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MOBILE TELECONSULTATIONS IN ACUTE BURN CARE:

ACCEPTANCE AND USER-EXPERIENCE AMONG EMERGENCY CARE PROVIDERS IN RESOURCE-POOR SETTINGS

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"The future is already here – it's just not very evenly distributed"

- William Gibson Ford

ABSTRACT

Background: Burn injuries are a global health problem with severe consequences for those affected and nearly 95% of all burns occur in low- and middle-income countries (LMICs). While minor burns can be treated locally such as at the emergency department, severe burns need transfer to a specialist burns centre. However, non-specialists often lack the training and experience to accurately diagnose and manage burns. While smartphones have been shown to be feasible for remote consultations between frontline providers and burns specialists, barriers may impede successful uptake.

Aims: The aims of the thesis were to deepen the knowledge about referral patterns of patients with burns in resource poor settings, and to study perceptions and experiences among emergency staff's use of smartphones as a diagnostic support to improve the assessment, initial care and referrals of patients with burns.

Methods: ***Study I*** was a retrospective case study of 871 paediatric patients with burns at a trauma unit in Cape Town. Demographic, injury characteristics, and disposition was used to determine whether patients were referred according to local criteria. ***Study II*** was a mixed-methods study of the usability of a smartphone app (the Vula app) for burn injury consultations. Twenty-four emergency doctors and four burns specialists were enrolled in the study. A think-aloud study was conducted with all participants and their interaction with the app was video-recorded and later analysed using content analysis. The twenty-four emergency doctors also completed a usability questionnaire. ***Study III*** was a qualitative study where semi-structured interviews were conducted with 15 doctors regarding their experiences using the Vula app for burn consultations and referrals. The interview-guide and thematic analysis were informed by the Normalisation Process Theory. In ***Study IV,*** fifty-nine frontline health workers completed a questionnaire to assess their intention to use the Vula app. The questionnaire and the analysis were informed by the technology acceptance model (TAM).

Results: ***Study I***. Most referred patients fulfilled the referral criteria. However, of those treated and discharged from the trauma unit, 8 out of 10 children also fulfilled the criteria for referral. In ***Study II,*** the usability test and questionnaire showed that the doctors perceived the Vula app to be easy to use and useful. However, some problems were identified mainly related to navigation, and understanding of meaning of icon's terminologies. Some users also said that predefined options in the app limited their ability to express their clinical findings. ***Study III*** revealed several barriers and promotors for successful integration of the Vula app. Promotors included the already prevalent practice of using smartphones, that it was easy to use and the learning opportunity that the app offered. Barriers to successful integration included; inconsistent use of the app across specialities and lack of information, policies and infrastructure to support the users. ***In Study IV,*** almost all health professionals used smartphones in their work and were positive towards using Vula. Access to wireless internet and access to smartphones was mentioned to be a barrier.

Conclusions: Identifying patients with burns who are in need of referral is challenging. Mobile teleconsultations is therefore a way of assisting with diagnosis and initial management. The Vula app was easy to use and perceived to be useful, but several barriers need to be addressed for the app to become an integrated part of the practice in emergency care. In settings with considerably fewer resources, these barriers will likely be even more important to address prior to implementation.

LIST OF SCIENTIFIC PAPERS

I. Klingberg A, Wallis L, Rode H, Stenberg T, Laflamme L, Hasselberg. Assessing guidelines for burn referrals in a resource-constrained setting: Demographic and clinical factors associated with inter-facility transfer. Burns 2017; 43: 1070–1077.

II. Klingberg A, Wallis LA, Hasselberg M, Yen P-Y, Fritzell SC. Teleconsultation Using Mobile Phones for Diagnosis and Acute Care of Burn Injuries Among Emergency Physicians: Mixed-Methods Study. JMIR mHealth and uHealth. JMIR Publications Inc.; 2018 Oct 19;6(10) :e11076

III. Klingberg A, Wallis LA, Fritzell S, Hasselberg M. Just Vula it: Experiences among South African emergency doctors using a smartphone app for burn injury consultations. (Manuscript)

IV. Klingberg A, Sawe HR, Hammar U, Wallis LA, Hasselberg M. mHealth for Burn Injury Consultations in a Low-Resource Setting: An Acceptability Study Among Health Care Providers. Telemedicine and e-Health. Mary Ann Liebert Inc; 2019 Jun 4

CONTENTS

LIST OF ABBREVIATIONS

eHealth	The use of information and communications technology in support of health and health-related fields
HCI	Human-computer interaction
Health-ITUES	Health Information Technology Usability Evaluation Scale
HIC	High-income countries
ISO	The International Organization for Standardization
ITU	International Telecommunication Union
LIC	Low-income countries
LMIC	Low- and middle-income countries
mHealth	The use of mobile wireless technologies for health
NPT	Normalisation process theory
RCH	Red Cross Memorial War Hospital
SD	Standard deviation
SDG	Sustainable development goals
TAM	Technology acceptance model
TBSA	Total body surface area
UHC	Universal health Coverage
WHO	World Health Organization

BACKGROUND

GLOBAL BURDEN OF BURNS

Burn injuries are a global health problem with severe consequences for those affected. There are an estimated 153 000 deaths per year [1] and close to 11 million people seek medical attention for their burns [2]. Like other types of injuries, countries with the least resources suffer the highest incidence and mortality; nearly 95% of the global burden of burns occur in low- and middle-income countries (LMICs) [1]. The annual rate of death in LMICs is three times higher compared to high-income countries [3]. For children 0-14 years, the mortality rate is six times higher in LMICs compared to high-income countries (HICs), with the most significant disparity seen between low and high-income countries, where a child is 15 times more likely to die from burns [1].

While the rate of fatal burns is decreasing in both high and LMICs, the crude number of deaths in low-income countries is increasing [1]. According to WHO Global Health Estimates, the number of burn fatalities in LMICs is projected to increase from 143.000 in 2016 to 160.000 in 2030, mainly due to population growth [4]. Burns are not only unevenly distributed between regions and countries but within populations as well. For example, age, gender and socioeconomic status have all been linked to the risk of sustaining a burn injury [5]. In regards to age, children younger than five are at the highest risk [6, 7]. In most types of injuries, men are often over-represented. For burns, however, the proportion of women affected are similar to that of men [1], and in some populations and age groups, women are over-represented [1]. The higher risk among women in some contexts has been linked to differences in practices, where women spend more time in the house where they are exposed to open fires and unsafe cooking equipment [8, 9]. Socioeconomic status also strongly correlates with burn incidence and severity, where people with lower-incomes and education are at higher risk [5, 6]. Tightly linked with socioeconomic status are environmental risk factors, including living and working environments [10, 11]. Most burns occur in the home where overcrowding, lack of proper safety measures, and type of energy used for cooking, heating and lighting are all risk factors [12]. Especially in LMICs, burn injuries are often sustained in the kitchen or cooking area and is related to the type of cooking appliances and fuel sources [5, 11].

