural birth by faith”.

Secondary Health care

Secondary healthcare centers/facilities make up 12% of the healthcare facilities in Ilorin. This category consists of state government owned hospitals called General Hospitals. Most private hospitals in the state also fall into this category in terms of kind and quality of services they render. Except in cases of critical emergency like traffic accident, people are supposed to go to their local primary or basic healthcare facilities and only move up the chain based on recommendation. However, because of the dilapidated state of most of the primary health care facilities in the country, patients would rather go to the secondary health care facilities first. This attitude puts a lot of pressure on these facilities; therefore, they are always overcrowded and seem under served.

Tertiary Health care

Tertiary care is specialized consultative health care. They are usually suited to inpatients and referrals from primary and secondary care. This category of healthcare makes up just 0.25% of the healthcare eco-system. In Kwara state, there is only 1 tertiary health care facility to serve its over 1 million population, and it is the University of Ilorin teaching hospital.

Access to and use of ante-and post-natal care services

We have survey results for 57 participants regarding their ante-and post-natal experiences. We wanted to understand their experiences with the ante- and post-natal services they have had access to both as providers and consumers. The largest number of responses came from consumers of pre- and post-natal services, either women who are currently pregnant (CPs) or women who have been pregnant within the last three years (BL3Ys). We met most of the respondents at health care facilities, they all said they attended pre- and post-natal care. However, they had to pay to get a card opened on their first visit. (The card is a file which the health center used to keep track of patient records.) They also had to pay on every subsequent visit (to get their cards retrieved), to avoid all these expenses most pregnant women visited the PHCs only once during their pregnancy and only went back when they had complications. Additionally, SBAs stated that one of the major challenges they faced in providing pre- and post-natal care was illiteracy, as women could not communicate their situations clearly and gave incomplete information when filling the cards.

Ante- and Post-natal Experiences of Currently Pregnant Women (CP)

For this category of women, the average age was 26.38, the youngest woman that responded to the survey being 18 and the oldest woman's age was 40. Of the 25 women in this category, only 3 were above the age of 30. The average number of children was 1.86 with the

least number of children being none (i.e., a woman's first pregnancy) and the greatest number of children being 5. All the women stated they have used anti-natal and post-natal vitamins and services at some point during their pregnancy; however, it is unclear if they used the pre-natal service up to a minimum of 4 times which is the WHO recommendation referred to as "focused prenatal care". Only 4% of women in this group stated that they consulted or used skilled birth attendants during delivery. However, the doctors and nurses we interviewed said that most of women that came through their services were not consistent and did not deliver their babies at the hospital or primary health care facilities. Therefore, it is unclear whether the women used a midwife to assist with their birth and whether the midwife had any form of formal training in anti-natal care and/or post-natal care. All the respondents stated that they used or attended post-natal care services at least once. While all CPs stated Primary healthcare center (PHC) as a resource for information, 50% stated they used the internet also and 95.8% stated they consulted family, friends, and elderly women in their communities. The average distance to their closest PHC center or was about 30-minute commute. Most women made this commute on public motorcycles (also known as okada) which was their cheapest option however dangerous.

Ante- and Post-natal Experiences of Recently Pregnant Women

The average number of children for this group was 2.63 while 23.63% of women already had 4 children and 68.4% said they intend to have more children. This group was slightly older than the CP group with an average age of 27 and the youngest woman being 25. The oldest age was 40. Like the CP group, all the women stated that they used anti-natal vitamins and anti-and post-natal care services at some point during or after their pregnancy. It is not clear if they met the WHO recommended standards for ante-natal care and/or post-natal care. All the women stated PHCs as their primary source for maternal related information, 47.36% said they also

consulted the internet, and all (100%) admitted to consulting family, friends, and elderly women in their communities for information and help during their pregnancy.

Ante- and Post-natal experiences of Skilled and Unskilled Birth Attendants

The average years of experience of the group was 24 years. These 14 pre- and post-natal service providers represented a combined total of 336 years of experience with the least years of experience being 2 and the most being 34 years. These service providers have delivered over 3200 babies and 35.71% of them had a college degree and beyond. Respondents listed counseling, child health, personal hygiene, family planning, immunization, nutrition, and routine check-ups among the services they provided. Among SBAs, books and the internet were listed as the primary source of information by all. Additional resources mentioned included medical journals, information presented at seminars and workshops by trained professionals and experiences and knowledge shared by elderly women in the community. Lack of access to recent medical books and journals, insufficient funding and poor facilities were among the difficulties these groups faced in providing pre-and post-natal care to Ilorin women. Illiteracy was cited as the most common difficulty the group faced in communicating and providing their services to women. Other difficulties included detecting complications at an early stage because most women did not attend ante-natal care or visit the health centers until they had complications, lack of equipment, lack of cooperation by mothers because of their traditional and religious believes, poverty, unavailable resources to enhance diet of the mothers, out of pocket spending by SBAs and early teenage pregnancy. Some additional services SBAs mentioned would be critical to elevate the quality of service they provided included more beds in the wards, subsidies for the cost of services and more equipment. They also added that they would like to provide additional

services like advice on child hygiene, breastfeeding, care of newborns and education on what to do in cases of specific complications.

Use of technology

In addition to understanding the primary use of mobile phones by women in Ilorin, we also wanted to investigate if and how mobile technology has been used in the past to access healthcare services and information. For all surveys, we asked respondents about their access to and use of technology, especially internet, and mobile phones. Further, we asked respondents about their primary use of mobile phone, how they maintain their mobile phones (e.g., phone charging, additional call minutes and text, internet data, etc.), and whether the mobile phone was a personal device, or one used by entire family (shared).

