Exploring ICT4D in the South African Healthcare Context to Improve Efficiency and Healthcare Worker Experiences

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ABSTRACT
In this literature review we investigate the intersection of primary healthcare in South Africa and Information Communication Technologies (ICT). In particular, we focus on how this impacts healthcare workers. We examine four key areas of previous research: the difficulties of implementing ICT systems in the developing world, using waiting times to evaluate the success of healthcare systems, co-design techniques, and technologies for improving healthcare in South Africa. From the literature, we identify that healthcare is a complex space and failure is common. To help address this, we suggest co-design and related methods. We also identify that patient wait times are a significant issue in the South African primary healthcare context, and find that appointment systems are one possible way of reducing wait times. Our review of mobile technologies and tablet computers reveal promising findings for the effectiveness of these technologies in South African healthcare. Overall, we conclude that additional research is required in two areas. Firstly, it is largely unknown how various technologies can contribute to the efficiency of primary healthcare centres, the reduction of patient wait times and to the work of healthcare staff. Secondly, it is also largely unknown how these technologies might compare to one another in this context.

Keywords
E-health; ICT4D; HCI; Co-design; M-health; CHWs; Wait times; Appointments; USSD; SMS.

1. INTRODUCTION
Over the last 50 years, computer systems have increasingly become a part of modern healthcare, with varying degrees of success in improving patient care [1]. While implementing successful computer systems in the developed world is complex enough as is, the developing world has its own set of challenges. Some commonly cited examples are poor infrastructure, lack of skills and training, low levels of literacy and scarce resources [2]. As a result, healthcare administrators in the developing world must explore technologies and systems that aren't typically used in more developed areas.

This literature review aims to investigate the intersection of primary healthcare in South Africa and Information Communication Technologies (ICT), with an emphasis on how this impacts healthcare workers. By reviewing these areas, we seek to understand what previous research says about primary healthcare in South Africa, how this relates to ICT4D and what still remains to be studied. This literature review will discuss four main topics which we deem to be of particular interest to our area. These include the difficulties of implementing ICT systems in the developing world, using waiting times to evaluate the success of healthcare systems, co-design techniques which can be used to increase the likelihood of successful design, and technologies which may be applicable to improving healthcare in South Africa. Finally, we will discuss the findings of these areas and how they interact, concluding with the key findings in the literature.

2. E-HEALTH
E-health (or Electronic Health) has a fairly long history of innovation in healthcare, although it has been a tumultuous one. For the purposes of this literature review, we define e-health broadly as any form of healthcare that is supported by electronic systems, communications and processes. In this section we discuss the background of e-health and its context in South Africa.

2.1 Background
With the exciting prospect of improving healthcare safety and quality in mind, many institutions have looked towards electronic computing systems for healthcare – or "e-health" systems as they are commonly known. While computing systems have undoubtedly made a large impact on healthcare in recent years, the empirical evidence for success in e-health has not always been clear-cut. In a large scale study on the empirical impact of e-health on quality and safety, Black et al. determined that the empirical benefits of e-health systems often do not measure up to the expectations [3].

In the core areas of data storage and support for decision making, the reviewed studies often had contrasting findings, where there was not much consensus on the benefits of certain systems or new problems experienced due to e-health systems [4]. For example, digital prescription systems change hospital flows dramatically, and thus cause great harm when there is downtime and offline systems need to be reinstated. These findings align with Avison and Young, who have called for critical analysis of ICT in healthcare, with emphasis on the interpersonal and human-oriented aspects of healthcare [1]. These concerns are of particular interest to our area of research, as a core application of Human Computer Interaction (HCI) in healthcare is to prevent designing systems that do not achieve their objectives or suit their environment.

2.2 South African Context
2.2.1 Healthcare
While the relative successes and shortcomings of e-health systems in general have been discussed, the implications of these systems

in developing regions are quite different. In South Africa, where healthcare facilities and workers are often separated geographically by large distances, and healthcare resources are heavily burdened [2], the requirements for e-health are somewhat different. Ruxwana et al. highlighted that some of the key challenges to implementing e-health solutions came down to infrastructural issues, such as poorly maintained equipment, and a lack of ICT skills [2].

