M-KULINDA: EXPLORING DOMESTIC SECURITY IN RURAL KENYA USING HOME ALERT SYSTEM

By

George Hope Chidziwisano

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ABSTRACT

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The use of sensor-based technologies is pervasive in today's world, especially in the developed world where its applications are well realized. From smart homes to tracking locations to monitoring health, sensor-based technologies are becoming ubiquitous. However, the role of sensor-based technologies in a rural Kenyan household is underexplored. I explore the potential of a sensor-based technology probe's approach to enhancing domestic security in rural Kenyan households, where property theft is a persistent problem. The 'technology probes' approach was used to allow participates to reflect on a new technology in their homes and provides data to researchers based on their reflections. I designed "M-Kulinda", and deployed it in 20 households for four weeks.

The study has shown that residents in rural areas have interest in using sensor-based technologies to solve their problems however there are constraints which prevent them from fully realizing the potential of sensors in their lives. The implications of this research encourages researchers in Human Computer Interaction (HCI) in the design space to incorporate solutions to constraints that hinder people in the developing world from using technology. The study also contributes to HCI by showing the positive impact of using technology probes of different research products in different settings to understand how people in that particular setting would use that particular product. Sensors should also be used to complement already existing measures of security in the home.

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Chapter 1 Introduction

Over 50% of crimes in the developing world involve loss of property in the domestic space through theft (burglary) (Grote & Neubacher, 2016). For example, In 2014, there were 2259 reported cases of burglary in Kenya (RISC, 2016). While crime rates are declining in industrialized countries (Farrell, Tilley, & Tseloni, 2014) they are increasing in developing countries (Grote & Neubacher, 2016) and within the developing world, sub-Saharan Africa is the most affected by crime. This is a persistent problem — especially in rural areas — and results in significant property loss. In this thesis, I refer to security as the state of being protected against theft (burglary) of personal property, as well as protection of the domestic space from intruders. Security needs, help in keeping people safe from any harm in their living premises (Oishi, Diener, Lucas, & Suh, 1999).

The increased levels of theft in Kenya and other developing countries are due to different factors that include: low education levels; alcoholism; poverty; unemployment; and rivalry among ethnic groups (Bunei, Rono, & Chessa, 2013). These factors perpetrate theft because they mainly leave families with inadequate income to buy food and other necessities for the home. As a result victims resort into theft. Various measures have been used in developing countries to provide security at community and household level. These measures include: community policing; state police stations; private security companies; and household security measures like fencing, dogs, and padlocks. However these measures are not 100% effective for different reasons. For instance, community policing in rural areas do not have enough resources to perform its services (Kioko, 2017). On the other hand, police stations are mostly far away from rural areas thus police officers cannot be easily accessed by rural residents (Bunei, Auya, & Rono, 2016). In most cases by the time police officers arrive they find that the perpetrator has long gone (Mkutu & Sabala, 2007). Additionally, most rural residents cannot afford private security officers as they are expensive.

These services are not affordable in a rural Kenya where GDP per capita is less than $1242 (Olney et al., 2016). Evidence from prior research that the existing measures are not effective justifies a need to find other way for protecting households in rural areas (Bunei, Auya, et al., 2016).

Sensors have been used to address different concerns (see (Brereton, Soro, Vaisutis, & Roe, 2015; Howard, Kjeldskov, & Skov, 2007; Kshetri, 2017; Zhao, Yisrael, Smith, & Patel, 2014)); however, their potential for home protection in rural Africa has not been widely researched. This raises the following research questions:

1. How does the technology probe's approach inspire design for homes in rural Kenya?
2. In what ways can sensor-based security systems be used for home security in rural Kenya?
3. How do participants' experiences change over time when interacting with the probe?
4. What future research opportunities can be drawn by deploying a sensor-based technology probe?

To answer these questions, I conducted a study in rural Kenya using various methods. The study was conducted in two phases: baseline and follow-up studies. In the baseline study, I deployed — "M-Kulinda" (*kulinda* is Swahili for "protection") a "technology probe" that uses sensors to monitor households by sending users an SMS alert when it is activated. Over a month-long period, I asked 20 rural Kenyan households, to use the probe and documented their experiences using multiple methods. These methods included: semi-structured interviews and observations that were used during baseline study; diary study and data logging that were used to collect data while participants had the system. During the second phase, I used follow up interviews to learn more experiences participants encountered with M-Kulinda.

Participants used M-Kulinda in various ways to provide security in their homes, for example, participants used the system to monitor their poultry, their electronic devices and their lives. Participants used M-Kulinda in this way by placing it in their living rooms – where most electronic devices are kept – so that they could receive alerts through their mobile phone when burglars attempt to break in. Findings also suggest that the system fostered neighborhood cohesion in rural Kenya i.e. participants consistently suggested including functionalities that would enhance neighborhood cohesion like alarms. Participants were able to live with a sensor-based technology probe in their households, their experiences provided more insights on how sensor-based technologies can be used in rural Kenyan households.

The discussion in this study provide different design aspects on how sensor-based technologies can be used to enhance security in rural Kenya. Additionally, the study's implications offer an understanding that crime detection systems prevent burglary in rural Kenya which is a different case – according to prior research – in the developed world. Furthermore, this study proposes a broader ecological structure that helps to solve the real problems that causes insecurity in rural Kenya. These problems among others include political rivalry between people of different tribes. Though this study did not explore how sensors can be used to enhance mutual understanding among people of different tribes and political values, the implications suggests that HCI principles can be used to explore how sensor-based technologies can be used in providing domestic security.

Using technology probes to study security in rural Kenyan households draws attention to how rural households in sub-Saharan Africa use sensor-based security systems to suit their unique needs. The study extends prior work on security in the home (Erete, 2013) by suggesting that unlike in industrialized countries, crime detection systems strengthens neighborhood cohesion and play a role in dissuading thieves from invading a home. Studying sensor-based technologies in rural Kenya also broadens the geographic boundaries where technologies have not been studied practically using technology probes. This work provides further opportunities in HCI for studying sensor-based technologies in rural Africa as providing participants with a sensor-based technology probe helped them to reflect on other ways of using sensors in their homes thereby enlightening areas that need further research.

Chapter 2 Literature Review

This chapter provides an overview of prior work that is most relevant to this research. This includes literature on the domestic space, security in HCI, technology probes and sensors. I also discuss some of the factors that influence the adoption of technology including sensors in developing countries.

2.1 Domestic Spaces

Various research studies in HCI have focused on designing technology for the domestic space (Bourgeois, van der Linden, Price, & Kortuem, 2013; Choe et al., 2012; Choe, Lee, Kay, Pratt, & Kientz, 2015; Goel, Zhao, Vinisha, & Patel, 2015; Hasan & Ditsa, 1999). Desjardins *et al.* analyzed 121 papers that focused on research in the domestic space. Most of the work was done in the developed world, However, homes aren't the same everywhere and people's desires differ across cultures (Alstone, Gershenson, & Kammen, 2015; Brereton et al., 2015; Farrell et al., 2014). This suggests that the way people use technology probes in two different settings may not be the same. Social and cultural setting of an area has a huge impact on how technologies are used (Farrell et al., 2014). There are also social challenges that influence how technologies are used in different places around the world (Farrell et al., 2014). These challenges include gender, illiteracy and financial problems (E. Oduor et al., 2014). For example, in some cultures across Africa, women do not have a right to keep information in their mobile phones private from their husbands (E. Oduor et al., 2014); it is difficult for illiterate people to use other technologies that require some academic background; and low income levels prevent people in rural areas from accessing full systems, for instance most Facebook users in rural areas can only access Facebook lite (a free version of Facebook) because they do not have enough financial resources to purchase data plans (Willems, 2016).

Most of the research in rural Kenya and other developing countries mainly focus on: mobile phone usage; and how mobile applications help to address socio-economic problems in agriculture, health and education (Bidwell et al., 2008; Evers, 2001; Haack, 1996; Hutchinson et al., 2003). Though these studies are crucial in ICTD and HCI, little is known about how rural Kenyan communities and other developing countries use and react to new deployment through the use of technology probes. Bridging this gap is important in HCI to allow remote areas like rural Kenyan households use technology probes in their homes.

2.1.1 Domestic Security

Although domestic security has been understudied in prior HCI and ICTD research, it is a topic that scholars in criminology recognize as significant. Crime is a persistent problem in rural Africa and the most common types include: burglars breaking in households; poultry theft; cattle rustling; and theft in grocery stores (Bunei, McElwee, & Smith, 2016). Prior research also suggests that farm invasion to steal crops is another common form of theft in Kenya (Campbell, Gichohi, Mwangi, & Chege, 2000). Although there are few examples of these studies in rural Africa, findings from Bunei *et al.*, suggest that crime in the home is a problem that requires investigation (Bunei, Auya, et al., 2016).

Findings from prior research suggests that rural areas are mainly targeted by “thieves” more than urban ones because rural areas do not have close supervision (Bunei, Auya, et al., 2016), that is rural areas often lack social services like police stations (Njuki et al., 2012). One way people have worked to solve this problem, is through “community policing.” It was introduced where neighboring households are close together. These households have their own authorities where members report crime and conflict cases. This security measure is called ‘Nyumba Kumi’ (ten houses) in rural Kenya and it has proven to help in reducing crime (Kioko, 2017); however, the integration of this initiative with technology has not been studied. Communities in rural areas rely on "Nyumba Kumi" as a strong measure for security in their households. For example, when a stranger from another tribe has been seen in another territory that does not belong to his community, "Nyumba Kumi" authorities are responsible for finding out the motives of the stranger. If the motives are not clear enough, the stranger is forced out of the community (Kioko, 2017). These initiatives are helpful in rural areas and studying how they can be integrated with sensor-based technologies would strengthening their efficiency in proving security.

Within HCI Oduor *et al.* developed a smartphone application to report crime and claimed that participants preferred using online platform to report crime (C. Oduor, Acosta, & Makhanu, 2014). Unlike in cities where use of smartphones if growing, rural Kenyan communities still rely of feature phones: over 85% of mobile phone users use feature phones (Murugesan, 2013), as such the outcome of using smartphones in research might not be representative of the rural population. Prior research suggests providing people in rural areas with technology like sensors to secure their homes. For example Tilley *et al.* studied the economically disadvantaged population, living in the U.K's rural areas (Tilley, Tseloni, & Farrell, 2011), and concluded that providing people with more technology to secure their homes may decrease burglary especially in poorer neighborhoods.

