MASTER

Application of the technology acceptance model healthcare in Kenya

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Award date:
2015

Link to publication
Application of the Technology Acceptance Model: Healthcare in Kenya

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0871377

in partial fulfilment of the requirements for the degree of

Master of Science
in Human-Technology Interaction

Department of Industrial Engineering and Innovation Sciences
Eindhoven University of Technology (TU/e)

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Keywords:
Health care, Kenya, Technology Acceptance Model, Perceived Learnability, Trust, Intrusiveness, Blood Pressure Measurement
Abstract

In sub-Saharan Africa, the second leading causes of death are preventable diseases, which can be controlled to some extent with efficient and effective delivery of primary health care services. Thus, it is important to have appropriate technology which is well accepted by the potential end users.

We employed the Technology Acceptance Model (TAM) to understand what determines the user acceptance of medical technology in these settings. To our knowledge, TAM has been widely used in ICT adoption research, but it has not been used for medical domain before. Therefore, in our study, we attempted to test the applicability of TAM in this domain, in a representative setting, namely, Kenya, with a representative technology, namely, blood pressure measurement device. We used two devices for testing our model, the existing device (i.e., blood pressure cuff), and a new device conceptualized by Philips.

We used the structural TAM for constructing a model which included the two core constructs of TAM (i.e., perceived ease of use, and perceived usefulness), several user and device specific characteristics (like, medical expertise, age, measurement efficiency etc.), and two additional constructs (i.e., perceived learnability, and perceived trust). We investigated the relationship between the two core constructs, the role of the two additional constructs, and the external variables that determined user acceptance of the devices. Using questionnaires, we gathered data from different types of health workers of Kenya (i.e., Community Health Workers, and nurses from hospitals).

On analyzing data from 69 participants, we found that the core constructs were not two distinct constructs, instead a single construct which we labelled as, perceived usage, and hence this model did not indicate replicability from TAM-ICT to TAM-medical domain; perceived learnability did not play a meaningful role in this study; perceived trust played a significant role as an indicator of user acceptance. It was determined by four external variables, either directly (i.e., general trust in medical technology, and expected nervousness caused to the patients) or via perceived usage (i.e., intimidation caused to the health workers, and measurement efficiency). This result signified applied relevance of TAM research in medical domain. Moreover, we concluded that even though our model did not demonstrate a direct replication of TAM in the medical domain, because the structural TAM was retained by our resulting model, we considered this study as a preliminary research for future applications of TAM in domains other than ICT.
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Abbreviations

- TAM = Technology Acceptance Model
- ICT = Information Communication Technology
- CHW = Community Health Worker
- BP = Blood pressure
- PEU = Perceived ease of use
- PU = Perceived usefulness
- PL = Perceived learnability
- PT = Perceived trust
- SEM = Structural Equation Modeling
- EFA = Exploratory Factor Analysis
- CFA = Confirmatory Factor Analysis
- CFI = Comparative Fit Index
- TLI = Tucker-Lewis Index
- C.I. = Confidence Interval
- AVE = Average Variance Extracted
- RMSEA = Root Mean Square Error of Approximation
Acknowledgements

Martijn Willemsen has provided me with incredible mentorship throughout my study, and for that I am tremendously grateful to him. I received invaluable input from him during all our discussions, and he constantly helped me stretch my limits. I feel extremely fortunate to have worked under the guidance of Joyce Westerink, for her impeccable support through thick and thin. Without her constant help, this work would not have been possible.

I cannot thank Rick Bezemer enough for giving me the opportunity to work on this project at Philips, it has been an inspiring experience. With all the wonderful discussions, and his detailed feedback, he definitely played an important role in shaping this work. It has been absolutely fantastic knowing him, and I appreciate that he considered me worthy of his lessons. My heartfelt thanks reach out to Maarten van Herpen and Eddine Bahaa Sarroukh, who provided for my work trip to Kenya, and to Jacqueline Karachi and the local Philips team for receiving us there graciously. Jettie Hoonhout, and everyone I spoke with at Philips informed this study with their experience, and for that I offer them my deepest gratitude. Mark Graus has my utmost respect for all his help and patience in dealing with my questions.

I will not forget the lovely times spent with Edgar, Dhruv, Jordi, Rob, and all the ‘HTIers’ here in Eindhoven. I am thankful to Rodrigo, Nicol, and Antonio for serving as my guardian angels throughout the Master study, and Yefan for all the creative in-depth gatherings. Bambi, Rhythm, Suhail, Murru, and Nikhil, my best friends, have been a part of me, and have kept me together with their emotional support. I appreciate the goodwill offered by Preeti, Ankita, and Ronak, and the delightful visits from across the globe by Bharath, Anshu, and Nagarjun.

Sebas has kept me grounded throughout with his presence, love, and understanding. He has shared my highs and lows for the last one year, and words fail me when I attempt to express how happy I am to have met him. Lastly, I dedicate this work to my parents, and my big brother, Deepesh, for always being there for me, believing in me, and showering me with unconditional love and support.
Chapter 1

Introduction

1.1. Primary health care in sub-Saharan Africa

Preventable diseases, like lifestyle-associated cardiovascular diseases, are the second leading cause of death in the sub-Saharan Africa (Gaziano, 2007). Strong primary care systems have been recognized to control premature deaths by such diseases (Macinko, Starfield and Shi, 2003), and thus serve as a prime solution to mortality in low resource settings (Starfield, Shi and Macinko, 2005). However, in these settings, the medically trained workforce is limited, resulting in inadequate delivery of the primary care services. To address this problem, Community Health Worker (CHW) programs are being introduced here. CHWs are lesser trained personnel who undertake various tasks at the primary care level (Heaines et al., 2007). These tasks include screening the community members for specific diseases, for example, high blood pressure or hypertension.

For efficient and effective delivery of primary care services, appropriate medical technology is crucial (Kringos et al., 2010), specifically, technology which tailors to the needs and capabilities of its potential end-users, enabling them to carry out the tasks associated with their job. Advantages of an appropriate technology lie in minimization of the consultation time (Kringos et al., 2010), insurance of greater patient safety, reliable results, optimal operation of the device also by the lesser trained personnel (WHO, 2007), and consistent usage of care services (Starfield, Shi and Macinko, 2005). Designing technology such that it simplifies the required procedural skills can promote its appropriate usage (WHO, 2007). Moreover, making the technology easy to use can help users perceive it as useful, which finally augments the user acceptance of the technology (Park et al., 2009), and leads to successful implementation in market.

1.2. User acceptance of health care technology

User acceptance has been examined elaborately using Technology Acceptance Model (TAM), introduced by Davis (1986) in the domain of ICT. To determine the user acceptance of technological innovations, TAM posits two perceived constructs or cognitive beliefs: perceived ease of use (PEU) and perceived usefulness (PU) of a product or application. These two constructs are theorized and confirmed to mediate the effect of external variables on the belief of the prospective users, their
attitude, and intention to use. Perceived ease of use refers to “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989), while Perceived usefulness is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance”. These two factors, PEU and PU, are crucial indicators of the user acceptance of a technology.

Since its introduction, TAM has been essentially used for modeling the user acceptance of information systems. Subsequent investigations tailored the structural TAM to construct various versions of TAM for specific research contexts; e.g., the study by Park and colleagues (2009) where using TAM, they studied the user acceptance of a digital library system in developing countries. Since the original TAM has been used many a times, we refer to it has TAM-based framework in this report. In the context of medical device adoption, to our knowledge, TAM has not been applied, although user evaluation study for medical devices have been conducted before (Carayon, Hundt and Wetterneck, 2010). Therefore, we focus our research on exploring whether a TAM can be useful for determining the user acceptance of a tangible product in medical domain.

The significance of studying the user acceptance in early stage of medical technology development was to gain insights in whether the end users find value in this technology, and if its implementation could be successful in the market. Learning about the feedback and evaluation of the users before implementing a new technology can give an indication of the likelihood of its adoption (Rogers, 2003). It also gives more insights into the user-friendly design specifications (Norman, 1988), encourages the users to learn early on about the technology, and helps them feel more in control of the technology development procedure (Karsh, 2004).

1.3. Objective of this study

We wanted to construct a model using the TAM-based framework so that we could test its applicability for the domain of medical devices, in context of developing country, in our case, Kenya. In Kenya, as in similar sub-Saharan countries, there is a need for medical technologies which reduce their workload, and minimize the patient consultation time. Moreover, because of the popularity and effectiveness of the CHW programs, technologies used to conduct the primary care tasks, like screening and triage, should be made suitable for use by health workers of different expertise levels. Philips has conceptualized a blood pressure (BP) measurement device (Figure 1b) which is envisioned to improve upon the aforementioned aspects, and hence result in a device that is better in performance, and more preferred as compared to the traditionally used or the existing device (Figure 1a).
The new device dictates a new interaction style that might negatively affect its user acceptance, because it measures blood pressure when placed in contact with the chest, and can presumably be more intrusive to the personal space of the patients; whereas the existing device includes wrapping and inflating a cuff around the arm.