In response to these challenges, there has been great interest in the use of mobile phones for healthcare purposes in South Africa – the rise of so-called "m-health" technologies. [4, 5]. Some reasons for this relate to the fact that mobile phones are used by a large portion of the South African population – Tomlinson et al. identified that 93% South Africans are subscribed to a GSM network – and that mobile phones are considered to be relatively easy to use [5]. However, the literature does raise cause for concern as to the sustainability and overall effectiveness of m-health programmes [4, 5]. Leon et al. in particular, focus on scalability issues that face m-health pilot projects [4]. Their findings indicate that while individual pilot projects may have proved successful, these isolated and technically different systems are unlikely to allow for interoperability or widespread acceptance. Similarly, Sørensen et al. found that while a number of pilot ICT projects existed for AIDS treatment systems, stark differences in the project implementations and a lack of interoperability between projects has led to an unsustainable environment for these systems to develop [6].

2.2.2 Failure

Unfortunately, South Africa appears to have experienced a fair amount of failure in implementing e-health systems. One such failure is documented by LittleJohns et al., who investigated the botched implementation of an integrated hospital information system in the Limpopo Province – the largest medical information systems project at the time [7]. The project aimed to use the information system to improve care within the hospital through information sharing, standardization of administration and increased hospital efficiency. The project began experiencing issues when the systems failed to provide the expected benefits. Some of this related to infrastructural issues, where difficulties in managing computer systems in rural areas became apparent. It was also identified that the systems were not sufficiently integrated with the healthcare culture in hospitals, leading to users that didn't believe in the suitability of the project. The poor management and implementation of the project ultimately led to its demise, with contracting irregularities resulting in the freezing of funds [7].

While failure in ICT4D is often thought to be the result of ignoring foreseeable problems, a number of researchers identify the value of failure and learning from these experiences [8, 9]. Densmore suggests that researchers require "room for failure" when using HCI in ICT4D; that identifying a failing system and placing the users' needs first and foremost may be more important than implementing systems that do not work [8]. Highly relevant to both ICT4D failure and our interest in healthcare systems is Heeks' discussion on the topic. Heeks identifies a disconnect between the proposed design of healthcare systems and the real world experience [9]. Heeks' suggestion is that both the design and the real world experience need to constantly adjust in order to bridge this disconnect. For our research, this indicates that flexibility is highly important when implementing healthcare systems, and that choosing to fail a technology may be required in some cases in order to best serve the user.

What is clear from the literature on South African healthcare computing, is that there are a number of persistent problems which most projects will face. Infrastructural and cultural issues appear to be some of the most common, and this indicates that any future projects in this area need to strongly consider methods for alleviating such risks.

3. WAIT TIMES IN HEALTHCARE

Quantifying the quality and efficiency of healthcare has long been a research space in the medical field. One of the measures that is of particular interest to our research, is patient wait times.

3.1 The Impact of Wait Times

In South African primary healthcare, patient waiting time is considered to be a measure of the effectiveness of care facilities. De la Harpe and Benjamin describe long waiting times as a trigger for increased disorder and confusion in healthcare facilities [10]. This disorder may result from increased antagonism between pressured staff members, and disruptions to the normal flow of information through the healthcare facility [10].

It is fairly conclusively established in the literature that patient waiting times are a significant contributor to healthcare dissatisfaction, as well as the negative association between longer waiting times and patient contentment [11]. Anderson et al. concluded that the ratio of time spent with healthcare staff versus time spent waiting for treatment is also a key predictor of patient contentment [11]. In other words, waiting for long periods of time is considered to be less harmful to patient contentment if they are also treated for longer periods of time. However, in the South African primary healthcare context, staff are often under immense pressure to treat many patients during the day due to resourcing shortages [2]. This implies that the amount of time physicians can allocate to individual patients cannot easily be increased, and it follows that longer waiting times will thus likely result in lower levels of satisfaction among patients.