The fatal burns are only the tip of the iceberg, and many burn survivors face lifelong disability, disfigurement and emotional scars [6, 13]. Like other injuries, subsequent impairment may prevent people from living healthy and productive lives [14, 15]. What is most unfortunate is the fact that burns are highly preventable, as can be seen from the vast differences in burn incidence between HICs and LMICs. While in high-income countries, prevention strategies and investments in burn care have considerably lowered the rates of burn deaths and disability, such efforts have yet to be realised in low resource settings [16].

ORGANISATION OF BURN CARE

Comprehensive and high quality burn care is not only crucial for survival but for optimal physical and emotional recovery, as well as minimising scarring [17]. In recent decades, the world has witnessed dramatic improvements in the care of the severely burnt [18–20]. Coupled with successful prevention programs [21], this has led to decreasing rates of burn incidence, as well as severity, hospital length of stay and mortality. Much of the improvement in both survival and outcomes can be attributed to early fluid resuscitation, infection control, modulation of the hyper-metabolic response as well as advances in surgery, wound care and subsequent rehabilitation [22, 23]. Another reason is the multidisciplinary team approach, with teams consisting of burns surgeons, burn nurses, anaesthetists, respiratory therapists, occupational and physical therapists, dieticians, and psychosocial experts [24]. However, in the effort to maximise resource-utilisation, this approach has often led to centralisation of burn care with fewer hospitals providing comprehensive burn care [24].

Despite substantial advancements in burn care, these improvements have mostly been present in high-resource countries. One review found that many hospitals in LMICs have the capacity to offer initial burn management and basic resuscitation, but cannot provide advanced burn care [25]. Another review of trauma capacity in LMICs found that deficiencies in trauma care remain widespread [26]. Health professionals trained in burn care are scarce [25] and many countries lack burns surgeons and therefore burns patients are often operated on by general surgeons [25, 27]. Nurses specialised in burn care are also rare in many parts of the world [27] and other allied health professionals such as nutritionists, physiotherapists and psychologists are even rarer [28]. When care is available, dysfunctional referral systems, long distances and financial constraints may hinder access [27].

BURN DIAGNOSIS AND CARE

Burn classification

A burn is a the destruction to the skin, or other tissues, caused usually by heat, but also cold, electricity, chemicals, friction, or radiation [23]. Burns are typically classified by depth, body surface area burnt, mechanism of injury and intent [23]. Burn depth has traditionally been classified into four levels; first, second, third and fourth-degree burn. Today, superficial, partial-thickness and full-thickness are used to reflect the need for surgery [29]. Superficial and partial thickness most often only require conservative treatment, whereas deep partial-thickness and full-thickness burns require surgery and skin grafts [29]. The extent of the burn, total body surface area burnt (TBSA) are usually estimated using the Wallace rule of nine or the Lund and Browder chart [23]. The patient's palm, which is approximately one per cent of the body surface area, is often used [30]. Accurate burn size estimation is essential because of the calculation of fluid requirements [31]. The location of a burn is also an important factor and will inform treatment [23]. Special areas include the face, hands, feet, genitalia and perineum as well as burns affecting joints. While these are all clinical factors related to the burn itself, other factors, both clinical and non-clinical, will inform the care trajectory. Clinical factors include signs of inhalation burn or compromised airway and severe associated trauma, while non-clinical factors are, patient age, past medical history and suspicion of non-accidental burn [23]. Overall severity of the burn injury depends on a combination of the factors mentioned above and will guide the preferred disposition and care of these patients.

Burn Care and treatment

Minor burns

Minor burns can be classified as covering around five per cent of TBSA and as being no deeper than superficial partial thickness. These burns can be expected to heal spontaneously without the need for grafting within ten days to three weeks [23]. Most burn injuries are minor and can be treated as outpatients at primary care level, such as the emergency department [32]. Treatment of minor burns includes: cooling the burn, removing dead skin, cleaning the wound, applying appropriate dressing, managing pain and administering tetanus prophylaxis. Follow up is often required for re-dressing and for evaluation to ensure proper wound healing, and if a referral to a burns centre is necessary [23].

Severe burns

Severe burns include those with severe associated trauma, have an inhalational component, chemical or high-voltage electrical burns, cover a large surface area or are in need of surgery and skin graft [23]. In burns in young children and the elderly, a lesser TBSA may also be deemed severe [23]. These burns need to be stabilised and transferred to a burns centre or a facility with intensive care and surgical capacity. Initial stabilisation includes airway management, cardiovascular stabilisation, pain control, wound management and fluid resuscitation. Beyond the acute phase, management of a patient with a severe burn is a long process that involving not only the wound, but the psychologic, and social consequences of the injury. [23]

Burns in the Emergency Department

Frontline providers must diagnose and treat a wide variety of unscheduled patients with a variety of illnesses or injuries. The doctor's clinical decision making and initial treatment are crucial in this critical phase, as they are the link between first aid in the field and definitive in-hospital treatment. Patients with burns often first enter the health system through the emergency department. In this stage, the front-line provider must be able to accurately assess the burn and initiate treatment. Depending on burn severity, patients with burns can follow different trajectories. Minor burns can be managed and followed up locally, while severely burnt patients need to be stabilised and transferred to a burns centre. Some burns do not need urgent transfer or to be admitted, but still need follow-up by a burns specialist as an outpatient. However, burn assessment is often difficult [33], even by specialists [34], and many non-specialists lack experience and formal training in burn management [28, 34] and may not be comfortable in managing burns [35].

To guide front-line health workers in referral decision making, several national or local guidelines define what constitutes a "severe burn injury" [36, 37] according to criteria for referral to a dedicated burn centre (e.g. burn injuries in adults >20 % TBSA). Studies from mainly high-resource settings show that many patients who are referred to burns units/centres often do not match the criteria for transfer and this over-referral puts both a burden on the health system and the patient [38–43]. The main reason for non-compliance with the referral criteria is inaccurate surface area estimation [44–48] but also confusion on how to apply the criteria [49]. Additionally, overestimation or underestimation of burn size may result in incorrect fluid replacement, with subsequent risk of complications such as pneumonia [50, 51], hypovolemic shock [52] and compartment syndrome [45, 50, 53].

Telemedicine in burn care

Telemedicine is often proposed as a way of improving care and triage of patients with burns [54–56]. For example, telemedicine can be used for burn injury assessment, tele-consultation and follow up [55]. The benefits of telemedicine for burns is that burns are visual and video or images can be transmitted either in real time (synchronous) or store-and-forward (asynchronous). If a health provider is unsure whether a patient needs transfer to a hospital or not, or need advice on the best course of action, images or video can be sent to a burns specialist who can make an assessment. For example, Saffle et al [57] concluded that with telemedicine, burn injuries can successfully be evaluated leading to different courses of care, such as changed amount fluid resuscitation. They also saw that by supporting local physicians, transport could completely be avoided. With the introduction of the smartphone, telemedicine has entered a new era of easy to use devices that are fast, portable, with capabilities similar to modern computers, and also include cameras. A few studies describe the use of smartphone based telemedicine systems for burns [58, 59]. One review looked at other uses in burn care and identified four different categories of apps: calculators, information apps, book/journal apps, and games. For calculation apps, they found that these apps can make the produce calculation that are more objective compared to manual estimations [60]. Furthermore, smartphones have been used within burn care to discuss potential referrals or to give advice by using free commercial applications for communication such as WhatsApp [61, 62]. While these spontaneous and unplanned telemedicine systems are beneficial and often used due to lack of other options, these informal systems lack structure and are not always compliant with data security and patient confidentiality regulations [63].