2.2 Security in HCI

Technology's possible impact on limiting crime has been studied in HCI, but not in homes. Erete investigated burglars' behavior and found that technologies that detect burglary like alarms are not effective in preventing burglars from stealing. Her findings suggest that "high community cohesion (neighborhood cohesion) is the most effective deterrent of burglars" (Erete, 2013). Based on these findings, she suggests that technology should be designed to encourage neighborhood cohesion, that is technology work to encourage collective action by community members (Erete, 2013). In other research that was conducted in England to assess the effectiveness of anti-burglary measures, it was found that different security measures have different outcomes in preventing burglary (Tseloni, Thompson, Grove, Tilley, & Farrell, 2017). Findings from this research suggest that individual devices like external security lights and double door locks are the most effective compared to burglar alarms. The implications of this study suggested that a combination of different forms of security in the home helps in deterring burglary (Tseloni et al., 2017). Though crime detection measures like alarms have proven to be less helpful in deterring crime in the home Farell *et al.* found that crime detection measures are 25 time effective in preventing cars from being stolen (Farrell, Tseloni, & Tilley, 2011).

In a related study, Lewis and Lewis analyzed 865 posts from a community web forum to examine the use of technology in community policing (Lewis & Lewis, 2012). They found that residents use the forum to strengthen social ties, discuss ways to take collective action, share information and advice, and regulate social norms of the neighborhood and web forum. They proposed that technologies intended for crime prevention should be designed to support communication and problem-solving discussions among residents, rather than just providing information to people in a particular community.

At the same time, research suggests that technology can play an integral role in promoting civil liberties for people with various socioeconomic backgrounds across the world (Erete, 2013). Inequalities that influence crime are perpetuated by local policies that have mostly been shaped by groups with political power (Erete, 2013). This is also evident in Kenya where mostly the poor have no say in formulating policies (Kimalu, 2002) and results in policies that seem to favor the rich thereby inciting crime and violence from the poor. Erete proposed that HCI researchers should consider the broader ecological infrastructure that affect social issues. These opportunities should also be extended to developing regions. This presents an opportunity for HCI researchers to investigate the role technology can play in crime prevention.

The outcomes of this research might be different from how technology work to provide security in other regions across the globe due to different social and cultural settings of an area as well as needs of the people living in that area. Few studies in the developing world have considered the domestic space a defensible area that should be protected from unwanted physical intrusion (Bunei, Auya, et al., 2016). Little is known about how technology protects the domestic space and its impact on potential intruders (Erete, 2013). I begin to fill these gaps in the HCI literature, by using a technology probe to investigate domestic security in rural Kenyan households.

2.3 Technology Probes

Hutchinson *et al.* described the 'technology probes' method as "a particular type of probe that combines the social science goal of collecting information about the use and the users of the technology in a real- world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and designers to think of new kinds of technology to support their needs and desires" (Hutchinson et al., 2003). Technology probes do not necessarily turn families into designers but allow participants to be active partners in the design process. Probes are used in the early stages of the design process and are not focused on a specific purpose or expected manner of use; instead, they are to determine possible future technologies (Hutchinson et al., 2003).

Luckin *et al.* described a technology probe as a "working design robust enough to be deployed in the wild for an extended period so that participants can interact with the new technology and integrate it into their practices." (Luckin et al., 2013). They underscored that a technology probe is not a model to be used for demonstration. This means that through deployment in the field, technology probes create a concrete experience that cannot be easily imagined among participants. Hutchinson *et al.* proposed that technology probes should have the following characteristics: they should be simple; they should collect data about their own usage; they should not be iterated further during deployment (they are not prototypes); they should be flexible and open in terms of how they can be used; and they should be used to test novel ideas and provoke new narratives and practices (Hutchinson et al., 2003).

This approach has been widely-used within HCI for exploring how to design technologies for domestic settings (Browne, Bederson, Plaisant, & Druin, 2001; Hutchinson, Plaisant, & Druin, 2002; Langdale, Kay, & Kummerfeld, 2006; Odom et al., 2014; Pantazi et al., 2008). For example, Hutchinson *et al.* deployed Message Probe, a simple application that enables families members that live far away from each other communicate using Post It Notes in a zoomable platform (Hutchinson et al., 2003). Message probe was deployed in the USA and Spain and their findings suggested that the technology problems prevented families from communicating effectively. Regardless of the existing technical problems, families still used Message probe for communication. Among others, the probe was used to pick up children from school. The probe was also used for communication within the family before having a get together (Hutchinson et al., 2003). These activities revealed new areas of interest that require further research thus technology probes can be used to understand participants' needs thereby opening doors for new research.

In another research, *Madden et al.* used the technology probe approach to determine if culturally appropriate designs of ICTs could help support individual well-being (Madden, Cadet-James, Atkinson, & Watkin Lui, 2014). The study involved designing and developing a web based technology probe that would allow Australian aboriginal women share their stories and send messages to each other. The probe allowed women to: post and respond to messages; create or comment on a story; upload a comment on an image; and create or comment on a family picture (Madden et al., 2014). Findings from this research revealed that technology probes cannot only be used for inspirational purposes but also for gathering functionality requirements to determine a way forward. Additionally, Madden et al. encouraged using mixed qualitative research methods – like participant observation, cultural probes, and technology probes – in the same study in order to allow researchers develop a more solid understanding of what designs would be desired (Madden et al., 2014).

Bourgeois *et al*. deployed tablets that displayed how households consume energy (simulation) in six French houses to explore benefits and drawbacks of using technology probes (Bourgeois et al., 2013). They found that technology probes approach is an effective way to understand needs and desires of a real world setting. Additionally, technology probes provoke creative and innovative behavior among participants. However, technology probes require proper design to fit each and every household since every home is different (Bourgeois et al., 2013). Technology probes can also not be deployed physically – like the way Huntchnson *et al.* did with Message probe (Hutchinson et al., 2003) – for some complex problems. In such cases simulation can be used as it was done in for the household energy monitoring. In cases where simulation has been used there are always challenges as seen from the Bourgeois *et al's*. work that participants complained that the tablets they were using were consuming more energy since it was always on (Bourgeois et al., 2013). Furthermore, as Hutchinson *et al*. (Hutchinson et al., 2003) and Gaver *et al.* (Gaver, Dunne, & Pacenti, 1999) underscored that probes at their heart carry something consisting of the desires and beliefs of the designer, they are not 100% unbiased. Technology probes embodies the values of the designer that are manifested in the single functionality of the probe itself therefore they are not completely unbiased in the design space (Luckin et al., 2013).

These studies that have used technology probes have taken place in industrialized countries. Prior research has proved that geographical, cultural and social settings of a region influence how people use technology. For example, Oyugi *et al.* discussed how cross-cultural differences affect evaluation methods (Oyugi, Dunckley, & Smith, 2008). They found that research approaches have different outcomes depending on location. Cultural differences in signs, meanings, actions, conventions, norms or values raise challenging issues in the design of usable localized artifacts (Evers, 2001; Yeo, 1998). For example, they deployed prototypes in the UK and Kenya and established that the DUCE method (see [32]) was successful in the UK not in Kenya. This suggests that the same approach used in two different regions might have different outcomes.

This study builds upon technology probes methodology by balancing these multi-disciplinary influences. I used qualitative methods for data collection to learn about participants' behavior during the course of the study; I deployed a research product that worked in a real world setting; and the research product inspired participants to reflect on their lives.

2.4 Sensors

Sensor-based technologies are providing new ways to augment human interactions with materials (Kuznetsov, Odom, Pierce, & Paulos, 2011). Findings from prior research suggest that new applications based on sensors have improved the way of life: networks to support agricultural production (Howard et al., 2007), sensing systems for real world applications in health (Chen, Patel, & Keller, 2016; Goel et al., 2016, 2015; Whitmire et al., 2016; Zhao et al., 2014), embedded chips on appliances like kettles to support communication among family and friends in the UK (Brereton et al., 2015) and sensor-based technologies for learning about outdoor environments (Kshetri, 2017). Within HCI and Ubicomp there have been numerous studies that have focused on sensor-based technologies (Choe et al., 2012, 2015; Houben et al., 2016; Kientz et al., 2008;

Tolmie, Crabtree, Rodden, Colley, & Luger, 2016). For example, through the Aware Home Research Initiative, Kientz *et al.* evaluated user experiences with sensor-based applications in order to develop applications that solve users' needs in the home (Kientz et al., 2008). This is a notable example of research that focuses on sensor-based research in the home (Kientz et al., 2008). Through this project, it was proposed that the design of smart home applications should start with gathering requirements from inhabitants of the homes through formative methods. Crabtree and Tolmie explored how non-digital materials in the home can be incorporated with digital materials. With sensors, almost everything can be connected to a network thus looking at things that have not been made digital is very important (Crabtree & Tolmie, 2016). I build on these prior works through the process they have used to deploy sensor-based technologies in the domestic space.

Previously, home security sensor-based systems have been designed to be used for research in developing regions (Huang, Xiao, Meng, & Xiong, 2010). Among these, most of them rely on broadband internet services to provide feedback to users whenever crime is detected (Huang et al., 2010). As such, this only works in areas where broadband Internet services are available. In areas like rural Kenya, it would be difficult to use Internet based home security systems due to poor connectivity (Murugesan & Services, 2013). A review of prior work on sensors for security suggests that sensor-based system that would work on GSM network were only used for research purposes (Huang et al., 2010).

Research investigating sensor-based technologies in developing regions are few, despite their potential for addressing problems. However there are exceptions. For example sensors have been used to; protect cattle from theft (Kshetri, 2017) and track goods on transit using GPS (Crow, Davies, Paterson, & Miles, 2013). For instance, RFID based sensors have been used to track export cargo from factories to the frontier offices. A great impact in reducing diversion of goods in transits was realized after using RFID technologies (Siror et al., n.d.). Additionally, in Kenya there have been substantial advances where sensors are attached to animals in order to track their movement. Sensor-based technologies can be used in rural areas where livestock are free range. Sensors would be used in this case in order to track livestock thereby keeping them within their grazing area (Dlodlo, 2015). This is very important for a small scale farmer in developing countries because other than cattle, most animals in those regions are free range. As such, once a livestock has been stolen, it can be easily tracked (Baumüller, 2013).