	Own	Shared	Smart	Basic
CP	19	5	12	11
BL3Y	18	1	11	8
SBA/uSBA	14	0	13	1

Table 6: Distribution of participants by category and phone ownership

Although all the PHCs we visited had a computer, they had never used it to collect and/or keep record of patient information. The computers were not connected to the internet. Frequent power failure was stated as the main reason they never used the computers. In contrast, all respondents had access to cell phones, in fact, all 14 SBAs had smart phones and stated that they used it for calls, text, social media, news and to access the internet. Over 50% of CPs and BL3Y had access

to a smart phone (52% and 57.89%, respectively). 20% of women stated their cell phones were owned and shared by everyone in their household. 85% of the younger women under the age of 30 had personal phones and were excited to talk about social media. In addition to call and text 100% and 60% respectively, 48% of women also used their phones (shared or personal) for social media and to occasionally access the internet. Respondents were familiar with social media platforms especially Facebook and WhatsApp.

Phase II

Understanding the experiences of a predominantly non-literate (i.e., people with low or no literacy) user is critical for designing interfaces robust enough to meet the specific needs of these population because they are significantly different from the target users of typical user interfaces. In addition to information gather from literature review, this study informed a design tailored particularly to our target users (Ilorin women). In this phase, research question three: what mental models exists around antenatal and postnatal care for Ilorin women? And research questions four: How can these mental models inform the design process of a mobile application for Ilorin women with no/low literacy? are answered.

Using a combination of HCI and HCI4D techniques which included open card sorting, low fidelity prototyping, and a series of activities, Ilorin women's mental models of maternal care and how they organized information were articulated.

First, participants were asked to describe what each card meant to them. the card were derived from a google search using key words Nigeria, pregnancy and women. Then, open card sort was conducted which involved asking the respondents to put the cards into self-created

categories. They were also asked to label each category. And lastly, respondents were asked to arrange the self-created categories on a low fidelity prototype.

Table x below presents the cards (images) used, a description of the image, as well as respondents' average descriptions of the cards.

Card	Image Description	Participant Description
1	An unskilled birth attendant listening to fetus heartbeat with a Pinard stethoscope	Testing, scanning, antenatal,
2	A baby receiving oral medication from a health worker	Immunization
3	Six pregnant women, one man, and a toddler sitting, eating fruits and chatting in what seems to be a casual/social environment	Antenatal
4	Woman holding her new baby immediately after delivery in the presence of a birth attendant	Delivery, after delivery, postnatal, mother/child care
5	Nursing mothers holding their babies on their laps as they sit in row (looks like a queue). At one the end of the row, (the only visible end), there is a birth attendant using a sphygmomanometer on a woman	Mother care, child care, immunization, after delivery
6	It's a clinic setting with two nurses sitting at desks writing. Another nurse is injecting a baby and the baby was crying. There is also another woman playing with her baby in the background	Immunization, shots
7	Pregnant woman pushing in a labor room with birth attendants present	Delivery, labor

8	Skilled birth attendant (wearing a nurse uniform) listening to fetus' heart beat with a pinard stethoscope	Testing, scanning, antenatal,
9	Pregnant woman on a stretcher in the birth position with two uniformed nurses by her sides	Labor, delivery
10	A not pregnant women with iv line attached to her wrist sitting down crying while being attended to by a healthcare worker	Out patient, prenatal,
11	Birth attendant using ultrasound	Scanning, antenatal, ultrasound
12	Women carrying their babies in a clinic. It looks like they are talking to the two healthcare workers sitting behind a desk writing.	Immunization, postnatal, after delivery
13	A not pregnant women sitting on a stretcher in a ward as a doctor checks her blood pressure	Out patient, general check up
14	Nursing mothers holding their babies sited (in a queue) on a bench that starts at the entrance of a room.	After delivery, immunization
15	Mother lying on bed next to her baby while a skilled birth attendant examines the new born with a stethoscope in the ward. Both SBA and mother are smiling	After delivery check up
16	Three pregnant women seated at a clinic	Antenatal
17	A women sited breastfeeding her baby and other women sited holding their babies in the background	Breastfeeding, after delivery, immunization
18	A nurse massaging the stomach of a pregnant women lying flat on her back	Antenatal, testing, labor
19	Crying baby being injected	immunization
20	New mothers sited in a ward as they hold their babies. A	After delivery, mother care, child care

	doctor is taking notes as he speaks directly to one of the women	
21	A pregnant woman on a stretcher in pain	Labor, delivery
22	A woman sited breastfeeding her new baby as a nurse stood beside her smiling. They seem to be in a conversation	After delivery
23	Newborn baby on a scale	Postnatal, after delivery, weighing
24		
25		
26	An unskilled birth attendant massaging the stomach of a pregnant women lying flat on her back	Antenatal