These findings are confirmed by a number of studies in South Africa on the effectiveness of HIV/AIDS prevention and treatment clinics [12, 13]. Long wait times at these centers, coupled with relatively short physician treatment times, are said to decrease patient satisfaction [12]. These findings are of great importance, since patient satisfaction has been considered a measure of patient care quality for some time now [14]. Patient satisfaction may indicate the level of communication by healthcare workers, as well as how positive staff interactions were.

3.2 Reducing Wait Times

Given that long wait times are considered to have negative effects on healthcare quality and patient satisfaction [12-14], it follows that attempts should be made to reduce waiting times. In the late 90s, Rondeau investigated the potential strategies to reduce patient wait times in clinics [15]. The approaches to the problem all revolve around the idea that wait times are caused by a differential between the supply and demand for healthcare resources. In other words, the clinic's capacity to process patients is lower than the number of patients waiting for service.

According to Rondeau, the primary method to alleviate this strain on resources is an appointment system, which aims to "smooth" the level of demand for resources over all clinic hours [15]. This attempts to prevent incidents of high patient volumes in popular

time slots. However, Rondeau identifies a number of challenges that such a system would face. Some of these issues are handling patients that do not arrive, overbooking appointments to maximize throughput and implementing decision processes for patient queues. Additionally, Gupta and Denton identified that while it may appear as though patients and healthcare workers have aligned incentives with regards to an appointment system, it may in fact be the case that their incentives are conflicting [16]. Revenue-maximizing appointment systems may change the way that physicians behave, possibly reducing time allocated to patients to increase throughput, while cost-minimization systems may shift long waiting times to patients instead of the healthcare workers [16]. Hence, the literature indicates that while there are established methods for dealing with waiting times, solutions will be complex and could even lead to more problems in future.

Since wait times are lengthened by constraints on healthcare resources, and developing nations often struggle with a lack of healthcare resources [2], wait times are likely to be an issue in South Africa. In fact, De la Harpe and Benjamin provide insight into this difficulty with research into waiting times in South African clinics [10]. This research differs from Roondeau in that it focusses primarily on information flows between staff, and how this impacts wait time. De la Harpe and Benjamin identified that the some of the core issues resulting in long wait times were clinic processes. Finding patient data (only some of which is digitized) is time consuming and error-prone. The high patient load made it even more difficult for staff to operate effectively, often working with insufficient information and high levels of exasperation [10].

Perhaps the most problematic finding of De la Harpe and Benjamin's research was the difficulty in implementing booking systems. They found that the clinics were so understaffed that the implemented systems were largely ignored, or staff would simply create their own processes in order to get by, or patients would even resort to bribery to be seen [10]. This serves as a precaution for our area of research, since it strongly states that many of the problems faced relate to resources or social issues, rather than the technical solution used.

4. CO-DESIGN

The difficulty in designing complex systems has led to much research into techniques for improving the success of design. One such approach is co-design. In this section we compare various applications of co-design, some of the related design approaches such as user-centered design and participatory design, as well as the suitability of such approaches to the South African context.

4.1 Applications of Co-design

In a discussion on the historical adoption of ethnography, Dourish highlights the origins of participatory design as the democratization of the design process and the will to encourage participation in the changes resulting from the adoption of computing [17]. Kuhn and Muller have similar findings, however, they do emphasize that some participatory design practitioners focus on using democratic design processes to improve product quality and to attain domain knowledge [18].

Perhaps most relevant to our research is Muller's additional discussion of some of the benefits that are claimed from participatory design. Muller highlights improvements in communications between stakeholders and designers, comprehension of the problem, stakeholder buy-in and the challenging of core assumptions as potential benefits of this approach [19]. Encouragingly, these benefits are almost exactly aligned with some of the problems when implementing healthcare systems as described by the literature.

According to a large-scale review of co-design literature by Cumbula et al., co-design stems from user-centered design and participatory design, although it is most closely associated with the latter [20]. Hence, co-design inherits the democratic view that all involved stakeholders' perceptions should be accounted for, while using the close proximity to users to produce systems that are most effective [20]. These benefits are of particular interest to our research area, given that healthcare is a highly complex field which is difficult to design for. From the literature, it appears as though co-design (and possibly its precursors) might be a way to address some of the problems of designing systems for the healthcare field.