Mainly, the use of sensors in most developing regions have been realized at institutional level rather than at household level. For example, in agriculture sensors have been deployed in Africa to improve agricultural products. Masinde *et al.* described how the adoption of mobile phones and wireless sensor-based technologies are being used in Africa to provide immediate weather information to farmers (Masinde, Bagula, & Muthama, 2012). Their findings revealed that local collection of weather data using sensors provide a better way of delivering information to local communities through their mobile phones. The positive impact of this research on rural communities cannot be questioned however their approach did not provide a direct interaction between sensors and users. The sensors that collected weather data were not under the control of residents: residents were just recipients of weather information through their mobile phones. This approach has been used in many projects on sensors across Africa (Haack, 1996; Raji et al., 2015; Vogt et al., 2006). There is a need to deploy sensors directly in rural African households and understand how residents can interact with them and their impact.

2.5 Technology Adoption and Its Challenges

Technology adoption can either be studied at personal or household level. Brown *et al.* underscored that various researchers have studied technology adoption at personal level however not many studies have focused on technology adoption at household level (Brown & Venkatesh, 2005). Among other factors household lifecycle and income are the major factors that determine how households purchase property. Gilly and Enis proposed a theory that families go through different stages and each stage may determine what kind of property families need (Gilly & Enis, 1982). For example, "young families may like eating out while older families may want to acquire materials things such as automobiles for their households" (Brown & Venkatesh, 2005). The prior work provides theories that help in understanding why do people adopt technology however it is also important to go further and explore specific technologies that are adopted in the home.

Parente and Prescott proposed a theory of economic development that focuses on technology adoption and its barriers (Parente & Prescott, 1994). They underscored that for countries that have huge barriers to technology adoption, there is a need for more investment than countries that have fewer barriers of technology adoption (Parente & Prescott, 1994). The following paragraphs explain these factors: cultural values, inadequate access to electricity, inadequate access to the internet and lack of required infrastructure.

Traditional values and beliefs play a big role in most African rural areas however many aspects of technology are not culturally neutral (Hasan & Ditsa, 1999). Hardware and software are typically developed in industrialized countries. In rural areas, especially in developing countries, people deeply believe in their ancestors' cultural beliefs and these beliefs may be counter to some technologies. Through empirical evidence, prior research has revealed that culture plays a big role in influencing technology adoption including those that are based on sensors (Bagchi, Cerveny, Hart, & Peterson, 2003). Baghi *et al.* found that even after controlling some factors like economy and other indicators, there was some resistance in adopting computers, phones and internet in West Africa (Bagchi et al., 2003). Furthermore Hasan *et al.* found that three dimension of culture – power difference, uncertainty avoidance and time orientation – are major factors that hinder technology adoption. Those in power to preserve cultural values i.e. chiefs are often fearful of open nature of technology. This results in negative perception from rural residents towards technology when their elders are not positively accepting modern technology (Hasan & Ditsa, 1999). Additionally, some traditions perceive technology as risky in that it can bring diseases – for example beliefs that Bluetooth is dangerous as it is radioactive (Plotz, 2017) ;however, the rapid uptake of mobile phones in Kenya shows that people adopt technologies very fast.

Inadequate access to electricity is another problem that hinders adoption of sensors in developing countries. For example, in Kenya only 4.5% of rural households are connected to grid electricity (Ngugi, 2013). Intermittent power failures are also a challenge even for those who are connected to grid electricity. Rural residents who are off-grid rely on charging their mobile phones and other appliances in charging kiosks. In most developing countries, the use of "market based solar electricity" is increasing to subsidize intermittent power failures (Jacobson, 2007). For example, in 2009 only 5% of Kenya's population were using solar power in their homes (Byrne, 2011). As of 2015 the percentage of solar power users exponentially increased: over 10 million people (25%) are relying on solar power for lighting their houses and charging their electrical appliances (Arvidson & Nordstro, 2004). Households are now adopting solar power as an alternative to grid electricity through the existing pay as you go systems like M-Kopa (Arvidson & Nordstro, 2004).

Most sensor-based technologies require a robust network infrastructure with good internet availability. However, access to internet is a significant challenge in developing countries for a number of reasons including high cost associated with internet services, poor devices that are used to access the Internet as well as poor network infrastructure in rural areas (Coetzee & Eksteen, 2011). Over the last five years, broadband usage accessibility has increased in developing countries however it is not fully utilized due to two main reasons. First the cost associated with accessing broadband is very high. For example, in Malawi 1GB of internet data (which should be used within 1 week) provided by Airtel costs slightly more than $2. This is a very huge amount for a person who lives in a country where people spend less than a dollar a day (Coetzee & Eksteen, 2011). Second, though the Internet is available there is poor infrastructure to use the Internet. In rural areas of developing nations people rely greatly on feature phones which cannot be connected to the internet (Coetzee & Eksteen, 2011).

In some areas there is no network connectivity i.e. internet access and GSM network. This is a challenge for a successful deployment of sensor-based technologies since they mostly rely on availability of network. Prior research suggests the introduction of other network infrastructures like Television White Spaces (TVWS) that provide internet in areas which are not connected (Kumar et al., 2016; Murugesan, 2013; Nychis, DeBruhl, & Tang, 2014; Roberts, Garnett, & Chandra, 2015). In Malawi, TVWS was used to provide Internet in some schools and hospitals. However, the project only lasted in its pilot phase because the Government of Malawi had no money to successfully implement the project (Murugesan, 2013).

Chapter 3 System Overview

M-Kulinda is a sensor-based technology that is used to detect movement. Upon detecting motion, the system sends a text based message to a mobile that hosts a SIM card of a number embedded in the source code. Figure 1 illustrates the workflow of the system. There are other products of market that also has the same functionality as M-Kulinda however it was necessary to develop a specific prototype for this research for two reasons. First the products that were available on the market required use of grid electricity hence participants who do not have grid electricity would not be able to use the system. Additionally, products that were available on the market used a different form of network other than GSM. For example, most of the products required the use of Internet which is a scarce resource in rural Kenya.

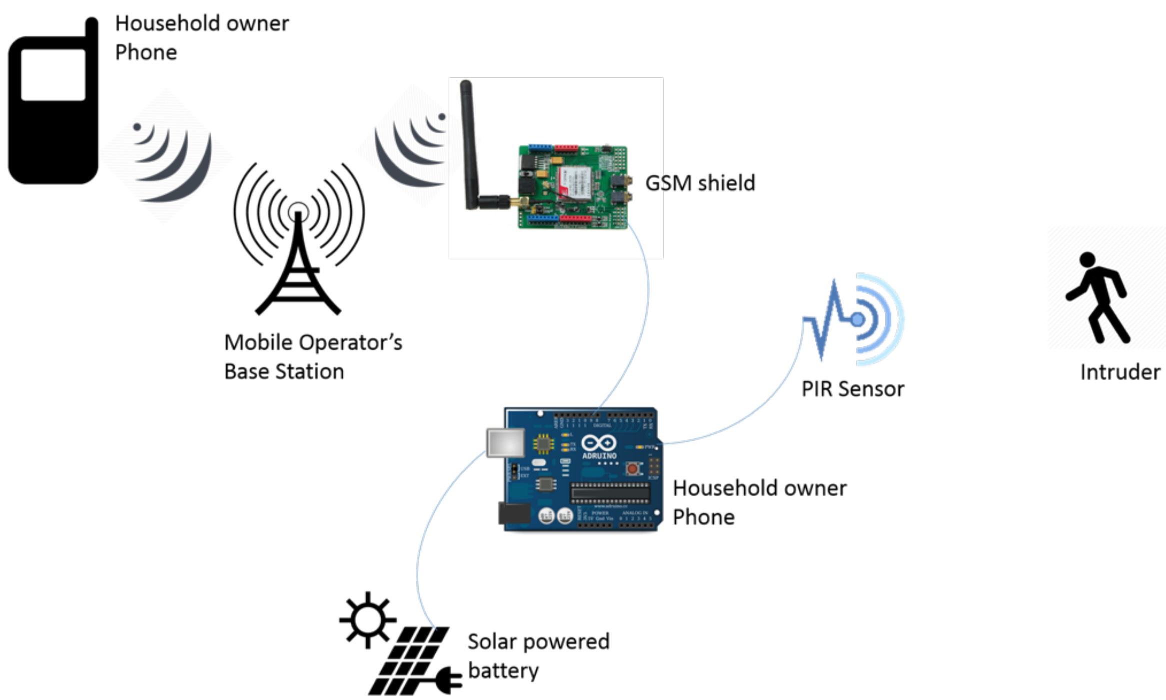

Figure 1: This figure shows system architecture for M-Kulinda and how the system works

When the system is switched on, it is activated by any motion it senses within its line of site. The signal is sent to the micro-controller that triggers the GSM shield to send a message to phone number indicated in the source code. The next sections discuss M-Kulinda's hardware and software.

3.1 System Hardware

The main components of M-Kulinda are: a control box that includes an Arduino microcontroller, SIM900 GSM shield, light emitting diode (LED) and a Pyroelectric Infrared (PIR) motion sensor. I used the Arduino microcontroller because it is open source (Pearce, 2012) and affordable. Each GSM shield has a slot where I inserted a SIM card; I added 100 KES (about $1) of "credit" to each SIM card. This was necessary to send messages to participants' mobile phones. A solar-powered battery, powered the system; it lasted up to 30 hours with a full charge.

I used a PIR sensor, rather than a reed switch (a fixed electrical switch operated by an applied magnetic field) because I wanted the probe to be mobile (Ha, Lee, & Lee, 2006), that is I wanted participants to be able to choose where to place it during evaluation. The PIR sensors detect motion made by humans and/or animals (up to 20ft and at a 120^0 detection angle) based on the amount of infrared radiated from the surrounding; when there is a change in the amount of infrared, the sensor detects the differential from its threshold hence it triggers a signal even in the dark (Zappi, Farella, & Benini, 2010).