MODERN DIGITAL TECHNOLOGIES TO STRENGTHEN HEALTH CARE

Throughout history, technologies have been the backbone of advancements in medicine and public health. Examples include the stethoscope, x-ray and vaccines to mention a few. Together with improved health care, successful public health interventions and most importantly, social and economic development, life expectancy has increased dramatically in recent decades. However, population growth and a rising number of people living with chronic conditions are putting pressure on health systems all around the world [64]. At the same time, injuries are expected to increase in many LMICs, many of which still struggle with the burden of infections and malnutrition. There is now a strong belief that the use of digital technologies can address health systems challenges, and to be a valuable resource for health services delivery and public health. In July 2019, The World Health Organization (WHO) released the draft *Global Strategy on Digital health 2020-2024*. This strategy aims to *"improve health for everyone, everywhere by accelerating the development and adoption of appropriate digital health solutions towards achieving the health-related Sustainable Development Goals and the General Programme of Works triple billion targets*" [65].

Many of the terms used to describe digital technologies for health overlap, and are used differently and interchangeably by different researchers and organisations. WHO use the term digital health as a general term covering, eHealth "*the use of information and communications technology in support of health and health-related fields*", and mHealth "*the use of mobile wireless technologies for health*". Digital health also include areas such as virtual and augmented reality for health, and the use of 'big data', genomics and artificial intelligence. One of the main drivers for research and investment in digital health in LMICs is the relatively high prevalence of digital devices, most notably mobile phones and tablets. Due to their ease of use and wide acceptance mobile phones and tablets are especially of interest, particularly in low- and middle-income countries, where mobile communication can increase access and overcome geographical barriers to health care. According to the International Telecommunication Union (ITU), in 2018 there were more mobile telephone subscriptions than people across the world, with more than 70% of which were in LMICs. Additionally, since 2007, mobile broadband subscriptions have increased from 268 million to 5.3 billion in 2018 [66].

Digital health to support health workers in LMIC

Many health systems, particularly in LMIC struggle to meet the health needs of the population they serve and one of the most pressing issues is the availability of skilled health workers [67, 68]. Digital health has the potential to assist health workers in various ways, such as access to information, training, and communication. Digital technologies such as smartphones have also made telemedicine services more accessible in LMICs, with the potential for less skilled health providers to consult with more specialist ones [69]. Such teleconsultation service can be through the exchange of video and images to be reviewed later or real-time communication. Teleconsultations covers a broad spectrum of both mode of communication and areas of use. One is the traditional telemedicine where providers link up via some type of medium, such as a video-link [70]. The other is that of electronic consultation and referral systems [71]. These systems are most commonly used to replace traditional paper based referrals where immediate feedback is not required.

Digital health in the emergency department

Digital devices, such as smartphones and tablets in the emergency room, are becoming more prevalent. With smartphones, taking and sending images is easier than ever, and therefore image-based teleconsultations is a growing area. It has been used in areas such as emergency medicine [72, 73], surgery [74], ophthalmology [75–77], dermatology [78–80], and radiology [81, 82]. Images can be taken directly with the smartphone at the point of care and be sent with messaging services such as WhatsApp, MMS or custom made applications [63, 82].

The interest in using smartphones and tablets for viewing pictures for diagnostic purposes has increased over the past years. One reason for this is larger screens [83] with higher resolution as well as cameras that can take higher quality pictures. One study comparing the use of smartphones with small versus large screen size concluded that larger screens are likely to lead to higher adoption of smartphones [83]. This, coupled with the fact that these devices are portable meaning that health workers are no longer constrained by their physical environment. A systematic review of image-based telemedicine systems for injury emergency care found that these systems could make a valid diagnosis and improve patient management [84]. Studies also report on the use of smartphones for video conferencing in emergency trauma care [85–87]. Other studies have compared reference apps to a standard paper-based tool in the emergency setting [88, 89]. There are several advantages to using apps compared to paper-based tools. One is that the tool is readily available on the phone with no need to locate the paper-based guidelines. Another is that apps can provide more advanced tools for calculations, eliminating the need for manual calculations. A third benefit is that when guidelines are revised, they can be more rapidly disseminated through the app compared to a paper-based tool. A problem with reference apps discussed in the literature is the possibility of apps containing wrong information or apps that perform incorrect calculations that may lead to an incorrect dosage of medication and subsequent harm to the patient [90].

Little information has been provided about user satisfaction, patient outcomes, or economic benefits for smartphone use in the emergency room. Only a few studies reports on the user perspective as its main area of study; however, in these studies, there is little information on how this was evaluated. In one study of an app for burn area calculation, students that used the app said they preferred the app over the paper-based tool [88]. In another study of an app for trauma bypass, the users thought that the app was faster to use than the paper-based tool; however, they had concerns about battery life and risk of infection using the smartphone [89]. User evaluation is an essential part of the overall evaluation of new systems that are implemented in an organisation - a system can be of high technical quality, but unless it is not appreciated by the users, the uptake will be low, and outcomes will be poor.

Another often discussed barrier to the introduction of mHealth systems is related to legal issues ethical considerations, patient safety and patient confidentiality [91, 92]. A few studies discuss this. Legal challenges related to patient privacy, data security, liability and responsibility, and regulation of apps and the use of smartphones [91]. Patient confidentiality is another critical issue. Sending sensitive information over the internet may make it possible for unauthorised people to access information. However, many countries, especially in low-and middle-income countries, have not yet developed regulatory frameworks concerning apps [93]. One the other side of the coin, regulations that are not up to date may hamper development and interest in further progression in the field [94].

Implementation of digital health initiatives

Following the intensified interest in digital health, researchers have also raised concerns regarding the limited evidence base of their impact [95, 96]. While digital technologies can offer considerable benefits, implementing such technologies also share the same fundamental challenges of other interventions in LMICs in general. These challenges include insufficient funding, poor management, lack of training and limited access to equipment and supplies [97]. Introducing new ways of working might also require new skills and behavioural changes. Explanations as to why many interventions have failed include poor access to devices and infrastructure, such as internet connectivity and electricity for charging, poor usability of devices or lack of understanding of how to use them, and finally a mismatch between what the technology offers and what health workers need.

There are a handful publications recommending how mHealth should be evaluated in order to inform development, scale-up and replication [98–100]. For example, the mHealth evidence reporting and assessment (mERA) checklist was developed by the WHO mHealth Technical Evidence Review Group in order to systematise how mHealth interventions are reported [99]. The checklist consists of 16 items and concerns three main questions: What (content), where (context), and how (technical features). Khoja et al. suggest e-health interventions to be evaluated at different stages which are: development stage, implementation stage, integration stage and sustained operation stage [100]. They further suggest these interventions to be evaluated in terms of health service outcomes, technology outcomes, economic outcomes, behavioural and sociotechnical outcomes, ethical outcomes, readiness and change outcomes and policy outcomes.