Table 7: Card descriptions

Identifying images with meaning

We asked participants to select and describe each image in the collection of images provided by the interviewer. Our analysis of the video-recorded interview indicated that most participants had similar descriptions for most cards. Some images resonated more across participants than others. For example, images that included a group of three or more pregnant women sitting together was generally referred to as antenatal as 95% of participant selected and described cards three and sixteen as antenatal (Table 7). Images of a pregnant woman being examined (e.g., using a pinard stethoscope, looking at an ultrasound, etc.) by skilled/unskilled birth attendants were also generally regarded as antenatal or a part of antenatal procedures. Other words used to describe these cards (cards 8, 11, and 26) included scanning, testing, and ultrasound. Eighty-five percent of the women who selected and interpreted cards (3) three and sixteen (16) as antenatal also identified cards 8, 11, and 16 as scanning and tests during antenatal. Images that did not include a woman who looked pregnant or had just delivered (e.g.,

cards 10 and 13) were confusing for participants and described as outpatient, general checkup and even prenatal. When probed further, women that used the word “prenatal” to describe these cards (cards 10 and 13) explained prenatal as a stage before antenatal (i.e., before, and immediately after a woman confirms she is pregnant). This suggested that although the images were selected by American researchers, they still created synergy around meaning for Ilorin women. Table 7 shows arbitrary numbers assigned to cards in the first column, image descriptions provided by researchers in the second column and participants’ descriptions of cards in the third column.

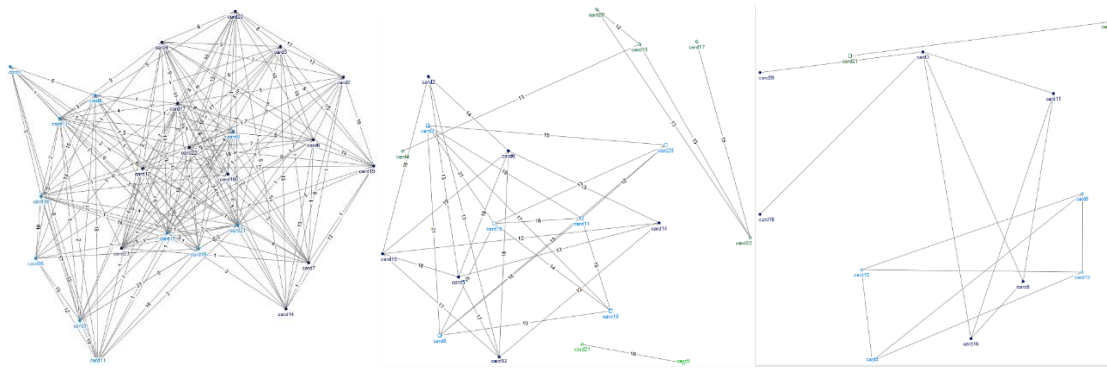


Figure 14: a) base case, b) 50% co-occurrence, and c) 75% co-occurrence

Grouping images into categories

After identifying and describing cards, participants were then asked to group images they thought were similar into categories and label the category. Like co-operative evaluation (Thomas, & Rankin, 2015) (Paul, 2014), participants were asked to consider themselves as co-designer and think aloud as they carried out activities. The number of categories created ranged from three to nine, with an average of seven. Category topics identified included, scanning/testing, antenatal, labor, delivery, after delivery, postnatal, mother healthcare, child healthcare, breastfeeding and immunization. Although somewhat similar, several mental models were identified that suggested

the need for a hierarchical menu for example, participants that created the topic called childcare went further to explain how childcare was an aspect of another topic they created called after delivery.

To identify strong relationships between cards and topics, data was further analyzed using card co-occurrence analysis (Righi et al., 2013), (Paul, 2014) and clause-Newman-Moore algorithm to generate clusters (Paul, 2014). Card co-occurrence is the number of times two cards are sorted together independent of the topic in which they are sorted (Paul, 2014). This allows for strong common relationships between cards to emerge regardless of the different sorting mental models expressed by participants. The higher the number of participants that sorted a pair of cards together, the higher the value of co-occurrence on that pair. Card relationships with 75% co-occurrence or greater were considered to have high confidence agreement, and card relationships with 50% co-occurrence or greater (which means half the participants created the relationship) were considered to have good or moderate confidence agreement. The base network in Figure 14 represented each card pair that was sorted together by at least 1 participant. Twenty-four of 26 cards used for this study were grouped into 175 pairs by at least 1 participant. This was the minimum percentage count of participants who sorted two cards together regardless of topic. Six was the average number of participants that made a similar sort regardless of topic. Of the 175 pairs, 35 pairs were identified to have good or moderate confidence (i.e., at least half of the participants created these card pairs), and 15 pairs were high confidence (i.e., at least 75% of participants created these card pairs).

The Clause-Newman-Moore cluster algorithm was then executed on data to identify mental models based on strength of the relationship between card pairs. The base network identified two dominant categories – before delivery and after delivery. The cluster algorithm also identified four categories in the 50% confidence agreement pairs---antenatal, labor / delivery, after delivery

and immunization. Additionally, three categories were identified in the 75% confidence agreement pairs---antenatal, labor/delivery, and immunization. Further analysis of cluster contents (cards within each cluster) combined with topic normalization (Righi et al., 2013), (Paul, 2014) identified four topics----antenatal, labor/delivery, after delivery, and immunization

Topics	Cards	Evidence notes
Immunization	14,19,12,6,5,2	High confidence
Antenatal	16,26,11,8,3,18	High confidence
After delivery	17,22,20,15,4	Good/moderate
Labor/Delivery	9,21	High confidence

Table 8: Final categories

Organization of Clusters

As part of encapsulating the mental models of Ilorin women around antenatal and postnatal care, we also wanted to learn about their expectations concerning how information should be organized on the mobile application UI. This is important for intuitive design as the goal was to design an interface without words to accommodate participants' inability to read words. All respondents arranged topical clusters chronologically, starting from pregnancy to after delivery. However, different groups of participants physically laid out each cluster on the UI in different ways. For example, most participants (53%) arranged the clusters on the low fidelity prototype from top to bottom, and then started a new column of clustered images when they ran out of space. Forty-three percent of participants made the arrangements row-wise (i.e., from left to right) whereas another 3% made row-wise arrangements moving from right to left. After probing why different groups chose to use different physical layouts for organizing the clustered images, we discovered that there were certain communities in Ilorin where children were enrolled in Almajiranci classes to learn Arabic and Islamic studies. Their exposure to

Arabic and Islamic studies stimulated a different approach to how these group of Ilorin women preferred to organize information. However, it was difficult to determine how Almajiranci classes influenced their mental model or if this was just an anomaly.