3.1.1 Hardware Development Process

The GSM shield consist of a manual switch that should be activated when powering up the shield. Since the shield would be inside a box, there would be no way to access the switch from outside. I soldered the switch thereby completing the GSM shield's circuitry so that it should always be on. Thereafter, I connected the GSM shield to the Arduino board by stacking the shield on top of the Arduino. Following this, I connected the PIR sensor to the terminals of the Arduino by soldering them. Since, the PIR sensor has three terminals: I soldered the 5V terminal to the 5V terminal of the Arduino; ground terminal to the ground terminal of the Arduino; and the output terminal to pin three of the Arduino. Additionally, I soldered the positive terminal (anode) of the LED to a 0.5kΩ resistor. Then I connected the other end of the resistor to pin seven of the Arduino. The negative terminal (cathode) of the LED was connected to the ground pin of the Arduino. That completed the circuitry of the system.

Figure 2: These figures consist of different phases during prototype fabrication. These include testing the hardware before assembly, making openings on the enclosing box, fixing PIR sensors to the box and final research products. This process took place at Michigan State University, College of Engineering

The next step required me to make openings on the enclosing box of the system. There were four openings I was supposed to make for the following: PIR sensor, since it cannot detect motion when it is blocked by an obstacle; GSM shield antenna so that it can easily access network; LED light so that users can easily see when the system is on; and plugging in the power cable to the Arduino. I used a drilling machine at MSU's College of Engineering Make Central to make the openings. This process required precision and accuracy so that the openings should not be too big or small. After that I made breadboards (7cm X 4.5cm) that were used for fixing the system into the enclosing box. I made for holes on each breadboard that would be used for screwing the board onto the box.

Each base of an Arduino was soldered to a breadboard thereby concretely fixing the system. Following this, I screwed each breadboard into the box thereby fixing it tightly. Then, I used epoxy glue to fix each PIR sensor on its opening inside the box. Following this, I fixed each LED on its opening in the box. Thereafter, I inserted each antenna on its opening and connect it to the GSM shield. Finally, the box was covered and screwed.

3.2 System Software

The system was programmed using a platform called Arduino, a simplified version of C++ programming language (See appendix for the source code that I developed to control the system). Jamieson defined an Arduino as an open source electronics prototyping platform based on flexible, easy to use hardware and software. The Arduino software consist of C++ libraries which can be encapsulated in Arduino scripts. The Arduino platform has an Integrated Programming Environment (IDE) that can be used for writing source code to be embedded in the micro-controller. One of the reason why I chose the Arduino platform is that it can work on different operating systems including OS X, Windows and Linux. For this project, I installed and used the

IDE on OS X. The OS X worked as an interface between the IDE and the Arduino board: I was able to program the Arduino board over a USB connection to the computer.

Another reason why the Arduino platform was chosen for this project is that it is convenient for prototyping. This is because the platform contains many libraries that can be encapsulated into the source program there is no need to develop all the functionalities required. For example, this project used a GSM shield which requires C++ functions to control its communication with Arduino. I did not develop any functionalities to control that communication since there are already existing libraries that can be included in the source code.

Furthermore, the Arduino software is free and open source. This provided me with a wide variety of examples that I could access to see how other developers used the Arduino platform. For example online platforms like Stack Overflow (Anderson, Huttenlocher, Kleinberg, & Leskovec, 2012) and Seeedstudio (Pro, 2017) provided answers to programming challenges I faced. It was easy and fast to debug errors and move to the next step. For instance, on Stack Overflow there are many examples of controlling peripherals that are attached to the Arduino. This helped to understand better how I connect GSM Shield and PIR sensor to the Arduino.

Chapter 4 Methodology

This chapter provides the research methods that were used to answer the research questions posed in the introduction. This research used the mixed methods approach. Johnson *et al*. defines the mixed methods approach as an intellectual and practical synthesis based on qualitative and quantitative methods (Johnson, Onwuegbuzie, & Turner, 2007). Qualitative methods (as explained below) were mainly used to: build trust and good rapport with participants; understand security background of the area; and understand participants' general experiences and reflections of the M-Kulinda. On the other hand, quantitative methods were used to log time stamps when the M-Kulinda was used by participants. In the next section I discuss: the study context, participants and sampling methods, data collection methods and analysis.

4.1 Study Context

The study took place in Bungoma County, Kenya, a rural area located in the western region of the country. Bungoma County was chosen out of Kenya's 47 counties because the research team has previously been collecting data in that county. Bungoma is about an eight-hour bus ride from Nairobi, Kenya's capital. Participants lived in three of the county's rural constituencies: Kanduyi, Kabuchai and Bumula. Similar to other rural settings in Africa, small-scale agriculture is the primary source of employment for 58 percent of households (Wiesmann, Kiteme, & Mwangi, 2014). Other than agriculture rely on small scale businesses like: selling groceries, fish, and farm produce; ferrying people using motorcycles and bicycles; and selling airtime scratch cards.

Figure 3: This figure shows map of Kenya highlighting Bungoma County where the study for the project took place

Households mainly rely on biomass as a source of energy (74.6%) (Rabah, 2005) and it is mainly used for cooking in the form of firewood and charcoal. Only 4.5 percent of households in the region are connected to Kenya's national electrical grid (Ngugi, 2013). The use of solar power is increasing in Kenya to allow households that cannot afford grid power access clean energy through pay as you go approach (Rolffs, Byrne, & Ockwell, 2014). As of 2015 over 10 million people are relying on solar power for lighting their houses and charging their electrical appliances (Alstone et al., 2015).

Mobile phone ownership is widespread with more than 80% of the population using mobile phones (Poushter & Oates, 2015). Domestic security is a major challenge in Bungoma. During the formative fieldwork I conducted in 2016, participants complained of losing their poultry, livestock, electronic devices and agricultural produce to thieves. The levels of crime are high in rural areas where police units are far away (Bunei, Auya, et al., 2016) and prior research suggest that 98% of residents witnessed crime within the last three months (Musoi, 2014).

4.2 Participants and Sampling Methods

Two local research assistants helped to identify participants, and to gain access to their households. In this study a household is defined as "a person or group of people, related or unrelated to each other, who live together in the same dwelling unit and share a common source of food" (Munene, 2003); 20 participated in the study. This sample size was proportional to the number of research products that were available: hardware fabrication process required more time hence it was difficult to develop more products and the study's budget was limited to 20 research products. Though the sample size was small for statistical analysis I had enough time to collect in-depth data from each participants through the use of qualitative research methods like in-depth interviews and diaries. Over the course of the deployment I primarily interacted with the head of household (12 men; 8 women). In some households, neighbors and children also participated in the interviews. Participants were recruited using snowball sampling: a sampling technique that yields a study sample through referrals made among people who share or know of others who possess some characteristics that are of research interest (Biernacki & Waldorf, 1981). This technique was used because I wanted participants who are well known and trustworthy as prior research that involved deployment studies indicated theft of probes (Matsuda, Nittono, & Ogawa, 2011).

Participants were involved in different kinds of income generating activities that included crop and poultry farming (9) like growing maize, millet, and rearing chickens; full wage employment (an administrator of community based organizations and her driver) (2); small-scale grocery store business (4); shoe repairing (1) and mobile phone repairing (1). Three participants were involved in volunteering in community based organizations. Participants who were involved in volunteering once worked as primary school teachers: they started volunteering after they retired. These participants are also involved in subsistence farming.

Descriptive	**Number of Participants**
Women	12
Men	8
Live in Bungoma CBD	8
Live out of Bungoma Central Business District (CBD)	12
Have Electricity	12
No electricity	8

Table 1: This table shows different attributes for the sample that took part in the study. The data is from a study conducted in May 2017 in Bungoma County, Kenya

One feature that distinguished participants was that participants who lived close to Bungoma Trading Center had access to different utilities like water and electricity while participants who lived in the outskirts did not have access to the utilities. It is a common trend for most African countries that in rural areas, households which are far away from the trading center do not have access to utilities (Komives, 2005). Twelve participants' households were not connected to the country's electricity grid where are eight participants were connected to grid power. Participants who were not connected to grid electricity mainly used solar energy to power their houses. All the participants who had grid power in their houses also had running tap water in their houses. The main distinguishing factor between participants who had access to services like electricity and tap water in their households was that participants who did not have those services lived off grid. Thus twelve participants lived in areas where they do not have access to grid electricity and tap water infrastructures. These participants mainly relied on firewood and charcoal for cooking; and kerosene and solar power for lighting their houses.

4.3 Data Collection

This was a two-phase study and in both phases, I primarily used qualitative research methods to collect data. The first phase, or baseline study, involved interviews, M-Kulinda deployment and home tours and the second phase, involved follow-up interviews and observations. The study also used diaries (Wiseman, Conteh, & Matovu, 2005) , that gave participants to document their experiences on daily basis for the whole period of study. Additional data collected included: time stamps when participants received alerts from the probe through messages that were logged into the SIM cards and messages participants sent to the author during the period of the study. The messages that were logged into the SIM cards consisted of time stamps whenever the system was active.

4.3.1 Phase I: Baseline Study and Prototype Deployment

English is widely spoken in Kenya and this was the language used during interviews. The interviews took place in the "sitting room" in participants' homes. Some of the questions that were asked included: what measures do people use to provide security of their property? Tell us about recent examples where you witnessed insecurity in the area? What do you know about sensor-based technologies? (Refer to the appendix for full interviewing protocol that were used). At the conclusion of each interview I toured participants' compounds to observe what security measures they used and then gave them the probe. On a daily basis, I wrote field notes to document the home tours for that particular day. The field notes consisted of some of the most interesting things I observed in participants' homes during the study. All interviews (during the first and second phases) were digitally recorded, and with participants' permission I took pictures during sessions.

Following these tours, I introduced the probe to participants. Participants were trained how to use the M-Kulinda. I first explained how the probe worked and then demonstrated it. Each participant provided their phone number so that I could embed it in the source code (set of instructions for controlling the probe). Thereafter, I embedded the source code into the probe using a laptop. Finally, I unplugged the M-Kulinda from the laptop. I then powered it with the solar battery. I then asked participants to move around along the line of sight of the probe, and sent them a test SMS message. I also gave participants instructions they could refer to over the course of the deployment (Figure 2). Lastly, I gave participants the primary researcher's mobile phone number and encouraged them to call if they encountered problems.

During this phase, I also gave participants the diaries and asked them to record their daily experiences with M-Kulinda over the four-week deployment period. Diaries included the following prompts: has anyone commented on the sensor today?; did you receive any messages from the sensor today and if so, what was your reaction?; and any comments about the system (see Figure 2).To motivate them to keep writing in the diary I sent them 100 KES (about $1) worth of mobile phones credit every week.