In a review by Chib et al. on mHealth adoption in low-resource environments, the authors concluded there was a paucity of studies that could explain the theoretical mechanisms underlying technology adoption [101]. In another article by Lundin and Dumont, the authors identified eight factors that are critical for creating mobile health solutions that are both scalable and sustainable [102]. For example, that mHealth solutions need to be aligned with existing infrastructure and health strategies and fit the local setting with the involvement of all stakeholders. They further discuss that scalability needs to be considered from the start, financing needs to be mainstreamed, standards for interoperability with the existing health information system taken into account, and finally, these programs need to be evaluated in order to build an evidence base for further scale-up.

Evaluation of digital health

New technologies are often implemented in order to increase the efficiency and effectiveness of different work processes. Still, many new technologies fail to reach their full potential or at worst are rejected [103]. When introducing new technologies in an organisation, it is necessary to consider both technical, social as well as organisational aspects [104]. One area of research that focuses on humans and technology and how they interact is the field of Human-Computer Interaction (HCI) [105]. HCI research has evolved from a focus on the interaction between humans and computers to also study the user experience (UX) of new technologies [105]. For developers of new technologies, it is no longer sufficient to make a product of high technical quality with a lot of features; it needs to appeal to the user's emotions as well.

One aspect out of the user experience is system usability. The International Organisation for Standardisation (ISO) defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO/IEC 9241-11 1998). According to Davis technology acceptance model (TAM) (figure 1), two main factors influence user acceptance and future intention to use technology: perceived ease of use and perceived usefulness [106]. Other factors that may explain the use of new technologies are extrinsic motivation [107], job-fit [108], relative advantage [109], outcome expectations [110], complexity [108], and image [109].

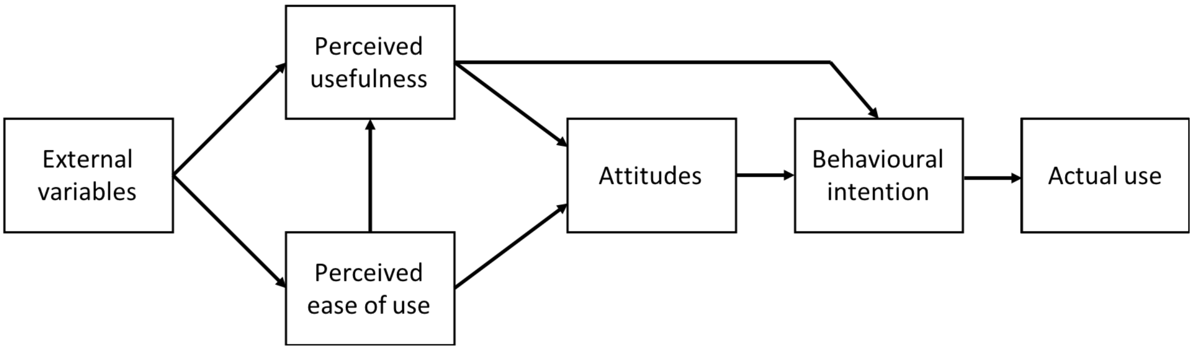


Figure 1: Technology acceptance model (TAM) Davis 1989

Usability evaluation can help to identify if the user encounters problems while using the system, which can further explain future intent to use the system. This information can also be used to further improve usability. Other studies show that the perceived quality of a system has an effect on the future intention to use it [111, 112]. According to Bennett (1984), usability not only depends on the tool, but also on the user and the task in a specific context [113]. Additionally, perceived quality is modified by control variables such as "situational factors" [114] and "demographic factors" [115], and for this reason, a system cannot be fully evaluated independently of its users or the context where it will be used.

Various methods for usability evaluation has been described in the literature, including both quantitative and qualitative methods such as; heuristic evaluation, cognitive walkthrough, think-aloud protocols, laboratory testing, remote evaluation and questionnaires. While some of these are looking at people's behaviours (what people do), others are rather looking at people's attitudes (what people say) [116]. Different questionnaires have been developed to test system usability of mobile devices [117–119]. However, methods for evaluating the usability of mHealth technologies are scarce. One of the few validated tools for evaluating mHealth applications is the *Health Information Technology Usability Evaluation Model* (Health-ITUEM) [120, 121]. Health-ITUEM uses constructs from TAM and ISO 9241-11 to define usability, such as perceived usefulness and perceived ease of use. The accompanying Health-IT Usability Evaluation Scale (Health-ITUES) is a customisable questionnaire that addresses four different domains: quality of work-life (QWL), perceived usefulness (PU), perceived ease of use (PEU) and user control (UC). The model has successfully been demonstrated for assessment of the usability of mHealth technology [121–123].

The theories described above, such as TAM, focus on individual acceptance and use of technology, but does not fully consider that interactions between humans and technology take place in a social and organisational context which also have an impact on acceptance, user experience and successful integration. Socio-technical systems theory can be used to understand how human, social and organisational factors, as well as technical factors, are interconnected. Socio-technical systems theory is useful when designing technical systems so that they work smoothly with the social or organisational system, as they capture both human and technical requirements [104]. Technological change not only influence the technical system but the social, cultural and management systems. Diffusion of innovations in healthcare have previously been described, both in theory and practice [124]. However, these theories are not sufficient to explain how complex interventions become practically workable in healthcare settings. May et al. (2007) define a complex intervention as "any deliberate initiated attempt to introduce new, or modify existing patterns of collective action in healthcare or some other formal organisation setting" (p. 3) [125]. Furthermore, there are different types of complex interventions – those that are directed at the actors (people) to change behaviours or outcomes, such as practice or roles, or those aimed at objects, such as the technology, in order to change actions. Interventions may also be directed at the contexts where the actors and objects exists, aiming to change the actions to achieve the intended goals. Additionally, health care organisations are inherently complex socio-technical environments with various overlapping organisational and professional roles [125]. Normalization i.e. embedding and integration of new interventions into practice are then only possible if agents, both individually and collectively have a shared a commitment and intent to operationalise the intervention in to practice [126].

A SMARTPHONE APP FOR BURN INJURY CONSULTATIONS

The focus of this thesis is a smartphone app for burns consultations and referrals. The app, called Vula, is a consultation and referral platform that allows frontline health providers to consult with specialists in various disciplines. The app is currently used in several parts of South Africa and supports nineteen different specialties such as ophthalmology, cardiology and internal medicine. This thesis focus on the burns part of the app. The option to refer burns on the app was introduced in 2016, and in 2018, almost 900 burns referrals were made using on the platform. The content and features of the burns part was designed with input from specialists in burns and emergency medicine through a series of panel of expert meetings.

When entering the app, the user is prompted to first select the speciality and whom to refer to. The main structure of each referral is as following; patient information (name, age, sex and weight) clinical details, past medical history, an option to ask a clinical question, and the ability to upload photos. In the burns part of the app, an interactive drawing feature allows the user to indicate burn depth and location of the burn (Figure 2). After completing the drawing the app will automatically calculate burn size and a fluid resuscitation protocol. The user also have the option to upload images of the burn and is encouraged to do so. After completing the form, the referral is sent to the burns specialist on call to review. The specialist will immediately receive the referral and can reply with their advice through a chat function. The specialist can choose to type their message or choose from a list of pre-defined management advice. The app is not a formally recognised referral system, and using the app is optional.