Figure 15: participant arranging card on low fidelity prototype

Card placement

To select the images used to represent categories on the first functional version of the application, we computed the number of times each card was put in a category by a participant. We then selected the card with highest frequency from each category as the image to represent the category. table below shows the card placement analysis.

Card Title	Card Number	antenatal	labor/delivery	immunization	after delivery
card title	1	83%	17%		
card title	2			61%	39%
card title	3	95%	5%		
card title	4	5%	38%	10%	48%
card title	5			78%	22%
card title	6			76%	24%
card title	7	20%	80%		
card title	8	95%	5%		
card title	9	10%	90%		
card title	10	17%	67%		17%
card title	11	95%	5%		
card title	12		5%	68%	26%
card title	13	36%	9%		55%
card title	14			79%	14%
card title	15		15%	10%	75%
card title	16	95%	5%		
card title	17	10%		10%	80%
card title	18	77%	23%		
card title	19			76%	19%
card title	20			30%	70%
card title	21	13%	78%		
card title	22	5%	5%	14%	76%
card title	23	20%	20%		60%
card title	24				
card title	25				
card title	26	100%			
# Different Cards		16	16	11	14
# High Agreement Cards		7	4	5	4
# Medium Agreement Cards		1	2	1	4
# Low Agreement Cards		8	10	5	6
Average Card Agreement		49%	29%	47%	45%

Table 9: card placement table

Social Capital

In phase I, we found that in the absence of access to antenatal and postnatal care information, Ilorin women turned to one another (family and friends) and elderly women in their communities for support and information around safe delivery. This suggests that there exists social capital that could be leveraged in both design and dissemination of an adoptable intervention. Therefore, we investigated and measured the social capital that existed amongst this population using Low- and medium-income countries Social Capital Assessment Tool for Maternal Health (LSCAT-MH) a social capital assessment tool tailored towards maternal care in LMIC context (Agampodi, Agampodi, Glozler, Lelwala, Sirisena, & Siribaddana, 2015). To the best of our knowledge, this is the first mention of social capital in relations to healthcare and more specifically maternal care in Nigeria. As described in the literature review, we focus on two aspects of social capital, cognitive components, and structural components.

Cognitive component: there is a strong sense of social cohesion and collective efficacy amongst Ilorin women. In each of the five neighborhoods where questionnaires were administered, there was a strong sense of neighborhood membership and relationship. Participants were more likely to listen to and ask for help from people in their neighborhood. They also stated that in case of emergency, they called a neighbor first. Participants stated that they helped or were helped by their neighbors with babysitting at no cost.

Phase III

Findings from phase one revealed the current state of maternal healthcare for Ilorin women, the healthcare ecosystem, existing ICT interventions in Nigeria, and how this population used technology. As the prices of devices plummet more people in the global south including Ilorin women now have access to android powered mobile devices they called “Android phone” or “China phone”. Which suggested that this population of women could benefit from mobile applications that run on android devices. In phase II, the mental models of Ilorin women and how they organized information was exposed. Armed with these results, a functional version of the Mtoto-bebe application was developed. In this phase research question five: how usable is Mtoto-bebe application by Ilorin women? Is answered. We wanted to investigate the usability of MTOTO-BEBE interface by Ilorin women, identify aspects of the interface that overloaded users, and whether the system functionality matched the user requirements.



Figure 16: participant interacting with Mtoto-bebe application

To achieve this, specific tasks were designed around navigating the MTOTO-BEBE application for participants to complete. The Mtoto-bebe application was deployed to Ilorin women using Expo snack and Expo Go. Expo Go is an application that allows users run expo snack on local devices. It is mainly used for testing purposes. The application is accessible through a (barcode) URL. We benefited from deploying the application through expo snack in two ways, 1) participants did not have to worry about internet data as they had to be on the same Wi-Fi (network) as the research team to access the application and 2) participants could use their own personal device to complete the activities.

	<u>Participants Assistance Score</u>										GAS
<u>Activity One (Create content)</u>	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	
Audio content	1	-	1	-	-	-	1	-	-	-	3
Video content	1	2	-	-	-	-	1	1	-	-	5
Upload	-	-	1	-	-	-	-	-	-	-	1
<u>Activity Two (Find content)</u>											
Antenatal	-	-	-	-	-	-	-	-	-	-	0
Labor/Delivery	-	-	-	-	-	-	-	-	-	-	0
Postnatal	-	-	1	-	-	-	-	-	-	1	2
Immunization	-	-	-	-	-	-	-	-	-	-	0

Table 10: general assistance score

To evaluate the usability of the system, which is the main interest, a *general assistant score* (GAS) was computed (Cuendet, Medhi, Bali & Cutrell, 2013). This score was the primary usability metric. For each activity, the weighted sum of the number of prompts in each category was computed. Whenever the interviewer provided help to a participant as they completed a task a score between 1 to 3 was recorded to weigh the help. The help provided by the interviewer was classified into three categories: 1 for simple encouragement, 2 for spoken remainder and 3 for hand holding. High scores indicated difficulty in completing tasks.