In order to understand which factors determines the acceptance of BP measurement device by different types of health workers, we constructed a TAM tailored to this context.

In this report, we describe the theories and findings that we used to construct our TAM, followed by the research questions that we addressed in this study (Chapter 2). Further, we lay out the methodologies of the study we conducted in Kenya to test the proposed model (Chapter 3). Then, we present the findings of the study (Chapter 4), and finally a reflection on the results in the discussion and conclusions (Chapter 5).
Chapter 2

Literature review and research formulation

2.1. Technology Acceptance Model (TAM)

Our theoretical foundation, the Technology Acceptance Model (TAM) was introduced by Davis (1986) with the purpose to explain the causes of user behavior concerning the adoption of information technology (Figure 2). Both TAM and its precursor, the Theory of Reasoned Action, postulate that perceptions about an innovation are instrumental to developing attitudes that eventually lead to technology utilization behavior.

The TAM entails causal relationships between design features of the system, user motivation towards the system (i.e., their cognitive and affective responses), and the actual behavioral response. In Figure 2, 'External variables', are the system features and the user capabilities that influence the cognitive response of the user; i.e., whether the system is perceived as useful and easy to use. Further, the more easy to use is the system, the more it is perceived as useful. The cognitive responses of the users in turn determine their affective response (i.e., their attitude towards the system). Finally, the attitude of the users towards the system, and the perceived usefulness together lead to the behavioral intention to use, which ultimately predicts the actual use of the system after implementation.
In literature (Karsh, 2004), user perceptions about technology have either been measured in terms of satisfaction with the performance of technology, or by behavioral intention to use, the willingness to use the technology. The former is typically used when the end users are not meant to use the technology of interest voluntarily. In healthcare, such situations are common when one device is replaced by another, following a decision at the management level of their health facility, and the caregivers are bound to use the new device. Therefore, to study the user acceptance of BP measurement devices, we focused on examining their user evaluations, and identifying which factors affect the technology acceptance.

Studied most often, the user perceptions which have been used as indicators of user acceptance were flexibility, response time, errors or breakdowns, usability or ease of use, and usefulness. The last two constructs, introduced before as Perceived usefulness (PU) and Perceived ease of use (PEU), have most thoroughly been investigated because they are both central to the TAM-based framework. Therefore, we also used PU and PEU as the central constructs for our TAM.

2.1.1. Perceived usefulness

Perceived usefulness is the degree to which a user believes that using specific technology would enhance his or her job performance. People tend to use or not use the technology depending on how useful the technology is perceived (Davis, 1989). Thus, if a health worker thinks that a medical device would help them provide better care to the patients, then they might perceive the device as useful. Perceived usefulness has confirmed to be a strong predictor of user acceptance by the subsequent research: Davis, 1989; Venkatesh and Davis, 2000; David, 1993; Venkatesh 2000; Adams, Nelson and Todd, 1992; Taylor and Todd, 1995; Agarwal and Prasad, 1999. This means that PU plays an instrumental role in determining user acceptance.

Perceived usefulness can impact measurable variables like the perceived task completion speed (Park et al., 2009), the influence of technology usage on enhancement in the job performance and productivity of the users (Davis, 1989; Laitenberger and Dreyer, 1998). In other words, PU can
likely be indicated by finding out how the users perceive various consequences of using a technology, for instance, the technology can be considered as useful if the users believe that the technology would help them to accomplish their specific tasks quicker, and using this technology would enhance their overall productivity, and improve their job performance.

2.1.2. Perceived ease of use

Even if the potential end user believes the technology is useful, but finds it difficult to use, they might avert from using that technology (Davis, 1989). Perceived ease of use is the degree to which a user believes that using a specific technology would require less effort. Thus, if a nurse thinks that a screening device gives her good results but demands a lot of effort, this might lead to under-usage of the device.

Perceived ease of use (PEU) can impact measurable variables like the perceived ease of control, (Davis, 1989; Laitenberger and Dreyer, 1998), and the simplification of the specific task that the technology provides (Davis, 1989). In other words, PEU can likely be indicated by finding out what the users think about using the device, for instance, the technology can be considered as easy to use if the users indicated that they had desired control over the use of device, and this device simplified the procedure of the task.

A technology that is perceived as easy to use, it either directly influences the adoption behavior of users, or its effect is mediated by the perceived usefulness of the device (Park et al., 2009). This indicates the importance of evaluating technologies in terms of this construct.

2.2. TAM for blood pressure measurement device in Kenya

Perceived usefulness and Perceived ease of use are at the core of the TAM-based framework, and with each specific investigation, this framework is instantiated into a model which fits the application context. Over time, many investigations have expanded the structural TAM, and by analyzing the evolution and modification of TAM-based framework over 88 empirical studies, King and He (2006) explained the structure of a generic TAM. The TAM-based framework has been expanded either by including external variables which are specific to the research, or by extending it using constructs based on various theories. For the former category, two of the modifications identified by King and He (2006) were variables related to user and system contexts, such as, computer literacy levels of the users, accessibility afforded by the system, etc. Complying with the latter category, previous studies have extended TAM using perceived constructs like self-expressiveness (Pedersen and Nysveen, 2003) and perceived trust (Koufaris and Hampton-Sosa, 2002).

Following the same structure, we constructed our model by introducing user and technology characteristics, and perceived constructs, which were relevant in our Kenyan BP measurement
application domain (Figure 3). Next, we discuss the relevant literature in reference to the aspects which built our TAM.

2.2.1. User characteristics

Identifying characteristics of potential users, such as expertise and skills, knowledge base, educational background, age, etc. can help in designing systems such that the technology knowledge and information structure aligns with the capabilities and mindset of the users (Zhang et al., 2003). For example, a primary level education might make prospective users perceive the technology as difficult to use. If tailored to their prior background, the technology can be made suitable for the users. Previous research included application-specific user variables, such as, prior experience, domain knowledge, education, age, and gender (Park et. al, 2009). The following user related variables were deemed relevant in our model:
1. **Medical expertise**

Higher technical expertise might positively bias individuals to evaluate a technology better (Park et al., 2009 and Ziefle and Schaar, 2010). The participants in this study were health workers with varying medical expertise levels. Most CHWs were expected to have minimal medical expertise limited only to the specific training that they had acquired; whereas nurses in hospitals were expected to have a medical school level training. These differences in the medical training attained by the two participant groups was expected to lead to different evaluations of the two devices.

2. **Prior experience**

Similar to having higher expertise, individuals who have used functionally similar technologies have been found to adopt the technology better (Atkin and LaRose, 1994; LaRose and Atkin, 1992; Hamilton, 2006; Taylor and Todd, 1995). In our study, most nurses were expected to have greater prior experience with the existing device, that is, the blood pressure measurement cuff, than the CHWs. However, within CHWs, depending on their seniority in the job as a CHW, they could have varying levels of prior experience with the existing device.

3. **Education**

For the same reasons as stated in the previous two characteristics, the education level of a user could also affect their evaluations, that is, a user with higher education could evaluate the technology better than another user. The education level for nurses was expected to be of college level or higher. However, the education level of CHWs could be varied, as anyone in the community can become a CHW, irrespective of their medical expertise, prior medical-task experiences, or education. But education indeed might have altered the acceptance levels of people.

4. **Age**

Cognitive aging research informs on the aging effects like decreasing psychomotor skills (Bosman and Charness, 1996). A few age effects (between age groups: 40-65 and 65 and above) had been found in the user-acceptance study for healthcare technology (Kuo et. al, 2009). When introducing a new medical device, we found it important to account for these effects. The two devices used in this study differed in the physical effort required in interacting with the equipment (i.e., where the existing device needs to inflating the cuff by pumping, the new device needs placing on the measurement body position). Hence, in the context of health workers in Kenya, age could be an important predictor for user evaluations.

5. **General trust in technology**

If the general stance of an individual about technology is positive, then that individual tends to presume that he/she will achieve better outcomes, because they also assume that the technology is reliable. This general stance towards technology is irrespective of what they assume about the specific technology (McKnight et al., 1998). As a control variable, we included the general stance of health workers on medical technology.
2.2.2. Technology characteristics

Park and colleagues (2009) used a TAM-based framework to understand the acceptance of a digital library system by the users of several developing countries. They used system based characteristics like accessibility, visibility, library assistance, in order to find the direct effect of the affordance of the system on the user evaluation. Apposite to the blood pressure measurement devices in our study, we included the following variables in the model. The devices in the study were expected to vary on each of these characteristics, so that their effects could be distinguishable based on the evaluation of the two devices. The following variables were relevant to the two devices used:

1. **Measurement efficiency**
The time it takes to complete the BP measurement procedure could have an effect on the user perceptions of the two devices. Their perceptions could depend on how much value do the health worker groups assigned to time efficiency of the measurement procedure. If they valued reducing consultation times, then the device which they perceived as faster at measuring BP might be better evaluated.