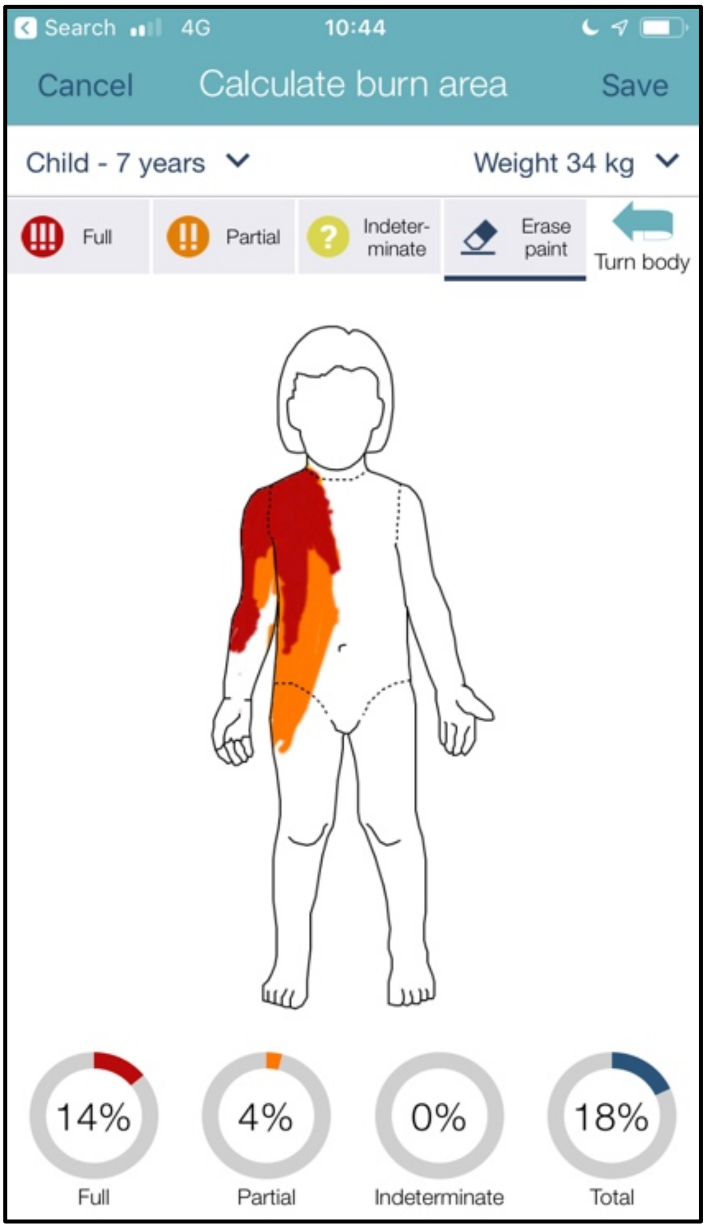


Figure 2: Screenshot of the Vula App

AIMS AND RESEARCH QUESTIONS

The aims of the thesis were to deepen the knowledge about referral patterns of patients with burns in resource poor settings, and to study perceptions and experiences among emergency staff's use of smartphones as a diagnostic support to improve the assessment, initial care and referrals of patients with burns.

- Are patients with burns referred according to local burn criteria? (Study I)
- What are the demographic and clinical factors associated with referral? (Study I)
- How do emergency doctors experience the usability of the Vula app for remote consultations and referrals of burn injuries? (Study II)
- What promotes and hinders the embedding and integration of the Vula app for burn injury consultations and referrals in the emergency centre? (Study III)
- What is the Intention to use the Vula app burn injury consultation and referrals among front line health workers in a low-resource setting? (Study IV)

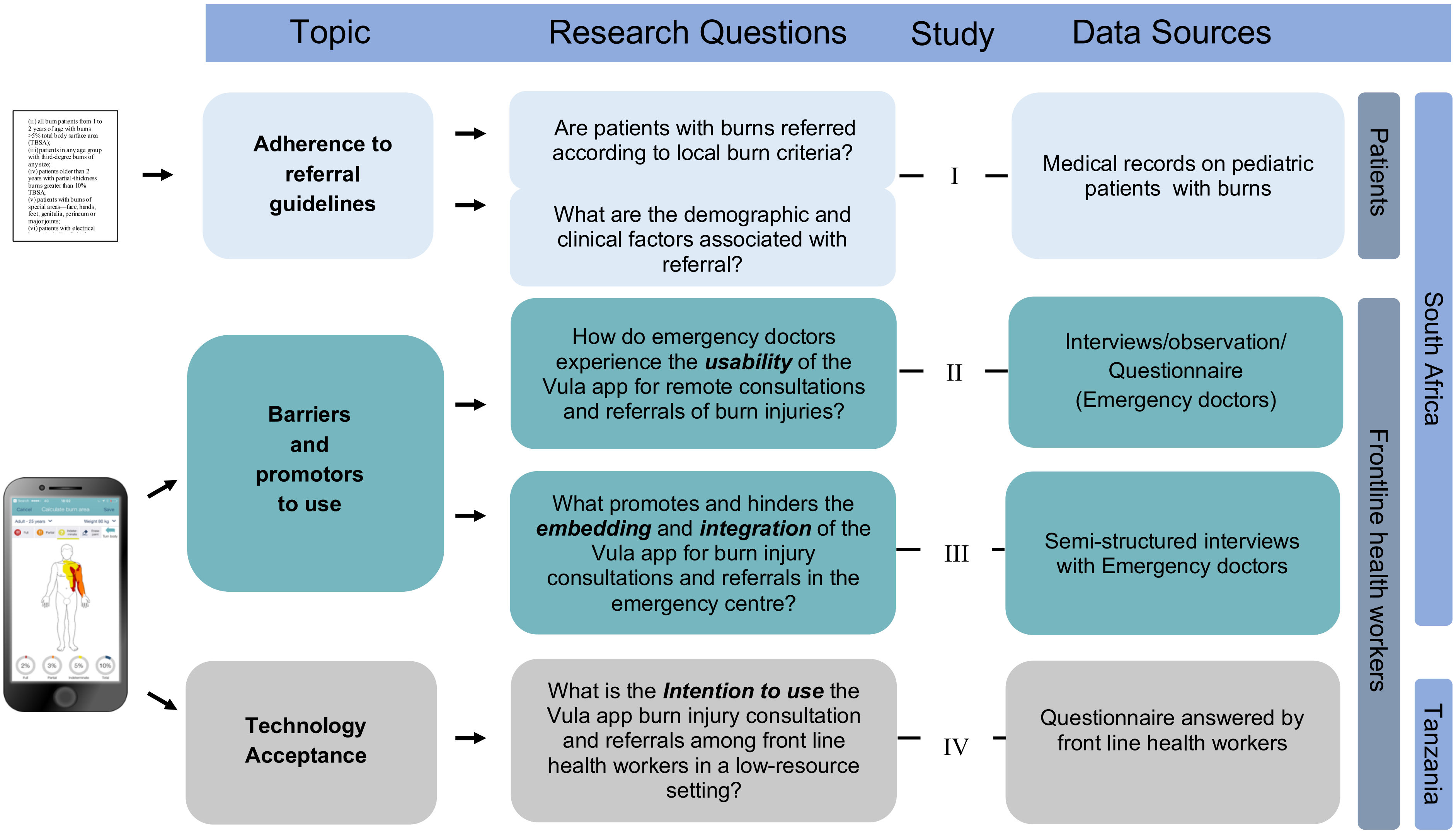


Figure 3: Overview of study topics, research questions, data sources, participants and settings.