4.2 Co-design and Participatory Design in South Africa

While there is evidence internationally that co-design may improve the likelihood of success in computing projects, the question of whether this holds for the developing areas is not as clear. Generally, there appears to be less literature on the application of formal co-design in South Africa, although a number of projects appear to make use of user participation to inform design decisions. Most closely related to our area of research is the work of De la Harpe, who investigated the benefits of participatory design practices when developing a mobile application for home-based healthcare [21]. De la Harpe's motivation for the research was based on findings similar to ours – namely that designing systems for developing regions is challenging in part due to lack of resources, user experience with technology and previous examples of successful interventions. The findings of the research are encouraging, since De la Harpe identified that the participatory approach indeed enabled developers and designers to gain local insight into the problems faced by the users [21]. Ultimately, it was understood that the approach did in fact contribute to the design and development of the system.

In a similar area, Maunder et al. investigated user-centered design approaches with special emphasis on tools for the developing world [22]. Interestingly, one such approach involved making use of prototypes with high fidelity earlier on in the project in order to better explain the system to users. This appears to run counter to standard practice when prototyping, but may be relevant in our research given that users will not always be able to identify problems with a system when the prototype's fidelity is low. Maunder et al.'s findings indicate that even user-centered design and accompanying processes may not reliably ensure project success. In keeping with much of the literature, the researchers also emphasized that the cultural and social aspects of any such project are difficult to design for, and user-centered design does not guarantee a better understanding of such aspects [22].

For our purposes, the findings on co-design and user-centered design indicate that user involvement is key if a project is to be successful in the developing context. However, such approaches do not guarantee that systems will be appropriate. Other larger issues, such as socio-cultural complexities, may in fact overshadow the benefits of these approaches.

5. Healthcare Workers and ICT4D

The interaction between healthcare workers and technologies for development is an important aspect of our research. While the

impact of ICT on patients has been studied fairly extensively in the literature, in our findings there appeared to be less research available on the impact of ICT on healthcare workers.

5.1 Mobile Phones and GSM Technologies

Given the widespread access to mobile devices, Global System for Mobile Communications (GSM) technologies have often been the choice for healthcare services in developing regions.

5.1.1 SMS

One area of focus in the research is on Community Healthcare Workers (CHWs). DeRenzi et al. noted that CHWs are increasingly being provided with mobile phones to help them work more effectively in the field [23]. Their research leveraged this in order to create a Short Messaging Service (SMS) reminder system to encourage CHWs to make routine visits to patients in a timeous manner. The SMS technology proved to be effective for this purpose, with high delivery rates and reasonably low costs per patient. The research concluded that the reminder system successfully reduced the average number of days that CHWs were overdue for routine patient visits, but only when overdue reminders were escalated to a supervisor. This highlights an intrinsic issue with any healthcare system, namely that the technology is only one relatively small aspect of the problem, and social aspects are often key to the success of computing systems.

In a similar area to DeRenzi et al.'s work, Koshy et al. implemented an SMS reminder system for primary healthcare appointments [24]. While the study focused on patients rather than CHWs, and was not performed in South Africa, the use of SMS technologies to aid an appointment system is highly relevant to our research. The researchers found that their appointment system resulted in a statistically significant reduction to missed appointments – the rate of non-attendance was 38% lower than the control group [24]. They also determined that the SMS reminder system was more cost-effective both from an infrastructural perspective and from the use of labour [24]. While the work of Koshy et al. does not address how SMS technologies fare in the developing world, other works do. Mapham reviewed a number of heathcare systems where SMS technologies played a primary role [25]. The research spanned appointment systems such as Koshy et al.'s work, information systems, self-assessment tools, social support networks, patient dairies and surveying tools. Mapham concluded that while SMS-based systems have flaws and do not necessarily address complex social issues surrounding healthcare, they are applicable to a number of healthcare problems in the developing world [25]. That is, as a technology, SMS can provide a promising infrastructure for healthcare systems.