Thank you for agreeing to participate in this study. Please respond to questions that seem relevant to you—everyday. Limit your answers to 1 to 3 sentences.

1. **Did anything surprising happen at your compound today?**
2. **Has anyone commented on the sensor today?**
3. **Did you receive any messages from the sensor today?**
    a. **If so, what was your reaction?**
4. **What time(s) was system on today?**
5. **Any comments about the system?**

When recording your entries, please provide the date and question number.
This book is property of Please return it to
after the study is over. If you have questions call me at

Figure 4: This figure shows diary study guidelines participants used to enter data into the diaries. These guidelines were printed on the cover page of the diaries

4.3.2 Phase II: Follow-Up Study

Three-to-four-weeks after the initial interview, I returned to participants' homes to conduct follow-up interviews. The goal of these interviews was to learn about participants' experiences with the M-Kulinda, in particular what (if any) impact if had on domestic security. The interview protocol included these questions: tell me three things you appreciated about the system; tell me three things you did not appreciate about the system; tell me about receiving messages; when did you receive them and what was your reaction? what should be changed about the system and how do you see your future life with the use of sensors. During this phase I also toured participant's compounds, asking them to show us where else they used the probe (for those who placed outside of their homes). As compensation for their participation, recipients received the solar charger, used to power the system (valued at about $25).

4.4 Data Analysis

Data analysis began in the field; I wrote field-notes documenting observations every-day. Interviews were then transcribed and I used open coding to identify themes (Strauss, 1987). I then, used an affinity diagraming process to organize these categories into groups based on their relationship at a higher level—these are the findings presented here. The credibility and trustworthiness of these findings was enhanced through triangulation, which involved the analysis of the field notes, interview transcripts, digital photographs, diary entries, messages sent from participants as well as data collected from the logged-on SIM cards (documenting when SMS messages were sent).

Chapter 5 Findings

This chapter begins by providing an overview of participants' compounds and the security measures they use in their homes. Next I present the findings about their experiences with M-Kulinda, this includes their general reactions to the system as well as their perceptions of sensors. Significantly, I found that M-Kulinda prompted different reactions from participants; it successfully worked as a technology probe. Despite its single functionality, participants used the probe for a variety of unexpected purposes.

5.1 Participants' Households and Security Measures

Most participants lived on compounds: that is demarcated areas with more than three structures on them, including a main house. Structures on compounds typically included a house where parents sleep and where household's most valuable property (e.g., TVs, radios, and food) was kept. They also included a boy's house, a girl's house, a pit latrine, a poultry house, and a kitchen. All structures were typically constructed out of brick, mud and/or thatch and had corrugated sheet metal roofs.

Participants used different materials to define their properties' boundaries, and these also served as an initial security measure. To limit entry to their compounds these participants had a large iron gate with a sliding bolt lock (see figure 3). Those participants who were unable to afford these measures used banana trees, hedge and sisal to fence their households. Participants mentioned other forms of security used to protect their homes, such as using watchmen (*askari* in Swahili), and having multiple doors (layers on each other), for example a grill door, followed by a steel door and finally a wooden door. Iron doors that could be locked were preferred, but expensive.

We also observed this layering on windows: wire mesh, glass and grill wire. The security measures mentioned above are used to provide first line of defense—they deter thieves when they try to break into a compound and make it difficult for thieves to break in, for example a grill door provides participants with more security than a wooden door. However, when asked whether these forms of security are effective, participants' responses were mixed for example "Davis"[1] said:

They are not 100% reliable (...). Because you need something which is okay, when you look back you have like something solid, which you are sure about that: my home is secured. You are sure about that but with the key and a wooden door anybody can break in, it's not really secure.

These and similar responses suggests that the current measures of security are not reliable. Participants use these measures only because they have no other options to complement these already existing measures of security in the home.

Figure 5: This figure shows different security measures participants used to protect their households. This data was collected in Kenya's Bungoma County in May, 2017

[1] To preserve their anonymity, we replaced participants' real names with pseudonyms.

Participants expressed mixed views regarding the status of security in the households of Bungoma city compared to rural areas. Participants who live in remote areas from Bungoma city, said that the security in the area has been good. On the contrary participants who live in the areas close to Bungoma city said that the security in the area is not good. Davis described the security of the area in this way:

"It is one of the poorest area in terms of security. After the interview I will show you outside this house, I have been rearing chicken. It was on Tuesday last week they broke my kitchen and they took off all the chickens. They were around 15. In January this year thieves came, we were not around. They came and actually they wanted to break into this house but because we had... because we had an inner padlock so they destroyed the one that was outside but they were unable to cut the one that was inside. But they successfully entered the kitchen. They took some chickens that were there and this bicycle".

Figure 6: This figure shows a participant's chicken house that was destroyed by thieves. This data was collected in May 2017 in Bungoma County, Kenya

Overall, participants said that insecurity is mostly common during rainy season and at night. As participants expressed "when it is raining it is somehow hard to get the sound of things happening around so they take advantage of that as opposed to when it's calm and you can easily hear thus making them fearful."

5.2 Experiences Using M-Kulinda

Nineteen participants used the probe throughout the four-week evaluation period; one participant encountered technical problems that limited his use of the probe. Participants told me that they mostly used the M-Kulinda at night because during the day there was always someone at their home, typically women who are largely responsible the domestic activities (e.g., cleaning, food preparation, childcare, etc.). Evidence from the data collected from the SIM cards supported what participants said: more than 850 alerts out of a total of 1176 alerts were received between 5pm and 5am as shown in the graph in figure 5.

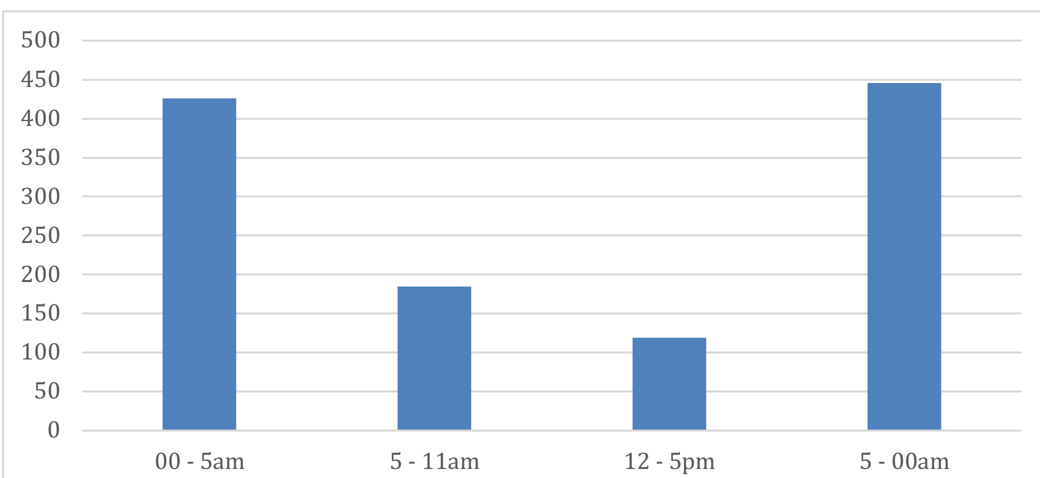

Figure 7: This figure is a graph showing different times participants received messages during the four week period. This data was collected in May 2017 in Bungoma County, Kenya

During the baseline study participants said that crime mostly takes place at night which may explain this finding. Though data from follow-up study indicated that there was no crime reported during deployment period for all participants, we learned that chickens and agricultural produce were most likely to be stolen at night. M-Kulinda had no mechanism of detecting false alarms however data from diaries suggests that eight out of 20 participants found M-Kulinda useful for detecting intruders including unexpected visitors. Another reason our probe was mostly used as night, was because of charging the battery, which had to be done during the daytime.

Figure 8: This figure shows an example of how participants who did not have grid electricity in their homes charge solar batteries to power M-Kulinda. This data was collected in May 2017 in Bungoma County, Kenya

5.2.1 General Reactions to M-Kulinda

All participants were enthusiastic about the M-Kulinda. They were appreciative that the probe helped them monitor their premises when no one was there: they especially liked that the probe was able to send them an SMS alert. Martha's comments captures other participants' enthusiasm for the system, she said:

The sensor was able to send me a message whenever it has detected something. I was happy there was something watching over my house. I could have a peaceful sleep.

Other evidence that suggested the probe was successful, included the SMS messages participants sent to the author and their diary entries. During the study, 14 participants called and sent messages (at least three times) to the principal researcher on a weekly basis (Figure 5). This appreciation for the system extended beyond participants and also included their neighbors who expressed interest in participating in the study, and some of these messages were inquiries into whether or not the neighbors could also participate in the study.

At the conclusions of the deployment, it seemed that participants generally had positive experience with the probe, as evidenced by their integration of the probe into their everyday activities, how they used it and concerns expressed at the end of the study about us taking the probe back, for example:

So you are taking the sensor? Why are you taking it away, I got used to it. Can I buy it?

Of course, this positive feedback may be biased and influenced by the researchers' affiliation with an American university (Dell, Vaidyanathan, Medhi, Cutrell, & Thies, 2012), however, the consistency and frequency of the positive reactions led us to generally conclude that M-Kulinda was useful for responding to participants' concerns about domestic security.

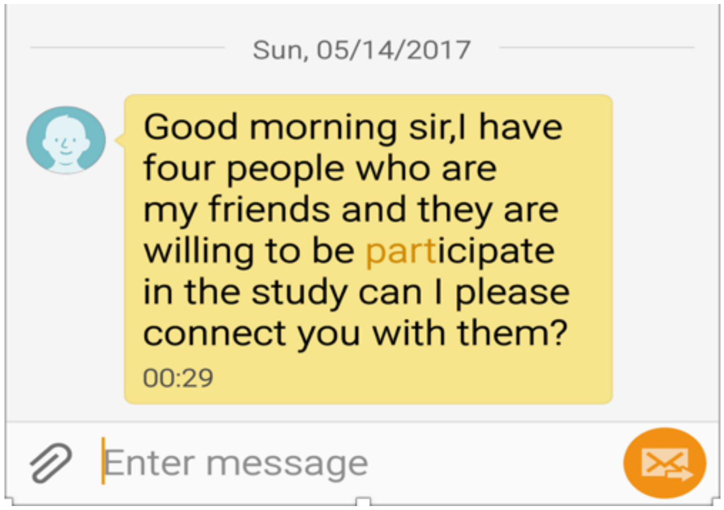

Figure 9: This figure shows a representative SMS from participants to me during the study period. This data was collected in May 2017 in Bungoma County, Kenya

5.3 M-Kulinda Usage

Technology probes should give participants flexibility so that they can be used in different ways (Hutchinson et al., 2003); here I describe instances of this in the study, they include home surveillance, neighborhood cohesion and complementing non-digital forms of security in the home. The total number of messages by all participants support that participants used M-Kulinda on daily basis. As shown in table 1, there were 1176 alerts for the whole period. The mean number of alerts was 58.8 with a range of 0 – 90 alerts per participant. This means that on average participants received two alerts each day.