MATERIALS AND METHODS

OVERVIEW

This thesis is based on four studies outlined in figure 3. Study I, II and III were conducted in South Africa and study IV in Tanzania (Figure 4). Study country indicators can be found in table 1. All studies rely on primary data sources.

STUDY SETTINGS

South Africa

Study I, II and III were all conducted in the Western Cape Province of South Africa. South Africa is an upper-middle-income country and has the world's highest income inequalities by any measure [127]. More than half of South Africa's population remain under the upper-bound national poverty line and are considered chronically poor with rural areas having the highest poverty [128]. The current unemployment of 29% remains a key challenge [128]. The poor tend to live in overcrowded housing conditions [128], which has been associated with poorer health outcomes [129, 130]; in 2015, about 4 out of 10 people in South Africa were living in such conditions [128]. In 2018, two-thirds of the population resided in urban areas, and the remaining one-third lived in rural regions [131]. It is also estimated that in 2018, 13% of the population lived in informal dwellings, i.e. makeshift houses such as shacks or shanties, and 16% rely on non-electrical sources for cooking and heating [132].

South Africa is battling a quadruple burden of disease including infectious diseases, maternal and child mortality and malnutrition, non-communicable diseases as well as violence and injuries [133]. The health care system in South Africa is two-tiered and comprises a private and public health sector. Public health services are divided into primary, secondary and tertiary levels and managed by the provincial departments of health. The primary health care is mainly made up of nurse-driven clinics, but also include the district level hospital and community health centres. However, access to health care is unevenly distributed across income groups, and only 17% are enrolled in a health insurance scheme, with the remaining population relying on mostly free but chronically underfunded public sector [132]. One of the most critical bottlenecks to health service delivery in South Africa is access to human resources for health, especially access to specialist doctors and nurses. It's estimated that only 20% of the specialists are serving 84% of the population [134]. Skilled health workers are also not equally distributed between urban and rural areas and between the private and public sector. For example, while around a third of the population live in rural South Africa, only 12% of the doctors work in these areas [135]. To provide all South African citizens with essential health services and to move towards universal health coverage (UHC), the government has started implementing a tax-funded National Health Insurance (NHI) [136]. In South Africa *The National Health Act* as well as the *eHealth Strategy South Africa 2012-2017* have emphasised that technology should be used to tackle the shortfalls within the health system [137].

The Western Cape where studies I-III were conducted, is situated on the south-western coast of the country and is the home of 6.3 million, with about two-thirds of the population living in the Cape Town metropolitan area. The province has 450 primary health facilities, 34 district hospital and eight regional hospitals [138]. In South Africa, burn care is mainly provided at the emergency departments and varies depending on the facility and access to trained staff [139]. In Cape Town, two hospitals, one for children up to 12 years old, and one for adults (13+) provide specialist burn care for the province. While minor to moderate burns can be managed at the primary and secondary level, patients with major or complex burns meeting the provincial burn criteria should be referred and managed at one of the two burns centres [37].

Burns in South Africa

There is no national register of burns, but one recent study from the Northern Cape Province found that about 3% of trauma admissions were due to burns [140]. According to WHO data, about 2200 people die each year from burns in South Africa [1]. In the Western Cape province, a study looking at causes of paediatric trauma presenting at the Red Cross Memorial War Hospital found that the number of children with burns nearly doubled between 2007 and 2011 [141]. Another study found that burns were responsible for 7% of trauma deaths in 2000 [142]. Studies from the region consistently show that especially young children are affected by burns [12, 143–145]. This high prevalence has been attributed to a number of environmental and socio-demographic factors [10], such as the use of hazardous energy sources, crowded living spaces, lack of child supervision, houses built out of highly flammable materials, lack of knowledge on risk factors and limited programs targeting prevention [146]. While burn care in South Africa is reported to be satisfactory, insufficient infrastructure and lack of consumables at primary health care level are a significant concern. Health care providers also report concerns about inadequate training in burn care [139].

Tanzania

Study IV was conducted in Dar Es Salaam, Tanzania. Tanzania is located on the eastern coast of Africa and is among the poorest countries in the world. The country is struggling with inadequate infrastructure, low education levels and a high burden of disease. Almost two-thirds of the 4.3 million inhabitants in Dar Es Salaam reside in informal settlements with limited infrastructure (16).

Tanzania has a decentralised health system, with most health care facilities concentrated in Dar Es Salaam. There are shortages of health professionals halting its progress in achieving the health-related Sustainable Development Goals (SDGs). Overall, public spending on health has been declining in the last ten years and is currently at 4.1% of GDP, far off the Abuja declaration target of 15% [147]. The Tanzanian health workforce consists of a range of health workers with only a small proportion being professionals health workers, such as doctors or specialised nurses. Also, most of these skilled health workers are found in urban areas where most hospitals are located. For example, one survey found that more than half of the doctors in the country reside in the Dar Es Salaam region [148]. In a report from 2007, The Ministry of Health and Social Welfare declared the referral system between levels of care to be ‘basically non-functional’ much due to a lack of skilled health workers with appropriate supervision, lack of equipment, poor transport and communication infrastructure [149].

Burns in Tanzania

A recent survey of the patients seeking care at district and regional hospitals in mainland Tanzania found that 3.5% of all trauma cases were due to burns, with patients under five years most affected [150]. Compared to South Africa, Tanzania has no dedicated burns units; hence the care of these patients predominately fall on the general surgical departments [151]. In general, there is a shortage of staff trained in burn care, and a lack of the appropriate equipment and consumables to manage burns [152].

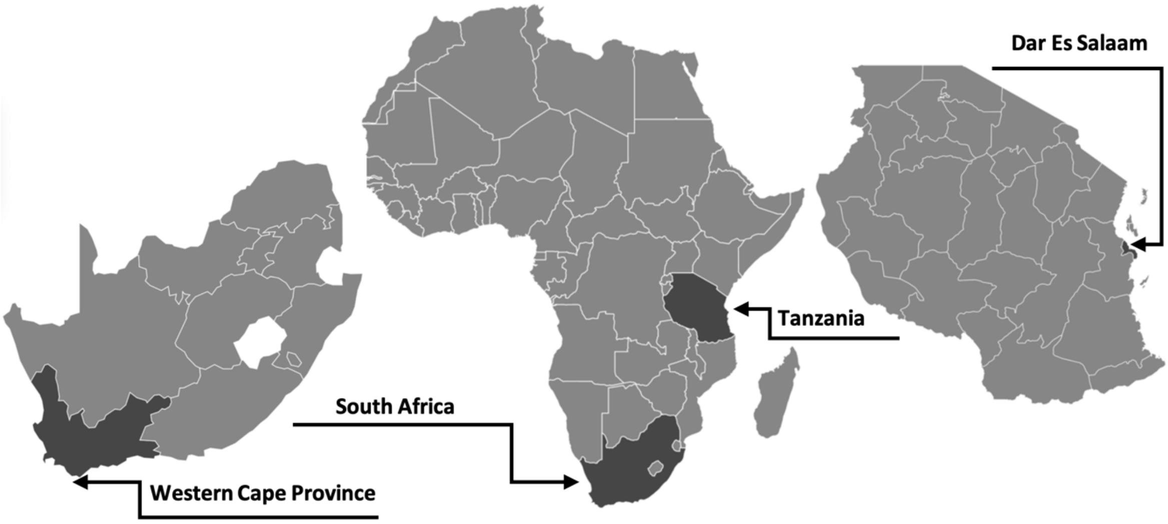


Figure 4: Map of Africa – The two study countries indicated

Table 1: Study country indicators – estimated by the world bank [153]