2. **Intimidation**
Medical devices can be intimidating for patients and that can hamper the workflow of a healthcare process. To avoid this, an invention was providing decorative covers for medical equipment like stethoscope and blood pressure cuff (Eddy, 1997). Arguably, the form of the equipment could also have differing intimidation effect which might further affect the perception of the device.

3. **Intrusiveness: personal space violation**
Personal space refers to the invisible space which individuals claim to have around them. It can vary with gender, age and the point of contact; people find the chest as a less comfortable point of contact, while the arms are more comfortable (Cheng, 2011). The two devices have different procedures for measuring BP. Where the existing device is wrapped around the arm and inflated to a high pressure value, the new one is placed against the chest with skin contact. This in turn makes the inter-personal interaction (via the BP devices) between a health worker and a patient different for the two devices. As the new device is meant to be used on the chest, using it might involve touching (direct or indirect physical contact, e.g. while using the device) that can be invasive to personal space of the patients. Since such a factor could consciously or subconsciously alter the perception of a technology, we kept this variable as one of the predictors of user acceptance.

4. **Intrusiveness: feeling of nervousness**
On violation of personal space, an individual can react with anxiety, as revealed by physiological measures, direct observations, and self-reports (Burgoon and Jones, 1976). Therefore, if health workers expected that the patients would feel nervous due to the use of the device (point of contact), their user evaluations might get influenced.
2.2.3. Extension with Perceived learnability

In ICT evaluation, Nielsen (1993) identified learnability as one of the most crucial measures to determine the overall usability of a system. Perceived learnability for a novice and an expert user can differ given their prior skill level and understanding of similar systems. Moreover, a certain device can be easy to use, after one learns how to use it, but the first learning barrier for different devices might vary. This construct of Perceived learnability was considered as a user acceptance measure in a medical device acceptance study, where the purpose was to determine which device-specific characteristics influenced the perceived learnability (Carayon, Hundt and Wetterneck, 2010).

To our knowledge, this construct in a TAM is non-existent in the literature, and so we proposed to include the factor of perceived learnability (PL) in our TAM. Often in ICT adoption (Nielsen, 1993), the factors of ease of use and learnability are interchangeably used, hence we treat this factor similar to 'Perceived ease of use'. In the context of medical device (hardware), it was also interesting to investigate whether these two perceived constructs are distinct and if PL would be a valuable extra construct in our TAM. In our participant group, it was expected that the novice group (CHWs) would find the devices difficult to learn to operate, prone to errors (Carayon, Hundt and Wetterneck, 2010), and a higher effort expectancy (Venkatesh, et al., 2003).

2.2.4. Extension with Perceived trust

In TAM research, trust has been used whenever deemed importance in the context, for example in online shopping (Koufaris and Hampton-Sosa, 2002; King and He, 2006). Previous study (Koufaris and Hampton-Sosa, 2012) in e-commerce concluded that the experience of customers with a website influenced their trust in the company through their beliefs in their website. In the field of healthcare, trust in medical actors is regarded as an important contributing factor to better services (Sewell, 2015).

Thus, the trust of health workers in these specific BP measurement technology could be a factor of high importance to study. Koufaris and Hampton-Sosa (2002) research revealed that both PU and PEU positively influence trust of customers in the website and through it, in the company itself. We intended to model trust in a similar way, that is, as determined by PU, PEU, and PL. We also intended to find which device and health worker characteristics might have an influence on the trust of the health workers in technology. The general trust of users in medical technology might directly affect their final trust evaluation. And if the device is perceived as intimidating or uncomfortably intrusive to their personal space, by logic it could be seen as unfriendly, which can further lead to low trust (Wang and Benbasat, 2008).
2.3. Research questions and significance of the study

In our study, we modeled the various characteristics of the actors involved (health workers, and the devices), and as described in the previous section (2.2), we explored how these characteristics might determine the evaluations of the two BP measurement devices by the health workers. Regarding our specific TAM, we aimed to answer the following main and sub research questions:

**Main question:** Is it possible to construct a TAM (involving perceived ease of use, and perceived usefulness as the core acceptance constructs, and perceived learnability, and perceived trust as two additional constructs), for the case of the acceptance of a medical device by health workers in Kenya?

**Sub-question 1:** Are perceived usefulness and perceived ease of use related in a similar way as described in literature for ICT adoption (Park et al, 2009)?

**Sub-question 2:** Is it meaningful to include perceived learnability as an additional factor or mediator in the model?

**Sub-question 3:** Does the additional construct of perceived trust play an important role in this model, similar to the previous research (Koufaris and Hampton-Sosa, 2002)?

**Sub-question 4:** How do the device characteristics (measurement efficiency, intimidation, personal space violation, and feeling of nervousness), and user characteristics (general trust, medical expertise, prior experience, education, and age) influence the perceived ease of use, perceived usefulness, perceived learnability and trust in the device?

Based on the literature (Section 2.2), we attempt to answer the research questions with the proposed hypotheses as presented in our model below (Figure 4).
Hypotheses 1 and 2 concern the part of the model which demonstrates relationships between the perceived constructs.

H1: The higher the perceived usefulness, ease of use, and learnability, the higher will be the perceived trust.
H2a: Perceived ease of use will positively influence Perceived usefulness.
H2b: Perceived learnability will positively influence Perceived usefulness.

Hypotheses 3-7 predict inter-relationships between user characteristics and perceived constructs.

H3: The higher the medical expertise level of the health workers, the more positive will be their use-based evaluations of the device (in terms of learnability, ease of use, and usefulness).
H4: More prior experience with the existing device will result in more positive use-based evaluation of the existing device.
H5: Greater education will lead to more positive perception of the use-based evaluations.
H6: Higher age will negatively influence the use-based perception of the devices.
H7: The trust of health workers in technology will be a direct influence of their general trust in medical technology.
Hypotheses 8-11 predict inter-relationships between device characteristics and perceived constructs.

H8: Higher measurement efficiency will positively influence use-based evaluations.
H9: Intimidation caused by a device will worsen the overall perception of that device.
H10: If the device is perceived to cause violation to personal space of the patients, the perceived trust of the device will be negatively affected.
H11: If the device is perceived to cause feeling of nervousness to the patient, the perceived trust of the device will be negatively affected.

The value of testing these hypotheses to answer our research questions was threefold: First, in the applicability of TAM in a different field of interest than ICT, that is, tangible medical technology in a developing country. This study had the potential to add to the vast research pool related to the application of user acceptance models. Second, we could learn about the role of the perceived construct of learnability in such a model. Third, we could find out if like in previous ICT adoption research, perceived trust was also a meaningful construct in medical technology domain. And finally to identify the inter-relationships between the various user and device characteristics, the usage-related experience constructs, and the estimated trust of these specific health worker groups in low-resource setting in Kenya.
3.1. Within-subject design for field study in Kenya

The purpose of this study was to answer whether a TAM, as we proposed in Figure 4, can be validated for a medical device in Kenya. We wanted to understand the relationship between the device and user characteristics, and the perceived constructs. For practical implications, we also aimed to gather insights to determine how distinguished were the two devices in the opinion of the health workers, and which characteristics of the devices and of the health workers influenced their evaluation of the devices.

We chose a within-subject design, a study where the same group of subjects were presented with both the aforementioned devices. This design keeps the results generalizable (i.e. has advantage to have good external validity) to other similar medical technologies which might have similar characteristics (e.g., screening and triage devices measuring heart rate, breathing rate, temperature, and SPO2). Moreover, fewer participants were required to attain an adequate level of statistical power, as the variability caused due to individual differences is avoided with a within-subject design (Ekstrand et al., 2014).

Despite of lesser control in the study, conducting a field study in Kenya could work to our advantage. The realistic setting that engrosses the contextual factors of the environment (health facility setting) in the feedback of health workers, can make their response towards similar devices generalizable to real-life; that is, have high ecological validity.

3.2. Participants and recruitment

In the proposed model, there are several user characteristics as independent variables. Therefore, we carefully selected the participants (health workers) such that the expertise related user characteristics (that is, expertise level, and prior experience with the technology), were evenly distributed into two groups: low levels and higher levels. The language of the questionnaires was English, so it was required that the participants understood English.
The recruitment of the health workers was vastly based on their availability, and was carried out using cluster sampling method; meaning that we randomly chose one health-facility, and then randomly recruited participants from that facility. We approached CHWs first as they are volunteers under government run programs who work in a mobile manner and are hence difficult to get access to. After recruiting 55 CHWs who had been recently trained for using the existing device and some other screening and triage devices, we approached three health-facilities, both private and public, to randomly recruit 27 nurses, the high-expertise health worker group. For recruiting both, the nurses and CHWs, we gained permission from management level personnel, by briefing them about the aim of the study and the session contents.

### 3.3. Study materials

We used questionnaires because we wanted large amounts of quantifiable data which could be objectively analyzed to test our framework.