As mentioned in earlier chapters, conducting user studies with no/low literate users in LMIC context presents peculiar challenges that are not persistent with typical users. One of the challenges was that No/low literate users tend to think they are the once being tested and not the technology. These group of users also feel intimidated by expensive device for the fear of breaking them. Therefore, it was important that participants felt comfortable with the testing device and remembered that in addition to being stakeholders, they are also co-designers. To manage these

challenges semi-structured interview was conducted as users completed task to encourage “think aloud” protocol. Also, deploying the application using Expo snack and Expo Go gave participants the opportunity to use their personal devices during the studies.

The application was well received, as co-designers, participants were excited to see and use what they helped create. The general assistance score was low across all activities which suggests the application was easy to use. In analyzing data collected from all phases of this dissertation, identifying information like names were not included, and although we went to the same communities, it was not explicitly noted in analysis if the same participant was involved in more than one phase of this research.

Participants were between ages 22-36, they all had access to an android phone either owned or shared. 80% owned an android powered device. 20% had access to an android powered device shared with their spouse or sibling. In addition to calls and text all respondent stated they used WhatsApp and Facebook. It is however unclear what features they used or how often they accessed their accounts on Facebook. We asked participants how much they spent on internet data monthly and how much data the money afforded them. Respondents used between 250 megabytes and 5 gigabytes of internet data monthly. With an average of one gigabyte of internet data per month. All participants created videos, and 60% created audio too.

All respondents Identified the images used to represent categories (antenatal, labor/delivery, postnatal and immunization) on the applications home page. Only 20% specifically used the word postnatal to describe card 3, which was the card that represented postnatal on the interface. To describe the categories most participants 75% used pregnancy, labor/delivery, immunization, and immunization respectively. 30% went back and tried to correct themselves once they realized that immunization should not appear twice. They changed their

description of the second category to mean “after delivery”. Sixty percent of the women did not think that clicking on the camera icon on the home page would navigate them to the video recorder. Their mental model of a camera is an object for taking pictures. Video recorder is an entirely different object.

Activity one: creating video/audio content

To create a video or audio content users had to make exactly one transition. Clicking on the back button on any page navigated back to the home screen.

Video content: At the bottom of the camera view were the camera control buttons. There were two buttons, one for capture and the other to switch between front and back cameras. All respondents clicked on the capture button without help. However, the capture button was also the record button. Clicking on the button took a photo while holding the button allowed for video recording until the button is left or the video recording max duration is reached. Because all participants stated they are familiar with and use WhatsApp, we choose this design for video recording as it is similar to that of WhatsApp. 50 percent of participants had to take a few tries or asked the interviewer in order to figure out how to record videos. The general assistance for video recording was 5. Which was the highest recorded during this phase of the study.

Audio content: like the video recording page, the audio screen also consisted of two buttons. A red circle button to record, and a black square button to stop recording. While 70% of participants used this feature with minimal to no help at all from the interviewer, a participant that first created video content before creating audio content tried to transfer their knowledge of hold to record. 30 percent of participants expected that the same button that started the recording would also stop it.

Save & upload content: After creating content, be it audio or video, the system presented the user with two options, a red cross and green check. All participants understood and used both buttons as intended. (Red cross to cancel and green check to accept). After accepting to keep a recording (audio or video), they had to select the category in which to save it. The four categories (antenatal, labor/delivery, postnatal and immunization) were represented as a radio button group. Each selection was accompanied with the same image from the home screen respectively. 60% of participants tried to click the image for selection instead of the radio button.

Below the radio group, there was a green button with a cloud and arrow up button. Although all participants used the button as intended, 80% percent of participants did not understand this icon. Further probing revealed that participants that click the button without asking the interviewer about the icon, said they did so because it was the only button, and it was color green, so it had to be positive.

Activity two: find content

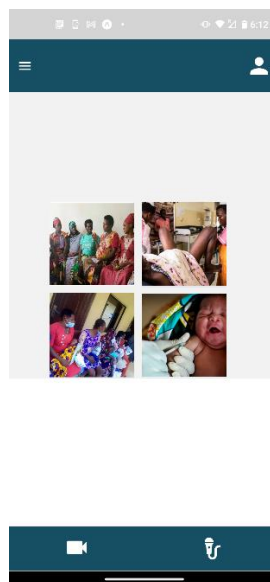


Figure 17: Home page

Finding content was easy for all participants. Once a user figured out what category to click on to find the desired content, it was literally one click away. All participants expected that information was stored in a chronological order, so even in the rare situation where they found the picture representing a category ambiguous, a combination of the sequence expectation and elimination made it easy for them to determine what category to look. As stated earlier, postnatal is not a category that participants identify with, however, when a participant was asked to find a content that was related to postnatal, which did easily. The interviewer asked her how she found it, and her response was “I know Antenatal, I know delivery and I know immunization, there was only one choice left”. This quote was translated from Yoruba to English.

Summary

This chapter presents findings from three phases of research which included a total of eight interviews, and 103 survey/semi-structured interview respondents. The findings show that including Ilorin women as co-designers in the participatory design of Mtoto-bebe mobile application had positive impact on their usability and adoption of the application.