Indicator	**Year**	**South Africa**	**Tanzania**
Total population (Millions)	2018	57.78	56.32
Gross national income per capita (PPP international $)	2018	13,230	3.160
Life expectancy at birth m/f	2017	60/67	65/68
Probability of dying under five (per 1 000 live births)	2017	37	54
Total expenditure on health per capita (Intl $)	2016	428.2	35.5
Total expenditure on health as % of GDP	2016	8.1	4.1
Physicians (per 100 000 people)	2016, 2014	81.8	2.0
Specialist Surgical workforce (per 100 000 people)	2014, 2016	11.5	0.5
Nurses and midwives (per 100 000 people)	2017, 2014	350	41
Hospital beds (per 1 000 people)	2005, 2010	2.8	0.7
Mobile cellular subscriptions (per 100 people)	2017	156	69.7
Individuals using the Internet (% of population)	2017	56.2	16
Access to clean fuels and technologies for cooking (% of population)*	2016	84.8	2.2

*Access to clean fuels and technologies for cooking is the proportion of total population primarily using clean cooking fuels and technologies for cooking

DESIGN, PARTICIPANTS, DATA COLLECTION AND ANALYSIS

Burn criteria adherence

- *Are patients with burns referred according to local burn criteria?*
- *What are the demographic and clinical factors associated with referral?*

Design and study sample

Study I was a retrospective cross-sectional study of children who sought care for their burns at the Red Cross Memorial Children's hospital (RCH) in Cape Town between February 1st, 2015 and September 30th, 2015. First, all patients who had sought care for a burn injury at the RCH trauma unit were identified in the register books. From these entries, patient identification number was extracted, and the patients' medical records were obtained from the medical records department. After excluding thirty-six cases due to incomplete information, 871 patients remained for further analysis (Table 2). The records where examined and information on injury and demographic characteristics of the patients, including disposition, was collected (See Appendix 1). This information was subsequently used to assess whether the patients fulfilled the local criteria for burn referral. Google Maps (Google, Inc., Mountain View, CA, U.S.A) was used to estimate travel distance to the RCH.

Data analysis

For descriptive purposes, mean and standard deviation (SD) were used to report on age and TBSA. Median was used for continuous data on age, TBSA, and travel distance.
For comparative analysis on continuous variables (age, TBSA, travel distance) Mann–Whitney U-test was used. Chi-square test was used to compare differences between boys and girls and differences in outcomes (meeting the referral/not meeting the referral criteria). In all analyses, a P-value 0.05 was considered significant.

Table 2 - Demographic and injury characteristics of children with burns at the RCH trauma unit, Cape Town South Africa (n=870). Study period Feb 1st 2015 – Sept 30th 2015.

	Boys	(%)	Girls	(%)	Δ%	Total	(%)
Age groups							
Infants/toddlers (<2)	268	(55.5)	208	(53.7)	1.7	476	(54.7)
Late toddlers (2-3)	115	(23.8)	86	(22.2)	1.6	201	(23.1)
Preschool (4-6)	54	(11.2)	50	(12.9)	-1.7	104	(12.0)
School-aged (7-12)	46	(9.5)	41	(10.6)	-1.1	87	(10.0)
No information	0	(0.0)	2	(0.5)	-0.5	2	(0.2)
Burn mechanism							
Scalds	399	(82.6)	313	(80.9)	1.7	712	(81.8)
Contact burns	39	(8.1)	40	(10.3)	-2.3	79	(9.1)
Fire/flame	32	(6.6)	25	(6.5)	0.2	57	(6.6)
Others*	12	(2.5)	8	(2.1)	0.4	20	(2.3)
No information	1	(0.2)	1	(0.3)	-0.1	2	(0.2)
TBSA							
0-5%	219	(45.3)	176	(45.5)	-0.1	395	(45.4)
6-10%	110	(22.8)	87	(22.5)	0.3	197	(22.6)
11-15%	44	(9.1)	40	(10.3)	-1.2	84	(9.7)
16-25%	22	(4.6)	24	(6.2)	-1.6	46	(5.3)
>25%	11	(2.3)	9	(2.3)	0.0	20	(2.3)
No information	77	(15.9)	51	(13.2)	2.7	128	(14.7)
Burn Depth							
Partial-thickness	380	(78.7)	304	(78.6)	0.1	684	(78.6)
Partial/Full thickness	12	(2.5)	5	(1.3)	1.2	17	(2.0)
Full-thickness	8	(1.7)	4	(1.0)	0.6	12	(1.4)
No information	83	(17.2)	74	(19.1)	-1.9	157	(18.0)
Abbreviated Injury Score (AIS)							
1-2	412	(85.3)	335	(86.6)	-1.3	747	(85.9)
3+	23	(4.8)	16	(4.1)	0.6	39	(4.5)
No Information	48	(9.9)	36	(9.3)	0.6	84	(9.7)
Time to presentation							
Same day	287	(59.4)	223	(57.6)	1.8	510	(58.6)
Day after	123	(25.5)	110	(28.4)	-3.0	233	(26.8)
2-6 days later	50	(10.4)	47	(12.1)	-1.8	97	(11.1)
7+ days later	7	(1.4)	3	(0.8)	0.7	10	(1.1)
No information	4	(0.8)	6	(1.6)	-0.7	10	(1.1)
Disposition at the trauma unit							
Referred to Burns Unit	344	(71.2)	249	(64.3)	**6.9**	593	(68.2)
Referred to ICU	8	(1.7)	9	(2.3)	-0.7	17	(2.0)
Treated at the trauma unit	127	(26.3)	126	(32.6)	**-6.3**	253	(29.1)
No information	4	(0.8)	3	(0.8)	0.1	7	(0.8)
Referral site							
Clinics	160	(33.1)	131	(33.9)	-0.8	291	(33.4)
Level 1	110	(22.8)	86	(22.2)	0.6	196	(22.5)
Level 2	30	(6.2)	20	(5.2)	1.0	50	(5.7)
Level 3	5	(1.0)	2	(0.5)	0.5	7	(0.8)
Private Hospital/Clinics**	9	(1.9)	7	(1.8)	0.1	16	(1.8)
Self-referred	69	(14.3)	57	(14.7)	-0.4	126	(14.5)
No information	100	(20.7)	84	(21.7)	1.0	184	(21.1)
Total	483	(55.5)	387	(44.5)	11	870***	(100.0)

*Others include: chemical burns and electrical burns
** Private Hospital/Clinics are not classified by level in this study
*** One child had missing information on gender and was excluded from this table

Barriers and promotors

- *How do emergency doctors and specialists experience the usability of the Vula app for remote consultations and referrals of burn injuries? (Study II)*

- *What promotes and hinders the embedding and integration of the Vula app for burn injury consultations and referrals in the emergency centre? (Study III)*

Participants

The study participants in Study II and III were doctors working at the emergency departments in the Cape Town metropolitan area. For study II, participants were sampled through convenience sampling at two emergency departments. The participants in study II had either no or little experience of using the Vula app for burns. For Study III, participants who had been using the app were enrolled. Participants were identified through the system-log of the app and selected based on having used the app for burns more than three times. In Study II, four burn consultants who had been active on the app were also recruited. Characteristics of study participants in study II and II can be found in table 3 (Burns consultants not included).