Attributes	Values
N	20
Total alerts	1176
Mean per person	58.8
Mean daily alerts	39.2
Mode	57
Median	62.5
Range	0 – 90

Table 2: This table shows number of messages participants received during the period of study. The data is from a study conducted in May 2017 in Bungoma County, Kenya

5.3.1 Home Surveillance

Despite installing M-Kulinda in a specific location in the households, 16 participants told us that they were able to use the probe in different places. These participants appreciated the probe's portability, because they were able to use it in different locations around the household as well as outside of their homes. Where they put it depended on participants' personal needs. For example, the most frequent use was monitoring poultry in the home. In Western Kenya, chickens are important for food and income. "Francis" used the probe for monitoring his chickens after noticing that they were dying mysteriously, he explains:

There was a time before the sensor came, some chicks were missing and I didn't know what was taking them but I wanted to know. When I put the sensor on top of the chicken house, it sent me a message. I rushed to see. I found big rats which caught the chicks. I was happy to know what is causing the problem.

Another example demonstrates how the M-Kulinda was used by men to monitor movements of family members. Similar to other rural settings in Africa (David, 1971), patriarchal attitudes remain the norm, and I encountered men who wanted to use the system to monitor their wives and daughters' movements, for example "Joel" heard rumors from his neighbors that his daughters sneak out at night and go to dances; he used the probe to find out whether what he heard was true.

I placed the probe in the girls' house and went back to sleep. Immediately it reached at 2am, I heard a message that something has happened. I woke up slowly and then I went slowly at their house. I did not knock, I did not do anything, quietly I hide there I heard they were talking, talking about an incidence that has happened at the dances that night, I heard all the story and I confirmed that it is true the girls sneak.

Participants also used M-Kulinda in their shops, for example, had a small business in town where she sold cold drinks and other groceries. She said that she used the system to monitor what time her employee came to work:

I placed the sensor in my shop, switch it on in the evening when I [knock off], in the morning, I receive alerts when my employee gets to work. At least I know whether she is late or not.

After using the probe, seven participants acknowledged using it to complement measures of security they have been using before. These participants expressed that the probe alerted them whenever an intruder tried to tamper with security measures they put in place, Betty explains:

At night, I switch the sensor on. Before the sensor, I used to work up every time I hear dogs barking. Things completely changed the time I was using the sensor: when I hear dogs barking, I *don't work up right away, I wait until the system alerts me as well then I know something serious is going on.*

These uses of the M-Kulinda demonstrate the multiple ways participants used the system to make it fit into their daily routines, especially to protect their priorities, whether it be monitoring their poultry, children, or shops. M-Kulinda changed participants' way of doing things as evidenced by different ways participants used it. For example, some participants said that they woke up every night to check around their compound but with M-Kulinda they only wake up if they have received an alert from the probe.

5.3.2 Experience Over Time

The trajectory of how participants experienced M-Kulinda changed over the course of the deployment. Chronologically, these experiences consisted of moments of excitement, frustration, acceptance and appreciation. Diary entries at the beginning of the study (first week) indicate that participants had high expectations as they consistently mentioned that they are thankful that they have found a new way of protecting their homes. Participants also frequently showed the probe to their neighbors and commented on this in their diaries, writing that their neighbors wanted to acquire the probe. Also during installation of the probe, participants expressed excitement when they received an alert on their phones. They were curious on how the system was working. For example, here is Mable's reaction after testing the probe and seeing that it is working:

So is it you or the sensor that sent me an alert? How is it working? I am excited I will know what is going on even if I am not at home.

There were also some problems with the probe and after two weeks, nine participants called the principal researcher describing challenges they faced, these typically were related to keeping the solar battery charged, specifically it was taking too long to charge and they did not want to leave the battery outside (without monitoring) because someone may steal it. One participant explains:

The charging process takes long and I can't leave it outside by itself. It might be stolen. Sometimes I take the battery with me and charge it while I am at my garden.

Another frustration, identified in participants' diary entries were related to the high number of alerts they received on their mobile phones, indeed some received 90 alerts over the course of the study. In addition to the number of messages, participants were also frustrated that many SMS were unrelated to security, but were just alerting them that a family member had entered their household. However, at the end of the study participants found their ways to ensure that they were not getting alerts unnecessarily. The impact of the probe in their lives outweighed the challenges they faced. Betty's quote from her diary reflected other participants' reactions:

Two weeks after using the sensor, I was frustrated that it was sending messages even if it sensed me. However, with time, I found my way around it. I was only switching it on when I am not at home or when I am sleeping. This helped in reducing unnecessary alerts. When the system alerted me when my boy entered the room where I keep money, I was alerted too. The benefits of the sensor buried my frustrations and I got used to it.

This quote is representative of other participants' experiences with the M-Kulinda, that is it improved with time: they found many ways of making it useful in their home. Odom *et al.* found that, new technologies are novel and they are received with excitement. As times goes, the novelty wears off and people may be frustrated; however, if the experiences improve with time, people find ways of using the technology and finally accept it into their everyday lives (Odom et al., 2014). The fact that M-Kulinda's usage improved with time and participants eventually appreciated how it worked justifies prior research's (see (Odom et al., 2014)) findings in a different geographical, social and cultural setting.

5.3.3 Neighborhood Cohesion

During baseline interviews participants consistently mentioned that when they were away at work or travelling they relied on their neighbors to tell them what was happening (e.g., neighbors would call when they see people standing by their compound gate). The increase in mobile phone penetration in Kenya has helped in improving economic and social standards (Aker & Mbiti, 2010) though its use in some areas like home security is overlooked. "Mercy", for example, described how the mobile phone strengthens neighborhood cohesion:

If somebody tries to stand around you will see my neighbor will call, there is somebody at the gate, so it has been helpful in that way because they can alert there is somebody hovering around you or somebody trying to open your gate.

After using M-Kulinda, participants showed the same trend of response whenever they receive an alert while they are far from home. They would call other household members who are nearby to check what is going on. If there was no one at home, participants would call their neighbors to check their home, in one participant's words:

Sometimes I get alerts when I am not home so I wonder what is happening. I call my neighbors to check the compound for me.

Further, and related to sending SMS alerts, participants suggested that rather than sending the messages to a single mobile phone, it would be more effective if other household members—as well as their neighbors—also received the alerts, a finding which suggest M-Kulinda could help to reinforce neighborhood; "Peter" explains:

I want something like alarm to complement the alert I receive. When I put alarm, many people they can see what's happening. Even if I am not at home neighbors can come.

In prior research, Erete suggests that neighborhood cohesion is a major security measure than applications that are put in place to dissuade burglars (Erete, 2013). Collectively, findings suggest that neighborhood cohesion is crucial for home protection, specifically participants' consistent suggestions for inclusion of audio alarms reveals how important this is in rural Kenya.

5.3.4 Experimenting with M-Kulinda

M-Kulinda was also used as a platform where participants experimented the functionalities of sensor-based technologies. Participants experimented with the M-Kulinda in different ways included testing its capabilities as well as demonstrating and discussing with friends. This shows how interested participants were with M-Kulinda.

Participants were more interested in understanding how M-Kulinda work and its capabilities. Julius explained that he wanted to know the range at which the system can detect movement. To do so, he experimented with the system on a big ground. He switched the system on the system while he was behind it and asked his friend who stood far away to start moving towards the system. The moment he saw the light on, he signaled his friend to stop. Then they measured the distance covered which was found to be about 9.8 meters. Participants also tested whether the system could detect motion behind transparent windows. Eric explains:

"One day, I wanted to know if the sensor can detect motion behind a window. So I closed the window and switch on the system. Then I moved behind only to notice that I did not receive any message in my phone. I realized that the sensor cannot detect motion behind windows."

Most participants also liked testing the system with their friends. Mostly participants demonstrated how the sensor works to their friends. Upon doing so, they mostly had discussions when they explored other ways the system can be used as well as other possible uses of sensors to solve their problems. This suggests how stimulating and interesting M-Kulinda was among participants and their friends. The system provoked different imaginations from participants that were recorded in the diaries to inspire future design on sensor-based technologies.

5.4 Participants' Perceptions on Sensors

An unexpected outcome of the deployment was learning that the probe was useful for understanding how technology could address their concerns about domestic security, and more generally about participants' perceptions of sensors. Though participants' understanding of sensors varied, there was shared ideas about how they could be used in their homes to support other activates. During the baseline interviews, all participants only mentioned that sensors can be used to detect when something is wrong; "Neli" explains:

Notify[ing] you that there's something going on, like there are those cars which they put in a gadget so that whenever someone touches the car, the owner of the car might detect that there's somebody touching my car.

Participants used the M-Kulinda as a point of reflection for other uses of sensors in their households. M-Kulinda made participants think about other ways sensors can help in their lives beyond home protection and these reflections should be used for designing sensor-based systems that benefit rural African residents. Betty explains:

It can detect when the water is there or not by use of that sensor. You know a times water goes off for a long period. And when it comes you cannot detect with your naked eyes unless you go and open the tap and see.

"Betty's" perception of sensors can be used in her everyday life, as well as other participants' comments, suggest that M-Kulinda deepened their understanding of how sensors work and what they can be used for. The single functionality in M-Kulinda enabled participants to think beyond regarding other ways sensors can help in their lives. A comparison of participants' views regarding sensors before M-Kulinda deployment and after four weeks of use suggests a change on how participants perceive sensors. This illustrates that the installation of the M-Kulinda in participants' homes transitioned participants' knowledge on how sensors can be used in their homes. Sengers *et al.* observe that reflection on unconscious values embedded in computing and the practices that it supports can and should be a core principle of technology design (Sengers, Boehner, David, & Kaye, 2005).