In phase I, the healthcare ecosystem of Ilorin was mapped, most Ilorin only had access to primary healthcare as this represented 88% of the healthcare facilities in the state. Also, because of the quality of care and service rendered at these facilities, 96% of Ilorin women looked to elders, and unskilled birth attendants in their communities for help around maternal care and information. The use of technology, specifically mobile by Ilorin women and birth attendants was also investigated in this phase and the results revealed that over 50% of Ilorin women owned android powered mobile devices and other access to this kind of device in shared form. Results from phase I confirmed that the ubiquitous property of mobile phones made them an ideal candidate to present ante- and post-natal care information to Ilorin women.

Designing mobile application for application for no/low literate users in LMIC context presents unique challenges that are not as common in designing for typical users. Results from phase II revealed the mental models that existed around maternal care among Ilorin women. Also revealed were icons, representative images, and organization structures for this population of women.

Findings from phase III showed that Ilorin women were receptive of the application. additionally, the population also found it easy to navigate through and use the application with little to minimal mediation.

CHAPTER VI– DISCUSSION

Our goal was to provide an alternate source of antenatal and postnatal care information to no/low literate populations in resource constraint areas. We chose Ilorin, Nigeria as a case study because it is my hometown, I have personally lost family to maternal mortality the MMR of Ilorin which is 980 deaths is very high and above the national average. To achieve this goal, we divided the study into phases as we asked and answered the following research questions

1. In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria?
2. In terms of healthcare services for women, what is the ecosystem of available maternal and childcare in Ilorin?
3. what mental models exists around antenatal and postnatal care for Ilorin women?
4. How can these mental models inform the design process of a mobile application Mtoto-bebe for Ilorin women with no/low literacy?
5. How usable is the Mtoto-bebe application by Ilorin women?

In this chapter I will address and discuss each of this question.

First, we sort to understand the healthcare eco-system in Ilorin. how and what services Ilorin women used and accessed. Furthermore, what challenges do this group of women face in accessing and using the resources in terms of maternal care available to them.

Use of ante-natal and post-natal care services

For financial reasons, most Ilorin women only attended one antenatal care meeting at Primary healthcare center and only came back when they had complications. This is detrimental to the health of both mother and child because healthcare providers are not afforded the chance

to detect complications at an early stage and women don't get to learn about preventative measures. Another economic status factor that affected the use of ante- and post-natal care by Ilorin women was distance to the PHCs. The risk and cost of commuting 30 minutes on a motorcycle to attend ante-natal and/or post-natal care was high for the women suggesting that an intervention must be cost-effective and easily accessible. Also, with over 1 million people in Ilorin, limited personal and lack of equipment, the PHCs are always crowded therefore, the average wait time to see a doctor or nurse is about three (3) hours, which suggests that an adoptable intervention should be readily available with minimal hassle.

Accessing ante-natal and post-natal care information

Communication barriers create a hostile situation that makes women feel the SBAs are disrespectful and condescending as explained by one of the pregnant respondents who had already had 4 children and was pregnant for the fifth. So instead of turning to SBAs for ante- and post-natal information, women turned to traditional birth attendants, friends, family, women who had been pregnant before and older women in the community. This suggests that there exist additional entities within the pre- and post-natal care ecosystem that make up for what they lack in technical training with a great deal of societal capital. We call these additional entities atypical service providers, as they provide ante-natal and post-natal care information and services but not for monetary gain.

Identifying the challenges and factors that impact access to and utilization of health services suggested a technology solution could be viable. Therefore, we asked the question, *In the context of healthcare, what are the technology usages and practices of women and service providers in Ilorin, Nigeria?*

Use of Technology to provide access to ante-natal and post-natal care

Mobile phones are the most prevalent form of technology in Ilorin. Based on our findings as stated above and previous research conducted in Laare, Kenya (Thomas, & Rankin, 2015), we identified three design implications for designing mobile-based services to provide access to and deliver ante- and post-natal care: 1. Mobile technology that removes the barrier of illiteracy; 2. Mobile technology that leverages existing social capital and 3. Users and communal influencers as contributors, co-designers, and advocate of the interventions.

Mobile applications that eliminate the barrier of illiteracy

Illiteracy was cited by SBAs and uSBAs as the major difficulty in providing ante- and post-natal care for women in Ilorin. Therefore, interventions promoting access to ante- and post-natal care must be delivered in some form other than text (e.g., audio or video etc.).

Remembering that all respondents had access to mobile phones either owned or shared with family, we posit that mobile technology is the ideal platform for providing access to ante- and post-natal supplementary care. Mtoto-bebe presents this information in an easy-to-use interface that contains zero words therefore, eliminating the need for literacy to navigate.

Leveraging Social capital

Social capital can increase or decrease healthcare service utilization (Story, 2014). For example, civil participation can affect health care use through formally organized activities that address community issues and on the contrary, civil participation can reduce utilization of health care services by formation of bonding capital which can reduce individual freedom to make appropriate decisions.

Understanding and leveraging the kinds of social capital that exists in communities like Ilorin can impact the adoption of a technology intervention (Mtoto-bebe) as well as its content. Ilorin women reach out to

neighbors as a first course of resolve in case of emergencies, infusing social capital in the design of an intervention in this case Mtoto-bebe could present it as a neighbor for its target audience.