5.1.2 USSD

SMS systems are not the only GSM technology to be trialed with healthcare workers, Unstructured Supplementary Service Data (USSD) systems have also generated some interest in this regard. USSD systems offer a basic interactive menu system while still making use of widespread GSM networks, making applications built on USSD almost completely universal [26]. Perrier et al. found that while USSD systems can provide much of the same functionality as SMS systems, they are well suited to complex transactional communications [26], possibly due to the tailoring of menus to the user's responses and the use of sessions.

A relevant example of an implementation of such a USSD system was prototyped by Wouters et al. in 2009. The prototype was a USSD system that enabled the monitoring of patients between isolated home-care workers and clinics [27]. While the study encountered general challenges, the USSD system was largely successful, with researchers reporting that most of the users had come to grips with the interface within a few trials – although a small number of participants still struggled some weeks into the study [27]. Zhou et al. also had positive findings with USSD systems for healthcare workers, where it was determined that an information system accessible by mobile phones greatly aided staff when power outages afflicted healthcare centres [28]. In this way, the USSD system became an important alternative to the internet-based primary system that was being used. This informs us that there is some encouraging evidence that USSD systems can provide a technological base for interacting with health workers, and not just patients.

Another relevant example, although for different reasons, is the Clinic Finder USSD service as implemented by Parsons and Timler for any mobile phone user in South Africa [29]. Overall, the researchers found that while USSD was widely available on mobile phones, the technology caused a number of problems for the project. One such problem suggested by Parsons et al. was that USSD is not as commonly used as other mobile phone features. This led to a service that fewer users understood well, and may have reduced its usability. Another problem that was identified related to the availability of the service. Due to the number of sessions dropped and the poor prioritization of USSD on mobile networks, the service was believed to have sub-optimal availability and performance. Parsons et al. also suggested that the relatively high charge rates may have provided a disincentive for users to retry the service if anything went wrong [29].

5.2 Tablet Computers

While there appear to be a number of studies involving healthcare workers using GSM technologies or personal computers, there are far fewer examples of studies using tablet computers. Perhaps this is due to the fact that tablet computers are a relatively recent phenomenon, or that they are less common in developing areas. Of the few studies that were performed using tablet computers and were relevant to our research in healthcare, only one includes results that are of interest.

This was a study conducted by Zargaran et al., researching the effectiveness of an application for trauma care based on tablets in the Western Cape, South Africa [30]. While the study was focused largely on the software application, some findings are relevant to our research. Zaragan et al. determined that despite the high pressure environment and the large patient volumes, the system was implemented without serious interruption to the healthcare workflow [30]. It was also suggested that the natural usability of the tablets (swiping, tapping etc.) was a major advantage for the system.

While these findings appear to suggest that tablet computers are a viable technology for use in clinics, it should be noted that this study involved healthcare workers that were fairly well acquainted with modern technologies and computer tablets. These results may not be reproducible in a rural environment with lower levels of technological experience and literacy.

5.3 General Computing Systems

In South Africa, personal computers have become relatively commonplace in the healthcare environment. Larger hospitals are highly dependent on these systems for the efficient functioning of the hospital. However, healthcare centres in rural areas still lack some of the basic infrastructure and ICT training in order to

enable the use of computing [2]. This is where personal computers have a distinct disadvantage over mobile devices, since fewer users have experience with conventional computers in rural areas [4, 5].

In a similar fashion to researchers of m-health, the literature for the implementation of healthcare information systems also focusses on the importance of cultural fit, staff buy-in and training [31]. Herbst et al. emphasizes the need for a focus on more than just the software and hardware elements of a project, which is something that is raised in almost all the reviewed literature on e-health projects. In addition to this, Blaya et al. also identified that conventional e-health solutions, such as information systems, are often highly complex and more prone to failure than smaller projects [32]. Blaya et al. also discuss the difficulty in evaluating these large projects. This is an important point for our area of research, as a number of studies have claimed success in their implementation of a system. It is thus important to realise that the techniques for evaluating success need to be well thought out and objective if our research is to be trusted.