Chapter 6 Discussion

A key contribution of this study is to show how people in rural Kenyan households use technology probes to provide opportunities on how sensor-based technologies can be used in rural households. Participants' experiences of living with a technology probe in their houses consisted of a reflection of how sensor-based technologies can be helpful in their lives.

6.1 Design Implications

Our findings suggest some of the constraints participants consistently mentioned in their diaries and during follow-up interviews. These constraints provide guidelines for designing sensor-based security systems for rural Africa and provide a starting point for designing products that meet these users' needs.

The first thing to consider when designing for rural Africa is explore how the product will be integrated with existing infrastructure to deliver its functionality. This is important because for the product like M-Kulinda to work it relied on already existing systems like those that provided power and network. Designers should consider carefully how the products they are developing will be powered in rural Africa. For example, instead of including only one form of power supply, it is important to include other forms of powering the product so that it still works in case one of the forms of power supply is not supported.

Additionally, findings suggested that to design a better system for home protection in rural Kenya, there is a need to include more functionalities other than only a text based SMS. Based on participants' reflections on M-Kulinda, it is essential to ensure that the system has a mobile switch that allow participants to control the system remotely. This can easily solve a problem some participants encountered like forgetting to switch on the system when leaving their homes.

Alternatively, a switch can be placed on participants' doors where they can easily see it thereby helping them to remember switching on the system before they leave their homes.

Furthermore, home protection systems for rural Kenya should be integrated with security alarms, cameras and memory card slots. As prior research has shown, there are more feature phones than smartphones being used in rural Kenya (Murugesan, 2013), therefore integrating M-Kulinda with security cameras would require an interface for viewing recorded events. Findings suggested that participants indicated that if the system was integrated with a security camera, then they would put a memory card for recording events. When they required to view events, participants would take a memory card to someone who has a smartphone. Viewing recorded videos from friend's or relative's smartphone wouldn't be a problem as prior research has shown that in Kenya people have a tendency of sharing mobile phones (E. Oduor, Hillman, & Pang, 2013).

These insights justify the potential of a technology probe's approach in inspiring participants to be part of the design process. This also provides a perspective of how M-Kulinda should be modified for successful use in rural Kenya. I simply design M-Kulinda with one functionality however findings suggested that M-Kulinda's single functionality provoked participants to provide more insights on how sensor-based technologies should be designed for home protection in rural Kenya.

6.1.1 Designing for Strengthening Neighborhood Cohesion

Erete found that crime detection system like alarms do not dissuade burglars hence she encouraged adopting crime prevention systems that strengthen neighborhood cohesion. Based on findings, my view is that crime detection systems like alarms can also be used to foster neighborhood cohesion in rural Kenya. Crime detection systems can play a big role during different times for example when it is raining. During these instances the community is mostly inside their households and no one can watch another person's house unless watchmen. Crime detection systems should be designed for such cases to alert other members in their households whenever there is crime.

It is important for designers of crime detection systems to carefully consider constraints (e.g., poor network infrastructure and power problems). It is also important to consider ways in that users can easily communicate with their crime detection systems during the rain. For example, in this case using an alarm system would not be effective during rainy season because most houses do not have ceiling for their houses which helps reduce the noise when it is raining. This constraint can even make it hard for alarm systems to work effectively during rainy season. However, designing a system that uses a mobile phone as a platform for communication to the users would be effective.

6.1.2 Crime Detection Plays a Role in Neighborhood Cohesion

With higher penetration rate of mobile phones in rural Kenya (Kshetri, 2017), technology should be easily integrated with already existing initiatives that aim at fostering community cohesion. For example, all members of the 'Manyumba Kumi' project could be linked to a single automated real time system using sensors. The sensors could be used to detect cases of insecurity and instantly alert all members of that particular community of where insecurity has been detected. In this way, community members would be alerted and respond instantly to the situation.

Our findings suggest that participants recommended integrating the M-Kulinda system with alarms. Participants also recommended that M-Kulinda should be connected to their neighbors who are members of the 'Manyumba Kumi' project. This means that crime-detection measures would be used to foster community cohesion which according to Erete it is an example of crime-prevention measures. Based on findings, I argue that crime detection technologies are important for home protection. Crime detection technologies should therefore be integrated with already existing neighborhood cohesion measures like the 'Manyumba Kumi' project to provide home security.

6.2 Open-Ended Design

One of the goals of this study was to establish how participants adopt and use the probe. Findings suggest that participants were able to use the M-Kulinda for different purposes in their homes. I did not tell participants specifically what to do with the M-Kulinda: I simply told them that the probe can send an alert when it has detected motion. The choice what specific things to detect was left in the hands of the participants. In that way, participants reflected on how the M-Kulinda fit in their lives.

Home security might mean different things based on problems the subject is facing as such the open-ended nature of the M-Kulinda helped participants to easily fit it in their lives. By open-ended design, I mean participants could use the probe to solve whatever problem they are facing. For example, participants used the probe to monitor different things in the home including: poultry, electronics as well as daughters. This was possible because the probe was not only made to monitor a specific thing in the home: it was used to monitor anything participants wanted to protect.

Our study contributes to HCI by providing findings that justify the notion of designing open ended security based systems. The findings suggest that people in rural Africa have security problems in their homes that are non-specific. The design of the probe allowed participants to adopt and use it in their homes to address the non-specific security challenges each home faced.

6.2.1 M-Kulinda Helped Participants Think More about Sensors

In this study participants consistently mentioned that they have never used (let alone seen) a sensor-based technology, prior to receiving the probe. Findings suggest that exposing participants to sensors allowed them to think on how sensor-based technologies like M-Kulinda can help in their lives.

These findings suggest that probes can be used to explore peoples' attitudes towards sensor-based technologies in rural areas and other design possibilities. For example, researchers can deploy sensor-based technologies that monitor power outages. As this is one of the problems that came out of participants' reflection from this study, studying it would extend the work I have started in the right direction. Neither I nor my participants would think of monitoring power outages with sensors before the study. However, the power of technology probes allowed participants to think beyond thereby generating ideas for further research. In the end, a better solution for monitoring power outages would be established.

6.3 Automated Security Systems

In the findings, participants consistently said that when "thieves" see any sign of alert, they run away thinking that they have been seen. Unlike in industrialized regions (Erete, 2013), the use of crime detection technologies like alarms and lights are considered to be effective in rural Kenya. When "thieves" see a light switching on by itself, they would think that the owner is awake hence they would run away. This suggests that people's unfamiliar context with the technical details on how sensors operate strengthens security in the home.

Though these concepts prove to be successful in rural Kenya, they may not work in other regions due to different settings including how much knowledge about technology that particular place has. Thus despite that crime detection measures are not effective in industrialized nations (Erete, 2013), this study has shown that they are effective in rural Kenya.

6.4 Broader Ecological Structure

Erete proposed that HCI research must consider the broader ecological infrastructure that affect social issues (Erete, 2013). This agrees with our findings where participants expressed concern over injustices the people in power do the underprivileged. The injustices are mostly caused during political elections when some parties which have lost express concern through violent demonstrations (Erete, 2013). This shows that insecurity problems emanate not only from the grassroots but also from the high level institutional structure of the government and how they operate. HCI research can help in establishing possible ways on how technology can be used in stabilizing the election process in rural Kenya that would in the end satisfy all parties involved.

Chapter 7 Limitations and Future Work

The study helps in bridging the existing gap in HCI on how rural Kenyan communities use sensor based technologies for home protection, however, four weeks was a short period to learn about: the unintended consequences of using M-Kulinda for home security; whether the system actually supports neighborhood cohesion; and long term implications of the system on family member's personal privacy. Additionally, findings are not generalizable as we used non-probabilistic sampling methods to get a sample of twenty participants. There are different challenges that affected how M-Kulinda was used especially the infrastructural challenges participants faced. These challenges mainly include power and network problems. Participants who used solar battery to power the system complained that charging the system took too long than expected as such for some days they were not able to use the system especially when it was cloudy. Additionally, charging using solar power depended on light intensity on each day hence participants could not fully charge the battery for some days. Some households complained that they sometimes got an alert late due to network problems. I witnessed network problems in four households during the time we were deploying the M-Kulinda in participants' homes. These infrastructural challenges might have influenced participants' experiences with the M-Kulinda.

Findings suggest that participants reflected on different ways on how sensor-based technologies can be used in developing countries. Participants reflected on these solutions based on needs like: how can sensors be used to improve poultry and agrarian farming; how can micro-controllers be used to allow transfer of mobile money from one mobile operator to another; can sensors be used to alert people whether there is power and water outage or not and how can cameras and alarms be incorporated in sensor-based technologies to provide security in the home. In the future, I will return to Kenya with another research product that utilizes sensor based technologies to address these challenges.

Chapter 8 Conclusion

The M-Kulinda was successfully used to monitor participants' homes. The use of M-Kulinda in rural Kenya opened new opportunities for participants to realize how sensor-based technologies can be used in their households. M-Kulinda worked successfully as a technology probe by letting participants use the system beyond expectations. It was self-evident that participants would use M-Kulinda for protecting their property but the way in which participants used M-Kulinda for different activities like monitoring their chickens was beyond expectations. The study shows that deploying sensor-based technology probes in the developing world unveils other areas where sensors can be used. As participants used M-Kulinda as a point of reflection on how sensors can be used in their lives, they suggested different problems that can be solved by sensor-based technologies. Additionally, the system provoked discussion among participants and their neighbors about sensors which helped participants to reflect more about sensors. These novel findings suggests that technology probes approach works well in Africa to understand how participants would use a technology that is new in their home. These findings also deepen HCI community's understanding of the use of sensor-based technologies for home protection in developing countries.

Participants integrated M-Kulinda with their everyday activities to find solutions to their everyday challenges. Participants reflected on these solutions based on needs like: how can sensors be used to improve poultry and agrarian farming; how can micro-controllers be used to allow transfer of mobile money from one mobile operator to another; can sensors be used to alert people whether there is power and water outage or not and how can cameras and alarms be incorporated in sensor-based technologies to provide security in the home. These questions are important and they contribute to HCI as well as ICT4D since they provide insights for the solutions rural Kenyan residents are looking for to their problems. In the future, I will return to Kenya with another technology probe that addresses one of these problems.