Communal influence as Co-designers

Traditional and religious values are deeply embedded in low-and-medium-income countries (LMIC) in sub-Sahara Africa. SBAs shared stories of women leaving PHCs because caesarean section was recommended to them. Some women still believe giving birth in any way other than natural is a sign of weakness and diminishes their womanhood. Therefore, understanding the communal influence of traditional elders, religious leaders and primary teachers is critical to the success of any intervention to be adopted. We acknowledge the need to engage these communal influences as co-designers and advocate for pre- and post-natal services. The implications for service design argue for a participatory approach in which the communal influencers have a voice in the design of the intervention and how it is used since the members of the community listens to them. This does not in any way imply that professional expertise of health care providers and technology designers should be thrown out. Rather, the different stakeholders should work together to design alternate solutions that promote evidence-based practices that will be adopted and utilized by women in Ilorin and scale-up to other LMICs.

To design an application that would be intuitively usable by first, Ilorin women with potential to scale to other low/no literate women that also live in resource constrained areas outside of Ilorin we asked the questions *what mental models exists around antenatal and postnatal care for Ilorin women? And how can these mental models inform the design and expansion of Mtoto-bebe?*

Mental models

At a base level, Ilorin women's mental model of maternal care fell into two categories---before birth and after birth. It was easy to correlate this mental model to antenatal and postnatal, the two phases of maternal healthcare. Looking closely at the categories of antenatal and postnatal, topics like scanning, testing, labor, delivery, childcare, mother care, etc. emerged as separate categories.

Antenatal (before delivery): Participants were eager to talk about antenatal care. Their mental model of antenatal care included group activities that involved sharing pregnancy experiences, doing specific activities to stay healthy during pregnancy and to ease delivery (e.g., they exercised (danced) at the beginning of each session). They also learn about how to handle critical situations (e.g., breach birth) should they arise. In addition to attending antenatal care sessions at primary healthcare facilities, participants admitted to attending sessions organized in their compound. However, they did not call these sessions antenatal care. Other categories like scanning and testing, which was combined into the antenatal care category after card-occurrence analysis, were not inherently considered antenatal by Ilorin women because PHCs barely had any equipment. Therefore, scanning and testing were only done based on referral from attending antenatal sessions at PHCs. This reflected how the lack of healthcare services readily available to Ilorin women influenced the cultural norm of not expecting scanning and testing as part of antenatal care, a practice that can be detrimental in managing difficult pregnancies or avoiding emergency situations. For marginalized populations, adequate healthcare is critical to reducing health disparities that disproportionately affect African women and other women of color.

Postnatal (after delivery): Like antenatal care, postnatal care was also considered a group activity. However, the term "postnatal" rarely came up during interviews. Of the 36 participants, only 3 explicitly created a category called postnatal. "After delivery" was the more preferred term

for postnatal. However, quantitative analysis revealed that “after delivery” was not a high confidence category (Table 8). This confirmed previous studies like (Babalola & Fetusi, 2009) that postnatal care was the least utilized aspect of maternal care by Ilorin women. Cluster analysis indicated that there were aspects of postnatal care that most participants considered to be separate categories of their own. Decomposing the category “after delivery,” immunization was marked as a high confidence category. Topics like childcare, mother care, breastfeeding and counseling were combined into this category using the card co-occurrence analysis which depicted participants’ expectations of “after delivery” information. In contrast to “after delivery,” immunization was a high confidence category. Follow-up interviews with the head doctor at Okelele PHC revealed that even when women did not attend antenatal or postnatal sessions and did not give birth at healthcare facilities, they still brought their babies in for immunizations. We concluded that Ilorin mothers understood the importance of immunizations in protecting their children from diseases and untimely deaths.

Information architecture

Unlike the women who represented mothers, birth attendants, both skilled and unskilled, generally created three (3) categories of clustered images. Clustered images before labor were considered antenatal while the second category of clustered images represented labor/delivery. The labor/delivery was a new category birth attendants’ mental models that did not emerge in the participant mothers’ mental models. The birth attendants perceived all clustered images of “after delivery” to be postnatal. Categories were also arranged chronologically from top to bottom on the prototype.

The clustered categories were arranged in chronological order from conception to after delivery, regardless of the physical layout (e.g., top to bottom versus left to right). We concluded

that chronologically arranged information facilitates this particular group of women's abilities to find antenatal and postnatal care information. This confirmed previous research in which women living in rural Kenya also preferred chronologically arranged information (Thomas, Ranking & Mibuari, 2011; Thomas, & Rankin, 2015). As such, chronologically arranged information that reflects the different phases of maternal care will be used to define the information architecture of the next functional prototype interface. In addition to identifying categories that were most prevalent to Ilorin women, high confidence cards are candidates for group avatars or icons as words will not be used on the mobile application interface. We adjusted the confidence interval above 75% to identify very high confidence cards. For example, cards like 3 or 16 which resonated with 95% of participants as antenatal can be used to represent a group icon for antenatal information on the UI.

Beyond reading and writing, formal education influences various cognitive capabilities like language processing, visual organization and memory, mental spatial orientation, and general self-efficacy (Thies, 2015). This is evident in the differences in mental models of Ilorin women around maternal care compared to the expectations of the American-based research team that designed this study. For example, westerners tend to prefer topically arranged interfaces void of temporal information (Thies, 2015). It is also important to note that while differences in mental models and the underlying meaning of these models exists, there are also similarities. Though the images (cards) used in the study were selected by American researchers, they still created synergy for conveying meaningful information for Ilorin women. All these findings speak to honoring non-western women's perspective of life events and designing technology to support alternative world views.