#### 3.3.1. Questionnaire Design

The questionnaire was a combination of context-relevant questions (Appendix A) which were taken from questionnaires used in previous research (McKnight et al., 1998; Davis, 1989; Park et. al., 2009; Laitenberger and Dreyer, 1998; Carayon, Hundt and Wetterneck, 2010; Venkatesh, et. al., 2003; Koufaris and Sosa, 2002).

Keeping in mind that the participants had never participated in such a study, the questions were explicitly framed using simple/common words. The tone of the questions focused on evaluating the device rather than of judging their capability as that can be perceived as aggressive. We used example questions as aids to illustrate the dynamics of rating as each question was to be answered for both the devices.

To make the questionnaire easy to follow, we thoroughly worked on the flow of the questions. We began with easy to answer questions ("Age", Time taken in the measurement process), and continued with the questions which required them to state their perceptions of the technologies ("I would find this device easy to use"). By this time they were expected to get used to the rating style and to answer according to their opinions with less novice-barrier. And at the end, we asked the more personal questions like about personal space intrusion.

Since it was field research, it was difficult to determine beforehand what would be the organizational conditions in which we would interact with the participants. So we made the questionnaires in a booklet style, for which the health workers did not need a table in front while filling them. And the questionnaires included pictures to communicate quicker (Figure 5), look more inviting and to have a clear distinction between the questions, and the scales for the two devices. Based on the advice from researchers who had interacted with similar user groups before, we kept each page free of clutter by including fewer questions and plenty white spaces (where they could write comments as well).
3.3.1.1. Questions for Measurement model

Perceived constructs used in our model measure latent constructs, that is, unobservable characteristics of people (meaning subjective measurement) such as feelings, and opinions, which are believed to exist and they cause variations in their answers to the scale. For each construct item, we use multiple-item (to check reliability), 7-point Likert scaling where the participants responded to a set of statements in terms of their own degree of agreement (7) or disagreement (1). It is common practice to use the term “strongly agree/disagree”, but participants tend to avoid such extremes (Bertram, 2007), so we kept the extremes as “agree/disagree”. Measurement model includes the various perceived constructs which are assigned several (more than 2) question items, that presumably measure the associated construct.

In the Table 1, we present the items used for each construct items.
Table 1: Question items

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Items</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived ease of use</td>
<td>Ease of operation/control</td>
<td>I would find it easy to get this device to do what I want it to do.</td>
</tr>
<tr>
<td></td>
<td>Ease of use</td>
<td>I would find this device easy to use.</td>
</tr>
<tr>
<td></td>
<td>Ease of task performance</td>
<td>Using this device would make it easier to do blood pressure measurement.</td>
</tr>
<tr>
<td>Perceived usefulness</td>
<td>Task completion speed</td>
<td>Using this device in my job would enable me to accomplish tasks more quickly.</td>
</tr>
<tr>
<td></td>
<td>Job performance</td>
<td>Using this device would improve my job performance.</td>
</tr>
<tr>
<td></td>
<td>Productivity/ Effectiveness in job</td>
<td>Using this device would enhance my effectiveness (help me do my job better).</td>
</tr>
<tr>
<td></td>
<td>Usefulness in the job</td>
<td>I would find this device useful in my job.</td>
</tr>
<tr>
<td>Perceived learnability</td>
<td>Ease of learning the operation</td>
<td>Learning to operate this device would be easy for me.</td>
</tr>
<tr>
<td></td>
<td>Effort expected to be put in learning it</td>
<td>It would be easy for me to become skillful at using this device.</td>
</tr>
<tr>
<td></td>
<td>Prone to error</td>
<td>I am afraid I will make mistakes while using this device.</td>
</tr>
<tr>
<td>Perceived trust</td>
<td>Trust in performance</td>
<td>I trust this device will perform well (detect hypertension well).</td>
</tr>
<tr>
<td></td>
<td>Trust in device</td>
<td>I do NOT trust this device.</td>
</tr>
<tr>
<td></td>
<td>Trust in information</td>
<td>I trust this device will provide me information and decision support that I need my job.</td>
</tr>
</tbody>
</table>

3.3.1.2. Threats to validity and response bias

This questionnaire might lack validity as such a questionnaire has not been used before in this specific context and there is no way to know how well did the respondents understand the questions and how truthfully did they answer. To inspect for such effects, we included negative questions and open questions at various places, both to indicate whether the participant had read and understood the questions as intended or not. For example, if we detect an answering pattern in a participant data of selecting only 7s for ‘trust’ questions, the valid response to a negative item of trust should be a number on the other extreme area of the scale. Since negatively framed questions can also be difficult to comprehend, so in line with keeping the questionnaire simple we included only two such questions.
3.3.2. Mockup

Every participant had at least a week of prior experience with the existing device but the new device was in a conceptualization stage, as seen previously in Figure 2. To provide the participants with an aid for gaining the usage experiencing with the new device, we 3D-printed a handheld non-functional dummy form (Figure 6), which looked like a legit medical device and afforded the interaction style as required for taking measurement from this device.

![Mockup for the new device](image)

**Figure 6: Mockup for the new device**

3.4. Procedure

In one study session, the following steps were followed: reading and signing informed consent, introducing the study, briefing about the session, demonstration of the use of the devices and questionnaire filling.

The informed consent included a brief description of everything that a participant should know, ethically and practically, in order to give us their consent for collecting their answers, and further analyzing them for use in publishing, and/or development of technology. The first task therefore, was to read through the informed consent, and sign it if they agree to participate. Once they gave their consent, we began the study procedure.

In the beginning of the session, the introduction given to the participants included the purpose of the study, their role in the study, what is going to happen and for how long. Negative feedback was encouraged by informing the participants that the research is at an early stage of product development. To avoid any positive biases, none of the researchers showcased any Philips association via branding the mockup or wearing apparels of Philips.

The measurement processes carried out with both the devices were demonstrated by the researchers. The sessions took place either in groups (Figure 7) or as individual sessions (Figure 8).
All participants had used the existing device (Figure 1) before, so to make sure that they have some experience with the new device as well, they were encouraged to role-play with the mockup switching roles of health worker and patient. The participants were asked to remember the interaction experience with the two devices. The usage experiences were the basis of their answers in the questionnaire.

To make the task of filling in the questionnaire easier, we walked them through the questions. We explained how to use the scale, using the example questions, and later tried a sample question together with everyone to confirm their understanding of the rating procedure. Researchers helped in understanding the terms or question/statements which were not understood, on demand or if deemed necessary.
3.5. Analyses plan

With the data gathered, we had planned to first explore the distributions of the participants over several user variables, and the distributions of measured technology variables. The model based hypotheses were to be tested using a multivariate method, called Structural Equation Modeling (SEM). Researchers studying and applying TAM usually use SEM to verify the causal relationships in their proposed models (Park et al., 2009, Park, 2009, Nair and Das, 2012, Teo, 2009, Pedersen and Nysveen, 2003)

SEM is a comprehensive statistical technique which accounts for the variance among a set of variables to understand their interrelationships. This technique explains as much of their variance as possible within a specific model (Kline, 1998) and explicitly specifies the unexplained variance or error (Suhr, 2008). Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are usually employed first to assess whether the shared variance of the measured variables (question items) are attributable to latent constructs; latent constructs are the inferred variables which are calculated using the observed variables (responses on question items) in a mathematical model. While EFA identifies the latent variables based on the maximum amount of variance explained, (Suhr, 2006) CFA evaluates the model fit of the proposed measurement model (expected compositions of the items into a latent construct) (Thompson, 2004).

Unlike the traditional multiple regression method which rely on one statistical test (R-squared) to determine the significance of the analysis, SEM utilizes several statistical tests to assess the adequacy of the model fit. The model fit tests used in SEM and the criteria that indicates a good model fit are stated below.

1. **Chi-square**: A close to zero chi-square value indicates that the observed covariance does not differ much from the expected covariance and a p-value greater than 0.05 is considered good.
2. **CFI, TLI**: From a range of 0 to 1, a higher than 0.90 Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) indicates an acceptable model fit.
3. **RMSEA**: Root Mean Square Error of Approximation (RMSEA) is related to residuals and 0.06 or smaller value with p-value lower than 0.05 is a good model fit.

In case of inadequate model fit, certain modifications are made in the model depending on the significance of the estimates (Suhr, 2008). We used MPlus as the statistical tool to employ the aforementioned analyses. MPlus is a latent variable modeling program that allows an easy way of conducting SEM, EFA and CFA with ample options.
Chapter 4

Results

In this chapter, we present the study results as analyzed using the gathered data. First, we present a summary of the data, and then describe model testing based on our hypotheses (Figure 4).

Out of a total of 82 participants (55 CHWs, and 27 nurses), 13 (12 CHWs, and 1 nurse) were counted as non-respondents due to largely incomplete responses, or clear un-involvement observed during the study. Thereby, in total, we processed data from 69 participants (43 CHWs, and 26 nurses).

4.1. Summary of the gathered data

4.1.1. Characteristics of health workers

First of all, we present a summary of the participant information. The high (nurses) and low level (CHWs) health workers were expected to have different backgrounds (in terms of age, medical training, and prior experience). Their reported information illustrates how they really differed. The total number of nurses and CHWs were 26 and 43, respectively. The frequency data is presented in terms of proportions (i.e., 15% of nurses were aged 51 and more, while 30% of CHWs fell in that age group).