Findings also suggest major differences from prior research (Erete, 2013) on the role of crime detection systems in home protection. Unlike in industrialized countries where crime detection measures do not prevent thieves from burglary, this study showed that in rural areas sensor-based technologies prevent thieves from burglary. This difference might be due to: how people from different places perceive sensors; and their cultural values and beliefs. Furthermore, in rural Kenya crime detection systems like sensors may boost neighborhood cohesion. This means that sensor-based technologies can work well to complement already existing initiatives like the "Nyumba Kumi projects." Additionally, the study found that already existing measures of security in rural Kenya like using padlocks and grill doors are not 100% effective in protecting households from thieves. Findings suggests that augmenting these already existing measures can effectively work to boost domestic security.

This research has helped in bridging the existing gap in HCI on how rural Kenyan households use sensor-based technologies for home protection, however, the infrastructural challenges participants faced affected how they used the M-Kulinda. These challenges mainly include power and network problems. As participants who used solar to charge the battery complained about how long it took to charge the battery they could not use the M-Kulinda for somedays. Additionally, charging using solar power depended on light intensity on each day hence participants could not fully charge the battery for somedays. Some households complained that they sometimes got an alert late due to network problems. I witnessed network problems in four households during the time I was deploying the M-Kulinda in participants' homes. These infrastructural challenges might have influenced participants' experiences with M-Kulinda. These constraints should be put into consideration when designing for the developing world. It is important that designers should think about power supply and network connectivity for the systems they are developing. As revealed from this study these challenges proved it difficult for some participants to use the system. It is important that designs should incorporate long lasting solutions to these challenges in their designs.

APPENDICES

APPENDIX A: Informed Consent

Michigan State University, East Lansing, Michigan, U.S.

Project Title: Security System Project

Investigator: George Chidziwisano

1) CONSENT FORM

Introduction:

I am a student at Michigan State University in the United States. You have been asked to participate in this research. The purpose of the interview is to study IT based security systems in rural Kenyan households. To be clear, I do not work for technology companies. I am not here to advertise products; instead I am here to learn.

Procedures:

The name of the study is IT Based Security System for rural Kenya. If you agree to participate, you will be asked to take part in a 1 hour interview where I will ask security related questions. After the interview, I will install the security system in your house at a location you prefer. Then I will give you a diary where you will be writing your experiences with the security system. If you agree, I would also like to take photographs and make an audio recording of our interview, so that I can have an accurate record of the information you provide. I will transcribe these recordings and will keep the transcripts, as well as the photos, confidentially and securely in our possession.

Risks:

Your participation in this study does not involve any physical or emotional risk to you beyond that of everyday life.

Benefits:

Taking part in this study may help us better understand how security systems for successful use in rural Kenya should be developed.

Financial Information:

Participation in this study will involve no cost to you and you will be compensated with mobile telephone credit of 100KES as a token of appreciation for your time. You will receive it at the beginning of the discussion and keep it whether or not you choose to complete the process.

Confidentiality:

I will follow these procedures to keep your personal information confidential:

- I will keep collected data confidential to the extent allowed by law.
- I will keep your records under a code number rather than by name. In other words, your real name will not appear on the files associated with this project.
- The data collected for this research study will be protected on a password protected computer or in a locked file cabinet on the campus of Michigan State University for a minimum of three years after the close of the project. Only the appointed researcher's and the Human Research Protection Program (HRPP) will have access to the research data.

When results of this study are published your name and other facts that might point to you will not appear. The results of the research study may be published, but your name will not be used.

Subjects Rights:

Your participation in this research study is completely voluntary**.** If you decide not to participate, there will be no penalty or loss of benefits to which you are otherwise entitled. You can, of course, decline to discuss any issue, as well as stop participating at any time, without any penalty or loss of benefits to which you are otherwise entitled.

Whom to contact with questions:

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher:

Name: George Chidziwisano

Address: 404 Wilson Rd. Room 249

Communication Arts & Sciences

Michigan State University

East Lansing, MI 48824

Email: chidziwi@msu.edu

Phone Number: 0795620502

If you sign below, it means that you have read (*or have had read to you*) the information given in this consent form, and you would like to be a volunteer in this study.

Subject Name:________________________________

Subject Signature Date

Signature of Person Obtaining Consent Date

APPENDIX B: Interview Protocol

In-depth Interviews Protocol, Security System

Project Title: Security System Project

Investigator: George Chidziwisano

I am a student at Michigan State University in the United States. I am from Malawi. You have been asked to participate in this research. The purpose of the interview is to study IT based security systems in rural Kenyan households. To be clear, I do not work for technology companies. I am not here to advertise products; instead I am here to learn.

Informed Consent

- Read the informed consent and make sure participants have agreed and signed before proceeding
- Are you comfortable with us digitally recording?
- At the end of the interview you will receive 100KES and after the study you will be given the solar charger as compensation.

1) Introduction

- Tell me your name
- Tell me about yourself
    - What do you do for a living?
- Tell me how long you have stayed in this community
    - Why did you choose this location?

- How many people are staying in this house now?
    - How many children do you have?
- What valuable things do you keep outside your house?
    - How do you keep them secure?

2) Security Background

- Tell me what you know about the security of the homes in this area
    - In what ways are people in this area provide security?
    - Are there any experiences you have had that make you feel insecure living here?
        - If yes, tell me what happened
    - Which areas are used by a thief to enter houses in this community?

3) Security in the Home

- What security measures are in place around your home?
    - List them
- What are the things that are most important to keep secure?
    - List the things that are most important to you
        - How do you keep them secure?
    - Tell me about any actions you do to take care of your livestock and other materials that are outside
    - Are there other wild animals that threaten your livestock in this community?
        - If yes, tell me more about this

- What measures have you put outside your house to secure your livestock?
  - How effective are these measures?
- Tell me what visitors at your home do when they did not find you at home
  - How do you feel when you someone important tells you he came to your home but did not find you?
    - If you leave keys with neighbors, how do you know your neighbor did not enter the house before your visitor?
  - Has the mobile phone changed how you feel about security around your home?
- What else should I know about security in this area that you have not already told us?

4) Technology Probe

Diaries

As part of exercise you will use this diary to record your experiences with the security system for 4 weeks. Use the diary as your daily activities book with this system. Every time you interact with the system record your experiences with the system. Also indicate how you would want the system to be modified to effectively suit your needs. You may include experiences relating but not limited to:

- General knowledge about security
- If a security incident occurs, record it in your diary
- How the system responds when you switch it on/off
- Your reactions when you expect the system to work but it didn't

5) Deploy the Prototype:

- Explain and demonstrate how the prototype works then ask participants where they would want the sensors to be placed in around the house as well as where the micro-controller should be placed. Finally test the prototype to make sure that it is working properly.
- Do you have any questions for me?

Thank you for your participation in our study.

APPENDIX C: M-Kulinda Participants' Guidelines

Security System and Solar Charger Instructions

1. Using the system
    a. **Make sure** the sensor is facing the direction you want to monitor. **Do not** face the sensor towards the wall!
    b. **Only activate the security system when you are away and when you are sleeping.**
    c. **Note that the security system will only work when it is connected to the solar charger.**
    d. **DO NOT UNSEAL AND USE THE PORT COVERED WITH BLACK TAPE ON THE SOLAR CHARGER!**
2. Charging:
    a. Disconnect the solar charger—but not the cable—from the security system.
    b. Place the solar charger in the sun for at least 6 hours, and then reconnect the solar charger to the security system.
    c. **REMEMBER** to charge your solar battery whenever it is drained (approximately every 3 days).
3. IMPORTANT:
    a. **DO NOT USE THE SOLAR CHARGER TO CHARGE MOBILE PHONES DURING THE STUDY!**
    b. Call **George Chidziwisano (on 0795620502)** if you have any questions or you experience any problems.

APPENDIX D: Diary Study Guidelines

Thank you for agreeing to participate in this study. Please respond to questions that seem relevant to you—everyday. Limit your answers to 1 to 3 sentences.

1. **Did anything surprising happen at your compound today?**
2. **Has anyone commented on the sensor today?**
3. **Did you receive any messages from the sensor today?**
    a. **If so, what was your reaction?**
4. **What time(s) was system on today?**
5. **Any comments about the system?**

When recording your entries, please provide the date and question number.

This book is property of Michigan State University. Please return it to George Hope Chidziwisano after the study is over. If you have questions call me at 0795620502.

MICHIGAN STATE UNIVERSITY

APPENDIX E: Follow-Up Interviews

Follow-Up Protocol: Security System Study

I am conducting a short follow-up interview related to the study you are participating since 3 weeks ago. I want to know about your experiences with the sensor I gave you and other security related issues during the last 3 weeks.

There are no right or wrong answers. Please speak freely and tell me as much points as possible, I am here to learn from you. At the end of the interview, I will leave you with the solar charger and I will take the sensor with me for further improvements.

Before we start, do you have any questions for me?

Informed Consent

- Ask them if they are willing to participate in the study.
- Can we audio-record the interviews?

Start Recording

1. What things were you monitoring with the sensor in the last 3 weeks?
    a. Give me some examples
    b. What experiences have you had while monitoring those things?
2. Are there any other places where you have taken the sensor other than where we placed it at first?
    a. Tell me what you observed in those places?
3. How did you feel when you received a message on your phone that the sensor has been activated?

    a. What action did you take?
    b. What did that message mean to you?
    c. On average, how many massages were you receiving per day
4. Are there moments when you expected the system to work but it didn't?
    a. If yes, tell me more about that
    b. Is there anything you did for it to start working again?
5. What factors affected the operation of the sensor?
    a. List them
    b. Is there anything you did to overcome those factors?
6. Tell me what you feel should be changed about the system
    a. What other things would you want to be included on this device?
    b. What things do you think do not work well with the system?
7. How long does the battery last when you are using the system?
    a. How often were you charging the battery?
8. You told me about sensors before you used the system, now after using it, what is your impression of sensors?
    a. In what ways do you think sensors can be used in your household?
    b. Tell me what your neighbors say about the sensor
9. What is your impression of the materials which have been used to make the device?
10. If you were to design your own security system, how would it look like?
    a. Take a moment and imagine how it would be like?
    b. What things would you consider for your system?
11. What else do you want to tell me about your experience in the last three weeks?

12. Do you have any question for me?

Thank you!

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