Finally, *we asked how usable is Mtoto-bebe by Ilorin women?*

Mtoto-bebe Interface

The application was well received. As co-designers, participants were excited to see and use what they helped create. In analyzing data collected from all phases of this dissertation, identifying information like names were not included, and although we went to the same communities, it was not explicitly noted in analysis if the same participant was involved in more than one phase of this research.

More participants preferred to create video recordings over audio recording and participant also preferred to watch video content than they did listening to audio content. This is evident as all (100%) participants opted to make video recordings when given the option to choose. Even when the interviewer explicitly asked for audio recording from participants, they went further and volunteered to make video recording once they were done with the audio recording. With this in mind and given the current cost of and access to internet for this population, we ask the question: how can the Mtoto-bebe application backend be improved to reduce cost of data to its users.

Every respondent in this study stated they used or are familiar with WhatsApp. Therefore, video recording feature of Mtoto-bebe was designed to allow for a transfer of knowledge in the “hold to record” button for video recording. However, this feature recorded the highest general assistance score. It is unclear whether respondents also struggle to use the feature on WhatsApp or if they just never tried to use it. Further probe is required to determine if this feature should be left the way it is or if it needs to be refined.

Furthermore, Previous ICT interventions in LMIC context used mediation and a combination of modalities to make up for the inability of their target population to read. “Mediated Use” is when HCI4D researchers select and train mediators who are members of the

community in which an intervention would be deployed. In most cases of mediated use, only the mediator is given access to the application. Other users must go the mediator to use the application. In addition to mediated use, a combination of voice input through automatic speech recognizer (ASR) and audio description of buttons on an application were also popular.

Mediation: videoKheti & krishiPustak (Cuendet, Mehdi, Bali, & Cutrell, 2013; Medhi-Thies et al., 2014) depended heavily on mediation, the application was provided to select individuals in the respective communities in which they were deployed. These individuals had the applications installed on their mobile phone and were trained on how to use the application and they then allowed and helped other community members use these applications. Contrary to style of mediation, we found (as describe in the personas) that Ilorin women could benefit from a more organic form of mediation. As women who personally owned mobile devices but did identify as tech savvy stated they had friends or family who always used their devices to access internet applications like WhatsApp and Facebook. Therefore, Mtoto-bebe was deployed to users without assigned mediators or any form of prior training.

Audio description: on videoKheti (Cuendet, Mehdi, Bali, & Cutrell, 2013), one click on a button provided audio description of what the button does in the native language (dialect) to its users. Then a second click (or double click) provided the users the actual function of each button. While this kind of feedback can be helpful it becomes cumbersome once application scale is considered. In Nigeria alone there are over 500 spoken languages if users depend on audio feedback in their native language it becomes difficult for Mtoto-bebe to scale up past one ethnic group. To this end, Mtoto-bebe does not provide audio feedback in its design. Instead, the application is designed to leverage built-in accessibility APIs (e.g., screen reader) provided by Android and iOS mobile operating systems. We recommend that to design scalable applications,

HCI4D researchers should investigate and leverage mental models and dominant cognitive skills that already exists within no/low literate users in LMICs in their interface designs.

Automatic speech recognizer (ASR): no/low literate users especially in LMIC context can benefit from voice input. There are currently no full-fledged ASRs that can recognize languages and dialects in Nigeria. Designing systems like this is expensive and takes time. Interventions (e.g., videoKheti,) that have tried to include ASR in their applications capped the number of recognized words to 100. Which make such systems unscalable and hard to use without training or mediation because how do users know the accepted words? Until there are ASRs robust enough to recognize a broader range of words and phrases (to almost a conversational level) designed for languages in the global south, we advocate for the use of alternatives like images/photos as in Mtoto-bebe.

CHAPTER VII: CONCLUSION & FUTURE WORK

In this research, we designed, developed, deployed, and evaluated MTOTO-BEBE as an application that provided (non-literate) Ilorin women with greater access to ante-and post-natal care. First, to design an intervention that can achieve our goal of mitigating maternal mortality by bridging the gap between skilled birth attendants and pregnant women in Ilorin, we needed to first learn about the healthcare ecosystem in the community, ante- and post-natal services available to women and how these women access information as it pertains to ante-natal and post-natal care. We also needed to gain insight into how they accessed and used mobile technology. To do this, interviews were conducted, and questionnaires were created and disseminated to currently pregnant women, recently pregnant women, and skilled/unskilled birth attendants. Next, we investigated best practices for designing for no/low literate user and how these best practices can inform the design of Mtoto-bebe. To do this, activities using a combination of open card sorting (using images) and low fidelity prototype were designed for participants to complete. Finally, armed with findings from Phases I and II of the study, a functional version of Mtoto-bebe was developed and deployed. In phase III, I evaluated the functionality and efficacy of the application and its interface by Ilorin women. To do this, a functional version of the application was deployed using Expo Go, some women used the mobile phone we provided, and others opted to use their personal phones. Participants had to complete tasks that required them to navigate and use features of the application. To estimate the usability, general assessment score was used.

For mobile interventions to be adopted by LMIC populations, they should be usable by users with minimal or no training at all, and they should be robust to intermittent power and networking outages. Interdisciplinary and intradisciplinary research is needed to build and

evaluate mobile interventions that addresses healthcare for LMIC populations. Mtoto-bebe is at the intersection of multiple research areas including mobile computing, computing for social good, human computer interaction, human centered design, and public health. More research needs to be done in evaluating the efficacy of the applications interface and system among other Nigerian women. Furthermore, since the application is independent of words and language, it will be interesting to test its usability among low/no literate populations from other countries like Kenya and Haiti.

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