The health workers were almost equally divided into three age categories: below 40, 41-50 and above 50 years old. Most of them were females (84%), so there was not enough data per group to check differences based on gender. All the nurses were educated to college level while only 1/3rd of the CHWs were college educated. Expectedly, almost all the nurses had medical training longer than one year as compared to 1/4th of the CHWs with such training. Most nurses (84%) had prior experience with the existing device for longer than a year, while most of the CHWs (86%) did not.

4.1.2. Characteristics of BP measurement devices

The two medical devices were assumed to be different from each other in terms of time efficiency and intimidation factor. As seen in the bar chart in Figure 9, both types of health workers rated the new device very high on the speed of measurement as compared to the existing device. Both the health workers rated the devices below 4 (out of 7) for ‘intimidation caused’, indicating that none of the devices were very intimidating (Figure 10). But interestingly, CHWs seemed to be intimidated
more by the devices than the nurses ($\chi^2(2) = 15.54$, $p = 0.000$, Table 3 in Appendix depicts the differences between the responses of health workers over low-medium-high intimidation levels).

We had assumed that in opinion of the health workers, *personal space violation*, and *feeling of nervousness* caused by the new device (i.e., measurement on the chest) to the patients will be more than that caused by the existing device (i.e., measurement on the arm); Figures 11 and 12 suggest that this difference is only present for the nurses.

The CHWs do not seem to expect any difference in the personal space violation caused by the two devices. And in contrast to our original expectations, their response seem to indicate that they expect less nervousness to be caused by the new device ($\chi^2(2) = 8.72$, $p = 0.013$, Table 4 in...
Application of the TAM: Healthcare in Kenya

Appendix B depicts differences between responses of CHWs over low-medium-high nervousness levels).

After establishing how the two health worker groups differed on various characteristics, and how the two devices were perceived differently on their characteristics and their impact on the patients, we further investigated the effects of all these variables on the user acceptance constructs as seen in our TAM (Figure 4).

4.2. Measurement model: checking the constructs

Before investigating which user and technology characteristics influenced the perceived constructs, we ran a Confirmatory Factor Analysis (CFA) to validate the measured constructs; i.e., checked whether the items used for each construct (3 each for PEU, PL, PT, and 4 for PU) measured them reliably. The CFA model did not converge indicating that the questionnaire items were not grouped as designed. Therefore, we submitted the responses of the construct questionnaire (13 questions) to an Exploratory Factor Analysis (EFA) to see how the items in the questionnaire did relate to each other.

In EFA, we stepwise discarded the question items which cross-loaded on more than one factors, in order to discover the underlying factor structure. The analysis used ordinal dependent variables with weighted least squares estimator using a diagonal weight matrix (WLSMV) estimator and oblique rotation (Geomin) on observations clustered on 69 subjects. After discarding 5 questions out of the total of 13 (i.e., the items which do not have factor loadings in Table 2; ease of control, makes it easier to measure blood pressure, enhances effectiveness in job, useful in job, ease of learning to operate) we found three factors in contrast to the originally expected four constructs. Therefore, we revisited the question items and re-interpreted what the factors might be measuring based on the questions that loaded on them (as seen in EFA section of the Table 2).

On re-interpretation, the three derived factors were: perceived usage (3 items; ease of use, helps to accomplish tasks quicker and improves job performance), perceived performance of the device (3 items; easy to become skillful at using the device, functional performance and information and decision support by the device), and perceived trust (2 items; do not trust the device, afraid will make mistakes using this device) in the device.
Table 2. EFA and CFA of perceived constructs

<table>
<thead>
<tr>
<th>Predicted factors</th>
<th>Derived factors after EFA</th>
<th>Factors after CFA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Perceived usage</td>
<td>Perceived performance</td>
</tr>
<tr>
<td>Cronbach α</td>
<td>0.900</td>
<td>0.821</td>
</tr>
<tr>
<td>Average variance extracted (AVE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Perceived ease of use (PEU)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would find it easy to get this device to do what I want it to do.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would find this device easy to use.</td>
<td>0.817</td>
<td>0.088</td>
</tr>
<tr>
<td>Using this device would make it easier to do blood pressure measurement.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Perceived usefulness (PU)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using this device in my job would enable me to accomplish tasks more quickly.</td>
<td>0.877</td>
<td>-0.014</td>
</tr>
<tr>
<td>Using this device would improve my job performance.</td>
<td>0.932</td>
<td>0.082</td>
</tr>
<tr>
<td>Using this device would enhance my effectiveness (help me do my job better).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would find this device useful in my job.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Perceived learnability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning to operate this device would be easy for me.</td>
<td>0.428</td>
<td>0.528</td>
</tr>
<tr>
<td>It would be easy for me to become skillful at using this device.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am afraid I will make mistakes while using this device.</td>
<td>-0.042</td>
<td>-0.012</td>
</tr>
<tr>
<td><strong>Perceived trust</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I trust this device will perform well (detect hypertension well).</td>
<td>-0.004</td>
<td>0.911</td>
</tr>
<tr>
<td>I do NOT trust this device.</td>
<td>0.020</td>
<td>0.001</td>
</tr>
<tr>
<td>I trust this device will provide me information and decision support that I need in my job.</td>
<td>0.211</td>
<td>0.632</td>
</tr>
</tbody>
</table>
Even though one of the question items (i.e., *It would be easy for me to become skillful at using this device* in Table 2) had cross-loaded on two factors, the model fit was decent (RMSEA = 0.110 with a 90% C.I. between 0.051 and 0.173, CFI = 0.994, TLI = 0.977 and a $\chi^2(28) = 2071.041$ (p < 0.001)), so we kept it to further check the model fit with SEM.

In an initial SEM, we built a model similar to our hypothesized model (i.e., PEU, PL, and PU determine PT), where *perceived trust was determined by the other two derived constructs*; i.e., *perceived usage* and *perceived performance*. Moreover, we also checked the relationship between *perceived usage*, and *perceived performance*. We found that this model did not work well because the model estimated a very strong correlation between *perceived usage* and *perceived performance*, which basically meant they were indistinct factors. Therefore, we collapsed the usage and performance factors into one factor, and discarded the questions with low loadings until the model fitted well, finally retaining 3 items. The questions with low loadings were incidentally all under the *perceived performance* category, so we label the final construct used to represent PEU, PU, and PL, as *perceived usage*. The final two-construct model; i.e., *perceived usage* (3 items; ease of use, helps to accomplish tasks quicker and improves job performance), and *perceived trust* (2 items; do not trust the device, afraid will make mistakes using this device), was used to inspect the relationships between the device and user variables with the user evaluations.

In Table 2, the item loadings highlighted green were included in the final model. Yellow highlights had loaded high, but they worsened the model fit, so were not included. The underlined item loading indicates cross-loading.

The final CFA model with the two constructs fitted very well, with RMSEA = 0.038 with a 90% C.I. between 0.000 and 0.140, CFI = 1.000, TLI = .999 and a $\chi^2(4) = 4.767$ (p = 0.312). As reported in Table 2, the average variance extracted (AVE) for both the factors was greater than 0.50 (0.90, 0.66), thereby holding their convergent validity, and both the factor AVEs were greater than the correlation between the two latent factors (-0.43). The table also shows the final factor loadings of every item considered.

With this analysis, we derived the perceived constructs as observed in the gathered data. These constructs represent the data-derived model for the right part of our hypothesized model (i.e., Perceived constructs in Figure 4)

### 4.3. Structural model: checking the inter-relationships

We employed the Structural Equation Modeling technique to test the relationships between the external variables, and the derived perceived constructs.

In SEM, along with the derived constructs, we introduced the external variables as in Figure 4, in the order of the generated hypotheses. To prevent multi-collinearity problems, we only included variables with low inter-correlations (less than 0.6) (Appendix B, Table 5). If the variables did not have significant effects in the hypothesized relationships, we removed them from the model on-the-
go, and kept only the independent variables (i.e., external variables including the health worker, and device characteristics), which had significant effects.

The final model presents the significant relationships found after the running the SEM (Figure 13). This model included observations clustered on 67 participants, and the fit was good: RMSEA = 0.044 with a 90% C.I. between 0.000 and 0.089, CFI = 0.992, TLI = 0.988 and a $\chi^2(24) = 29.654$ (p = 0.196). We will test our hypotheses with the relations in the SEM model.

4.3.1. Testing of hypotheses with derived perceived constructs

H1 expected a positive impact of PEU, PU, and PL on PT. Since in the last section, we established a combined factor for PEU, PU, and PL, as perceived usage, this hypothesis is tested by the relation between perceived trust on perceived usage. The relation is significant ($\beta = 0.301$, p = 0.006). Hypotheses H2a and H2b expected positive effects of PEU and PL on PU, respectively. In section 4.2, we found that PEU, PL and PU were indistinguishable latent constructs, so we could not test these hypotheses.