6. DISCUSSION

At an initial glance, our research appears somewhat scattered, with journals from a number of healthcare areas. However, this is a necessary requirement for understanding the complexities of the South African healthcare space. In the developing context it is necessary to understand both what problems are commonly faced by researchers, and how they are solved. This relates some of the background discussion on e-health projects, such as the high rate of failure [7-9], to the literature on the benefits of co-design [20-22].

While there is much discussion on the failings of projects after the fact, there appears to be much less certainty as to how this can be avoided in future. Specifically, Maunder et al. mention their understanding that there are not any frameworks available currently that can guarantee success in ICT4D [22]. This led us to the inclusion of participatory design, user-centered design and co-design in this research as a potential approach to addressing these problems. The optimism of researchers that applied these design principles to the South African context is encouraging. While the research is cautious to claim “silver bullets” for ICT4D problems, co-design does appear to offer a way forward for healthcare projects in South Africa [21, 22].

Narrowing in on a primary healthcare problem in South Africa, we focused on wait times as a specific area of interest. While the literature on wait times internationally is fairly comprehensive, there appears to be far less research on the problem in South Africa. De la Harpe and Benjamin provide relevant conclusions on wait times in the South African context [10], although attempts to reduce wait times is discussed less. This may be a result of the general resourcing and infrastructural problems that are commonly mentioned in the literature [2, 7, 10]. Hence, De la Harpe and Benjamin’s assertion that social issues and resourcing problems may need to be fixed prior to systems that reduce wait times are implemented [10], appear to be a common view.

Finally, we focused on the technologies themselves. There appear to be a number of studies involving mobile technologies, such as USSD and SMS systems, however the literature is somewhat contradictory. Especially in USSD research, some findings were optimistic and encouraged more research into the use of USSD [27, 28], whereas others were more pessimistic [29]. While mobile phones generally captured a large amount of research attention, tablets did not. The most common finding involving tablets in healthcare related to data capture, and not much with healthcare systems directly.

7. CONCLUSIONS

At first glance, it may appear as though the wave of modern information technology innovations is poised to shake up healthcare in the developing world. While this may be true in the long run, closer inspection reveals some issues. There appears to be a great deal of evidence that healthcare’s complexity has resulted in a large number of failed projects over the years. From the literature, the consensus seems to point to socio-cultural complexities, infrastructural challenges and lack of resources as the most prominent reasons for failure [2, 7, 10]. It is also clear that sometimes technological solutions are premature, and simply focusing on optimizing the processes in healthcare centres can lead to more positive outcomes [8].

In this literature review we have focused on wait times as a measure of patient contentment and healthcare system efficiency. In this regard, we conclude that long wait times are indeed problematic for primary healthcare centres as is reported by the literature [10, 11]. Hence, we identify that reducing wait times is an important goal for South African healthcare administrators. One prominent way of achieving this goal is appointment systems. While some of these systems have been successful [15], their application to the developing world has resulted in a number of issues [10], and further research is needed to understand how such systems might succeed. Given the encouraging findings by South African researchers on the applicability of co-design, participatory design and user-centered design [20-22], it appears as though these tools may help address some of the problems highlighted by the healthcare literature. This might include improvements in communications between stakeholders and designers, understanding of the problem and stakeholder buy-in [19].

If we were to proceed to implement a system in the healthcare context, the evidence is not altogether clear on which technologies are best suited to South Africa. While journal articles emphasize the ubiquity of phones as a driver for success [5, 23], their benefits to the healthcare space are contested by some prominent failures [29]. Even less tested are tablet computers, although the findings of Zargaran et al. indicate that they may hold promise [30].

Overall, we have identified that there are a few areas that require additional research in the South African healthcare space. Firstly, it is largely unknown how various technologies (such as mobile platforms or conventional computer systems) can contribute to the efficiency of primary healthcare centres, the reduction of patient wait times and to the work of healthcare staff in particular. Secondly, it is also largely unknown how these technologies might compare to one another in this context. We suggest that these areas have potential for future research.

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