The direction of the arrows illustrates the nature of the relationship. Near the arrows, the type of relationship (positive or negative), regression coefficients (standard errors) and p-values are specified.

Figure 13. Derived structural model
4.3.2. Testing of hypotheses with variables related to the health workers

Our hypotheses (H3-H5) suggested that the medical background (objectively measured in terms of years), prior experience, and educational of the health workers should have a positive effect on the user evaluations. We found no such relationship, which means in spite of having more established professional backgrounds, the more experienced health workers did not evaluate the devices better. The age was expected to have a negative effect on the usage of the device (H6), however this effect was also non-existent. As per hypothesis H7, the general trust of health workers on medical technology was supposed to influence their perceived trust in the technology. This effect was strong and significant ($\beta = 0.704$, $p = 0.02$). Overall, other than the effect of general trust of health workers in technology on their perceived trust, the other user characteristics did not influence their evaluation of the medical devices in terms of their usage and trust in it.

4.3.3. Testing of hypotheses with variables related to the devices

According to the hypotheses (H8-H9), we expected that the two medical devices which differ from each other in terms of time efficiency, and intimidation factors, should have an effect on the perceived usage (i.e., derived PEU, PU, PL) and perceived trust (PT). We partially found these effects in the final framework. Those participants who perceived the device to be more time efficient also perceived it to have greater usage value (H8). This effect was close to significant ($\beta = 0.121$, $p = 0.085$) and hence suggests some support for the hypothesis. As predicted in H9, if the participants felt intimidated, they also perceived that the devices had lower usage value ($\beta = 0.131$, $p = 0.044$).

Hypothesis H10 expected that if health workers thought that the device could violate the personal space of patients, then they will trust the device less. This hypothesis was not supported. Hypothesis H11 expected that if the health workers thought that the device could cause high level of nervousness to the patients, then the health workers will trust the device less, and this hypothesis was supported ($\beta = 0.176$, $p = 0.002$). Finally, we also checked if the device in itself had any direct effects on the perceived usage, and found that indeed, the new device was overall evaluated better than the existing device. This might suggest that some external factors related to the device which were not accounted for in this study, they also influenced the perception of the usage and trust in device by health workers.

Structurally, in our final model, some independent variables influenced perceived trust directly, while the others had an influence which was mediated by perceived usage. Health workers trusted the devices more if their general trust in medical technology was high, and their trust was negatively influenced by the nervousness caused by the devices. They perceived the device to be more useful and usable if the devices caused less intimidation, and took less measurement time. This increase in perceived usage subsequently affected how the health workers trusted the devices, showing how perceived usage mediates the effects of these variables on trust. This structure resembled the hypothesized structure, where some independent variables influenced PT directly, while the effects from other variables to PT were mediated by PEU, PL, and PU.
In the next section, we discuss the stated results, highlight their implications, critique the study, and recommend future research options.
Chapter 5

Discussion and conclusions

The motivation behind conducting this study was to find out if the Technology Acceptance Model (TAM) (Davis, 1989) which is widely used in Information Communication Technology (ICT) adoption research, is also applicable in medical domain, specifically, screening and triage technology acceptance in sub-Saharan Africa. To investigate this, we focused on health workers in Kenya, and their acceptance of a blood pressure measurement device.

Literature review on the TAM-based framework and modified versions of TAM directed us how we can construct our model for this particular case study. Structurally, TAM consists of several components with causal and mediating relationships. The components include the core constructs of TAM, which are, perceived ease of use (PEU), and perceived usefulness (PU), the external variables, which depend on the user and technology characteristics relevant to the study, and alternative constructs. Complying to this structure, we constructed our model (Figure 3) using the core constructs, various health worker characteristics (from TAM literature), device specific characteristics, and two more perceived constructs, perceived learnability (PL) (from user acceptance literature in medical domain), and perceived trust (PT) (from TAM research in ICT domain). Our research questions were to understand whether on employing our TAM in this study, PEU determines PU like in previous literature, if PL and PT are meaningful additions to such a model, and to find the external variables determining the user acceptance of the devices (Figure 4).

We collected data about all the variables present in our TAM via a field study in Kenya, where we recruited health workers with various expertise levels; nurses, and Community Health Workers (CHWs). They were asked to fill questionnaires based on their usage experience with the two blood pressure measurement devices; with the existing device, their experience based on its use in their jobs, and with the new device, experience based on their interaction with a mockup of the new device during the study sessions. From the field study, where we conducted several group and individual survey sessions with 82 participants (health workers) in Kenya, data from 69 participants was valid, and was used for model analysis using Structural Equation Modeling (SEM).
5.1. Main Findings

5.1.1. Core constructs of TAM and their inter-relationship

In the TAM-based framework, PEU and PU have been considered as the core constructs. This framework was used in subsequent studies as modified versions. The models created had variables added to PEU and PU, which had specific relevance to the research. We constructed our model as well by using these two constructs, which we measured using questions similar to those in previous studies, and relevant to our context. On application of our model in Kenya however, the core constructs, PEU and PU, were not found to be two distinct constructs, rather a single construct. This construct was measured by question items about the ease of use of the device, the affordance of the device to accomplish the task quicker, and the enhancement of job performance by the device. These items represent how the device supports the user by making it easy to use, its positive effect on the task itself, and overall on the job of the health workers. Therefore, we interpreted this construct as perceived usage.

Previous research has found close causal relationship between the two core constructs, where PEU determines PU (Park et al., 2009). Since in our particular case study, we did not find these two as separate constructs, rather a single construct which combines the items of PEU and PU, our results might suggest that these two constructs signify different meanings for tangible screening and triage devices, as compared to ICT applications (where TAM is usually applied).

We speculate that the application domain of ICT addresses various parts of a system when measuring PU and PEU, while in tangible medical devices, the same part of the system is addressed for measuring the two constructs, which makes it difficult to distinguish them from each other. The usage of ICT applications is via a computer-like interface which usually incorporates multiple features for various functions, and allows navigation through a complex architecture; whereas, tangible screening and triage devices like the ones we used in our study have one functionality, and a defined procedure to utilize that functionality (like measuring blood pressure). For ICT applications, an estimate of PU might address the relevance of provided functionalities, and PEU might determine how intuitive is the usage and navigation. However, for blood pressure measurement device, where there is one functionality and a defined procedure of use, PU and PEU might not considered as separate constructs, as they together address the question of whether the device is relevant in context of use, and if the defined procedure is easy to perform.

Therefore, our results indicate that in contrast to TAM for ICT, which has PEU and PU as its two core constructs, applying TAM for the domain of tangible medical devices is not straightforward, and might require validation of TAM specific to an application-domain.

5.1.2. Importance of Perceived learnability as an additional construct to TAM

Other than PEU and PU, we had included two additional perceived constructs, PL, and PT in our model. To our knowledge PL has not been a part of the TAM literature. However, it had been
deemed important for ICT research where it is sometimes used interchangeably with PEU (Nielsen, 1993), and in medical device user acceptance research (Carayon, Hundt and Wetterneck, 2010). Therefore, we employed it in our model treating it similar to PEU, to find if it is meaningful to add PL as a construct in a TAM. We did not find a distinct role of PL in our study.

For our case, participants had to evaluate two devices, the existing one which they had learnt how to use in the past, and the new one, which was not yet functional, and therefore difficult to anticipate its learnability in future. Perhaps this dissociation made the comprehension of PL question items difficult. Moreover, in this context, independent learning of how to use the device is rare, as health workers are usually given trainings for operation of the devices. Therefore, for the participants, the concept of learnability of the device seemed to be more relatable to trainings than to the ability of the device of being intuitive to use, and self-instructional.

However PL was not very meaningful for our study, our results do not suggest that PL will not be useful for future TAM research. Because logically, the argument for including PL remains the same, that is, certain applications might be easy to use, once you have learnt how to use it; PL could be meaningful in other studies where the context of use and/or the application of interest is different.

5.1.3. Importance of Perceived trust in medical application domain

In e-commerce TAM research, PT was considered as an important perceived construct which was determined by PEU and PU (Koufaris and Hampton-Sosa, 2002). Due to the relevance of user trust in technology in medical domain, we added PT in our model in a similar manner that is, being determined by PEU, PL, and PU. Two question items measured the construct of PT; i.e., the question item of PL, system being prone to errors (i am afraid i will make mistakes while using this device) as mentioned earlier, and a straightforward question on trust framed negatively (i do not trust this device).

The responses of participants indicated that if a device is not trusted with its usage, it is also quite likely that they feel afraid that they’ll make mistakes while using it. And vice versa, a mistake in the world of medicine can be very costly, and healthcare personnel might not trust a device to be used for patients if its usage causes them to make errors in their judgment. Interestingly, our data-derived construct named as ‘perceived trust’ includes two negatively framed items, and hence can be debatably names as ‘perceived distrust’. Moody and colleagues (2015) found that in the online context, trust and distrust are not the extreme ends of a continuum, they are separate constructs. As negativity tends to influence evaluations more strongly than positivity (Ito et al., 1998), studying acceptance with the construct of distrust might be actually more interesting than measuring the construct of trust.

In our hypothesized model (Figure 4), we had expected that PEU and PU will determine PT, and based on our derived model, perceived usage (which combines PEU and PU) indeed positively influenced perceived trust. This supports the previous e-commerce study by Koufaris and Hampton-Sosa (2002), and transferability of this relationship in our study context indicates the importance of using PT as one of the user acceptance constructs in TAM for medical contexts.
5.1.4. Factors determining the user acceptance of BP measurement devices

Among the external variable which we accounted for, four of them demonstrated significant effects on perceived constructs. Where general trust in technology, and the feeling of nervousness affected perceived trust, time efficiency, and intimidation had causal effects on perceived usage (which mediated their effects to perceived trust).

5.1.4.1. Factors directly determining Perceived trust

General trust in technology determined user acceptance, particularly PT, as was expected. This confirms that if a user trusts a medical technology in general, they are more likely to trust medical technologies irrespective of their specific characteristics. Therefore, the two devices in the study were in general trusted more by those who had a general stance of high trust in medical technology. Following these results, we suggest that a TAM which considers PT as one their constructs, it should be useful to also consider General trust stance of participants as a control variable, to find out if the perceived trust of users in the technology being study is truly a consequence of the technology, or of their general trust.

Another external factor, the feeling of nervousness, also determined perceived trust. This relationship indicates that the trust in technology by health workers was not entirely irrespective of the impact of the devices.

The new device was expected to cause more personal space violation than the existing device due to the point of contact being the chest versus the arm (Cheng, 2011), which further expected to cause higher levels of nervous feeling in the patients (Burgoon and Jones, 1976). Both of these intrusiveness factors were expected to negatively affect PT. And although, we found no effect of personal space violation on the user acceptance constructs, we did find a direct causal effect of feeling of nervousness on PT. Since nervousness and personal space violation strongly correlated to each other (Appendix B), we propose that possibly, part of the nervousness expected to be caused to the patients was due to the point of contact with the body (chest position).

These two factors measuring impact of devices in terms of intrusiveness were extremely relevant in our study context, because previous TAM research (Hsu and Lu, 2004) suggested that social influences are an important contributing factor. It is important for a technology to be accepted from cultural and social perspectives, as both perspectives influence perception of personal space (Lomranz, 1976; Manzo, 2005). Moreover, personal space also plays a crucial role in medical settings, as nursing procedures usually include direct or indirect touching (Christine, 1998). Therefore, our study suggests that future application of TAM in settings like sub-Saharan Africa and medical domain specifically, the factor of nervousness caused due to personal space violation might play a crucial role.
5.1.4.2. Factors determining Perceived trust via Perceived usage

Time efficiency was expected to positively impact the user acceptance constructs, and as expected, it was a significant determinant for the acceptance of the devices. In our study, this factor was the main distinguishing characteristic of the two devices used. The new device which is designed to be faster also seems to be evaluated faster by both types of health workers than the existing one (bar charts in Chapter 4). This confirms that in Kenya there is a need of reducing the measurement time, and hence the consultation time, as was also illustrated in primary care research (Kringos et al., 2010). Therefore, in future TAM research based in medical settings in similar low-resource setting, time efficiency can be an important factor which can improve user acceptance of a technology.

The two devices differed from each other on factors like, portability, modern technology, size, form, which were not measured in our study. There was simultaneously also an extra effect caused by the type of device, which suggests that apart from time efficiency (where the two devices mainly differed), other external factors are also responsible for the evaluations of the devices. This might indicate that if possible, as many external factors of the device should be included in a TAM as are identified before conducting the study, in order to learn most about the determinants of user acceptance. This suggestion contradicts the trend in TAM research, where many aspects (like group, social, and cultural aspects) that might affect user acceptance are many times neglected, as also criticised by Bagozzi (2007).

Finally, we expected intimidation caused by the device to negatively affect user acceptance, and this was confirmed by a significant negative effect of intimidation on perceived usage. From the bar charts in Chapter 4, the intimidation seems to be caused not by the device, but is rather due to the participant group (the mean of intimidation experienced by CHWs is between ratings 3 and 4, while the mean for nurses is around rating 2). A possibly heightened feeling of intimidation by the device to CHWs could be explained by their lower familiarity with medical devices in general, similar to how people who are not much familiar with computers feel intimidated by them (Schulenberg and Melton, 2008). Thus in TAM research, which is applied for screening and triage acceptance, if the potential users might have low familiarity with the technology of use, then intimidation should be considered a possible determinant of user acceptance.

5.1.4.3. Factors which did not affect user acceptance in our TAM

The higher age was expected to lead to lower user acceptance (Kuo et. al, 2009), but contrary to our expectation, we found no age effects similar to the research of Park and colleagues (2009). The differences were expected due to a decrease in motor capabilities with an increasing age (Bosman and Charness, 1996). The absence of a significant effect of age on user acceptance in our results might be explained by the small range in our participant age groups (<40, 40-50, >50). The differences in the two participant types, nurses and CHWs, due to medical expertise, prior experience, and education were only visible in the intimidation caused by both the devices, as explained earlier. And finally, no effect of personal space violation on user acceptance might be
explained by the seemingly similar responses of CHWs towards violation by both the devices, but different user evaluation for those devices.

Our overall the structure of our data-derived TAM was similar to the structure explained by King and He (2006), that is, several causal and mediation relationships between external variables, and perceived constructs which are relevant in the specific user acceptance research.

5.2. Limitations

We identified certain limitations to our study which mainly concern the methods used, and so we propose alternatives for any follow-up TAM studies.

We had planned to recruit equal numbers of CHWs and nurses to have the same quantity of input from both low and high expertise groups, but due to time constraints for both, the participants and the researchers, it wasn't possible to recruit any more than 27 nurses to match the number of CHWs (i.e., 55).

During questionnaire filling, the participants either answered the questions after discussing in groups, or individually. This mainly depended on how the sessions were held, which further depended on the managerial permissions, and the availability of nurses and CHWs in terms of time. This led to an uncontrolled study, which is expected from a field study, but can be avoided by setting the criteria to always doing these sessions in groups. We observed that health workers naturally discussed all the questions amongst each other to fully understand and comprehend the scenario, perhaps due to their collectivistic culture. So in such settings, an open discussion of each question can be a part of the procedure which follows individual questionnaire filling.

Moreover, in our final analyses, we could not consider many questions due to low reliability. The causes included difficult question framing, and the demand of certain questions to anticipate the future behavior of the device. Such challenges can be tackled by involving a local team member while formulating the questions, and translation in local language could also be considered. Furthermore, participants should not be made to anticipate certain functionality by the device. For an early stage study like this one, if a functional prototype cannot be employed in the field for testing, a semi-functional mockup could be employed which allows the most important interactions, and/or a Wizard of Oz testing is another alternative; where a system seems to be automated but is actually being operated by a researcher.

In future, we also recommend to measure more device based characteristics in the study (while avoiding overfitting), in order to understand why one device is preferred over the other.
Finally, for future research which uses TAM as user acceptance model for the context of medical devices in sub-Saharan regions, the questionnaires need to be validated, so that the perceived constructs which are the real indicators of user acceptance can be reliably measured.

## 5.3. Conclusion

We studied the applicability of Technology Acceptance Model (TAM) from ICT adoption research, in the application domain of screening and triage technologies in a sub-Saharan setting. In our case we employed a TAM for studying the user acceptance of a representative screening and triage technology, namely, blood pressure measurement device, in a sub-Saharan country, namely, Kenya, with local health workers of different professional standings. Where we found some evidence of TAM being a good structural model to conduct user acceptance research in this application domain, we also found some limitations related with its transferability to this domain.

First of all, the two core constructs of TAM-based framework and its subsequent research were not distinct in our study. We suspect that this result was found due to non-transferability of the basic structural constructs of perceived ease of use (PEU), and perceived usefulness (PU), from ICT domain to a tangible medical device, due to fundamental differences in how they are used and experienced by a user. However, questions from these two constructs combined to form a single construct which we termed as Perceived usage. We conclude that to measure these constructs properly, there is a need to develop validated questionnaires for studying these perceived constructs in this application domain, and in this setting.

Second, we introduced perceived learnability (PL) in our TAM as an additional perceived construct, but it did not play a role in our particular study. Whether it can be meaningful to include PL as an additional construct is not clear from our study. The questions we used to measure PL in our study were not easy to comprehend by the participants given a non-functioning mockup of the new device. Therefore, we can suggest that the question items should be used carefully to measure PL in future, that is, after investigating its relevance in the context of research.

Third, we employed perceived trust (PT) from previous e-commerce based TAM research (Koufaris and Hampton-Sosa, 2002) in our case study, and found it to behave similarly (being determined by other variables of the model, directly or indirectly), and hence playing a crucial role in our model. Even though the meaning of trust was different in our study as compared to the previous research, this transferability shows that as long as PT is a relevant construct to a study, it might play an instrumental role in a TAM. As this construct was measured by two negatively framed items, we propose future research to determine whether the construct of perceived distrust could be an important construct in a TAM.
Fourth, we found how the external variables influenced the user acceptance of the blood pressure devices for health workers in Kenya. We conclude that a TAM that includes PT as a construct, should also consider General trust in technology as an external variable. Moreover, for the domain of screening and triage devices in social settings like sub-Saharan Africa, feeling of nervousness due to personal space violation should be an important determinant of PT. In similar settings where participants might be less familiar with the concerned technology, intimidation caused by the technology to the direct users is also suggested to be an important determinant of Perceived usage, and finally of Perceived trust. Furthermore, we found that time efficiency positively influenced Perceived usage of the devices, and this variable should be considered with high importance in healthcare settings of sub-Saharan Africa.

Finally, the overall structure of a usual TAM as analyzed and explained by King and He (2006), was retained in our resulting TAM, and that might suggest that although this model has limitations, it can still be a meaningful way to study the user acceptance in the application domain of screening and triage devices, in sub-Saharan Africa. In our study, there was no direct replication seen with the collapse of PEU and PU into one single construct, but this in general gives important insight into how a different domain might demand modifications in structural TAM as well. In general, TAM research is done to understand adoption of ICT applications, this study provides a preliminary example of how useful TAM can be to determine the user acceptance of other technology domains, such as medical technologies, in various contexts of use, like low-resource settings. Since many of the variables are applicable for other screening and triage devices as well, they can be employed in future TAM studies for the broader domain. An applied implication of this conclusion is that, such models can be helpful for manufacturers to conduct early stage user acceptance research in their target markets (like sub-Saharan Africa, where the need is high) to tailor their product designs more to the users for a successful implementation. Moreover, investors can also benefit from such research by evaluating technologies based on the criteria that they satisfy according to the external variables that determines user acceptance.

To conclude, in low-resources settings like sub-Saharan Africa, primary care services can play an instrumental role in controlling preventable diseases to some extent if intervened at an early stage. Primary care services like screening and triage needs appropriate technology for an effective and efficient delivery, such as, reduction in consultation time, and per head workload. And for that, these technologies should be tailored for its users, especially because they are being increasingly used by health care personnel of varying expertise levels. In our study, we demonstrated how an adapted version Technology Acceptance Model can potentially be a great way to determine which technology and user characteristics are impacting expected trust in and acceptance of new technologies in Kenya.
References


Priority Medical Devices project: methods used. WHO


## Appendix A: Questionnaire

Figure 14. Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age group:</td>
<td>16-20 years old</td>
</tr>
<tr>
<td></td>
<td>31-40 years old</td>
</tr>
<tr>
<td>2. Gender:</td>
<td>Male</td>
</tr>
<tr>
<td>3. Education level:</td>
<td>Primary school</td>
</tr>
<tr>
<td></td>
<td>I do not want to answer</td>
</tr>
<tr>
<td>4. For how long have you received a medical training?</td>
<td>one week</td>
</tr>
<tr>
<td></td>
<td>6 months - 1 year</td>
</tr>
<tr>
<td>5. For how long have you received a training for using a blood pressure cuff?</td>
<td>one week</td>
</tr>
<tr>
<td></td>
<td>6 months - 1 year</td>
</tr>
<tr>
<td>6. I generally trust health technology</td>
<td>Always true</td>
</tr>
<tr>
<td></td>
<td>I do not want to answer</td>
</tr>
</tbody>
</table>
Application of the TAM: Healthcare in Kenya

Mark your answers for Cuff & Tricorder

**Question 1:** I think the measurement process was

1. Very slow
2. Slow
3. Slow nor quick
4. Moderately intimidating
5. Not intimidating at all
6. Moderately intimidating
7. Very intimidating

State your opinion on the following statements for both Cuff and Tricorder, by marking on the scale from 1 to 7.

**Statement 1:** I would find it easy to get this device to do what I want it to do

1. Disagree
2. Disagree nor agree
3. Agree

**Statement 2:** I would find this device easy to use

1. Disagree
2. Disagree nor agree
3. Agree

Application of the TAM: Healthcare in Kenya

Statement 19: I trust this device will provide me information and decision support that I need my job

1. Disagree
2. 3.
4. Disagree nor agree
5. 6.
7. Agree

Which one is easier to use?
- Cuff
- Tricorder
- None

Which one would be more useful?
- Cuff
- Tricorder
- None

Which one would be easier to learn to operate?
- Cuff
- Tricorder
- None

Remarks or comments?
Compare your experience of taking measurement:

- Using Cuff: that is, wrapping it around the patient’s arm, increasing the pressure
- Using Tricorder on Upper chest: Placing tricorder at patient’s upper chest area
- Using Tricorder on Lower chest: Placing tricorder at patient’s lower chest area

**Question 1:** During the measurement, if I would be the patient, I would feel that the device is violating my personal space

<table>
<thead>
<tr>
<th>Arm</th>
<th>Not at all</th>
<th>2</th>
<th>3</th>
<th>Moderately</th>
<th>5</th>
<th>6</th>
<th>Very</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>Not at all</td>
<td>2</td>
<td>3</td>
<td>Moderately</td>
<td>5</td>
<td>6</td>
<td>Very</td>
</tr>
</tbody>
</table>

**Question 2:** During the measurement, if I would be the patient, I would feel

<table>
<thead>
<tr>
<th>Arm</th>
<th>Not nervous at all</th>
<th>2</th>
<th>3</th>
<th>Moderately nervous</th>
<th>5</th>
<th>6</th>
<th>Very nervous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>Not nervous at all</td>
<td>2</td>
<td>3</td>
<td>Moderately nervous</td>
<td>5</td>
<td>6</td>
<td>Very nervous</td>
</tr>
</tbody>
</table>
Appendix B: Result tables

Table 3. Pearson Chi-Square test for Intimidation level by health worker type

<table>
<thead>
<tr>
<th>Count (% of total)</th>
<th>Intimidation level</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (1,2)</td>
<td>Moderate (3,4,5)</td>
</tr>
<tr>
<td>Nurses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37 (27%)</td>
<td>11 (8%)</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>CHWs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 (24%)</td>
<td>35 (26%)</td>
<td>17 (13%)</td>
</tr>
</tbody>
</table>

Table 4. Pearson Chi-Square test for nervousness level (CHWs) by device type

<table>
<thead>
<tr>
<th>CHWs Count (% of total)</th>
<th>Feeling of nervousness</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (1,2)</td>
<td>Moderate (3,4,5)</td>
</tr>
<tr>
<td>Existing device</td>
<td>6 (8%)</td>
<td>26 (34%)</td>
</tr>
<tr>
<td>New device</td>
<td>15 (19%)</td>
<td>12 (15%)</td>
</tr>
</tbody>
</table>
Table 5. Correlation matrix for the external variables.

<table>
<thead>
<tr>
<th></th>
<th>General trust</th>
<th>Medical expertise</th>
<th>Prior experience</th>
<th>Education</th>
<th>Age</th>
<th>Measurement Efficiency</th>
<th>Intimidation</th>
<th>Personal space violation</th>
<th>Feeling of nervousness</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>General trust</td>
<td>1</td>
<td>0.211*</td>
<td>0.024</td>
<td>0.195*</td>
<td>0.031</td>
<td>-0.005</td>
<td>-0.112</td>
<td>0.079</td>
<td>-0.008</td>
<td>0.000</td>
</tr>
<tr>
<td>Medical expertise</td>
<td></td>
<td>1</td>
<td>0.208*</td>
<td>0.536**</td>
<td>-0.018</td>
<td>-0.069</td>
<td>-0.073</td>
<td>-0.221**</td>
<td>-0.183*</td>
<td>0.000</td>
</tr>
<tr>
<td>Prior experience</td>
<td></td>
<td></td>
<td>1</td>
<td>0.167</td>
<td>0.015</td>
<td>-0.143</td>
<td>-0.071</td>
<td>-0.067</td>
<td>-0.163</td>
<td>0.897**</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>-0.172*</td>
<td>-0.089</td>
<td>-0.164</td>
<td>-0.195*</td>
<td>-0.161</td>
<td>0.000</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.153</td>
<td>0.022</td>
<td>0.118</td>
<td>0.001</td>
<td>0.000</td>
</tr>
<tr>
<td>Measurement Efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.317**</td>
<td>0.176*</td>
<td>0.163</td>
<td>-0.160</td>
</tr>
<tr>
<td>Intimidation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.178*</td>
<td>0.164</td>
<td>-0.049</td>
<td></td>
</tr>
<tr>
<td>Personal space violation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>0.688**</td>
<td>-0.003</td>
<td></td>
</tr>
<tr>
<td>Feeling of nervousness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>-0.148</td>
<td></td>
</tr>
<tr>
<td>Device</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed)  
** Correlation is significant at the 0.001 level (2-tailed)