Table 3: Characteristics of study participants – Study II and III

Characteristics	Study II (n = 24)	Study III (n = 15)
Sex, n (%)		
Women	12	9
Men	12	6
Age (in years)		
Mean	27.6	29.0
Median	27	28
Range	25-34	27-39

Data collection and analysis

Study II – Usability

Study II was a mixed-methods study including a user-test (Think-aloud protocol) and a questionnaire (Health-ITUES). Data was collected in December 2016 and August 2017. During each user-test, the doctors used the app to assess a made-up case while "thinking aloud". The think-aloud method was chosen because it is suitable for understanding the users' cognitive processes while they perform a set of tasks [154, 155]. The doctors were given a case describing a patient with two burns on the right arm, one on the back and one on the front (See text-box 1).

Textbox 1: Case description of the patient

- **Weight: 80 kg**
- **Sex: Male**
- **Cause of burn:** Spilled hot coffee (3% of the body surface, one full-thickness and one partial thickness)
- **When did the injury happen:** 3 hours ago
- **Medical history:** Diabetes; Tuberculosis

The interviewer had marked the location and size of the burns on the arm with a marker to facilitate the examination. The participants were told to examine the patient and to use the app. Tasks descriptions can be found in Appendix 2. To record their interaction with the app the doctors were fitted with a small camera (GoPro Hero4, GoPro, Inc, San Mateo, California) (see Figure 5).

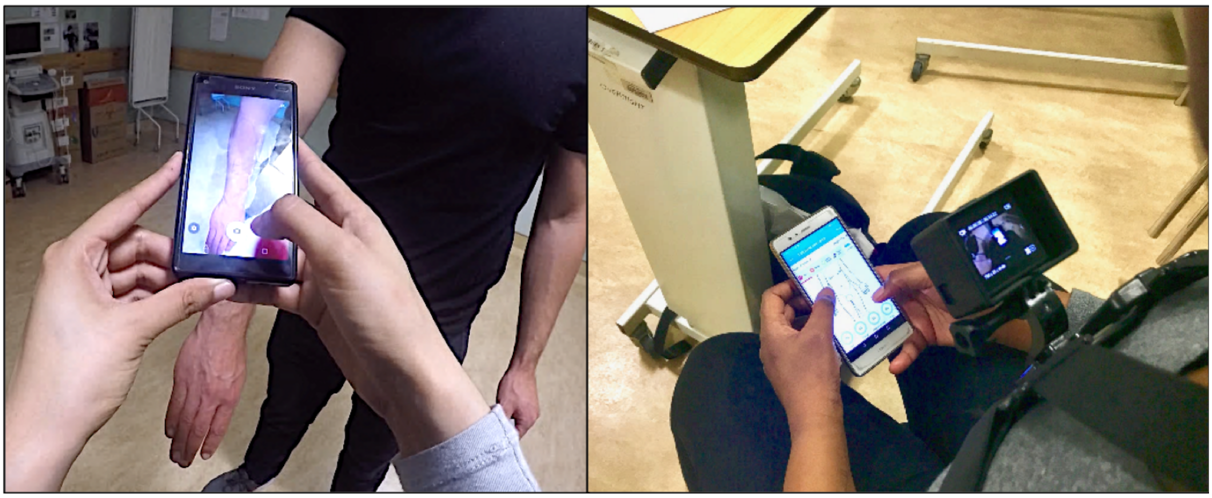


Figure 5: User taking a photo of burn injury (left picture), and camera mounted to the user's chest (right picture)

The videos were analysed with a software for analysis of qualitative data. Each video was analysed using content analysis [156, 157] with codes adapted from Kushniruk and Borycki (Table 4) [158].

Table 4: Usability themes and definitions [158]

Usability themes	Definition
Usability related aspects	These codes are used to describe usability problems, and issues identified when analysing video usability data. The codes focus on aspects of the user interface and the user-system interaction.
Usefulness of Content Codes	These codes are used to describe issues regarding the usefulness of the user interface or system being evaluated from analysing the data
Safety and Technology-Induced Error Codes	These codes are used to identify and tag errors made by users when analysing data

Health-ITUES Questionnaire

The doctors were also asked to fill out the Health Information Technology Usability Evaluation Scale (Health-ITUES) [120, 121] (Appendix 3). The Health-ITUES is a 20-item tool that can be customised down to item-level to reflect the specific tool, user, task and context. In this study this translated to; user - emergency staff, tool - the Vula App, task - management of burns and context - emergency care services. The 20 items are divided between four domains - quality of work-life, perceived usefulness, perceived ease of use, and user control. Each item is scored on 5-point Likert-scale, ranging from strongly disagree (1) to strongly agree (5), as well as an option for non-applicable.

Study III – Embedding and integration

The focus of the interviews was on how the doctors experienced using the Vula App for burn injury consultations and referrals. The interview guide (Appendix 4) and data analysis were underpinned by the Normalisation Process Theory (NPT) [159, 160]. NPT is a sociological theory that is used to understand how complex interventions are operationalised in everyday practice. The theory is organised around sixteen components divided into four core constructs (Table 5). These core constructs represent ongoing social processes leading to the embedding and integration of new practices. These constructs are:

- ***Coherence*** – does the intervention make sense to the people involved
- ***Cognitive participation*** – what promotes or inhibits users' enrolment and legitimisation of the practice
- ***Collective action*** – is about the work people do to put the intervention into practice,
- ***Reflexive monitoring*** – is what people do to assess the value of the intervention and how they themselves are affected by the intervention.

Thematic analysis as described by Braun and Clarke [161] was conducted to describe aspects that hindered or promoted the use and integration of the app in routine work. First, meaning units relating to the constructs were coded with codes representing the components of the NPT. In a second phase, the transcripts were coded inductively in order to find meaning units across the interviews. This second coding was done to identify meaning units both across and within the constructs and their components, and were finally grouped together into themes. Quotes were used to illustrate the findings.

Table 5. Coding framework for the analysis of qualitative interviews with emergency physicians concerning the Vula app for burns.

Coherence (Sense-making work)	Cognitive participation (Relationship work)	Collective action (Enacting work)	Reflexive monitoring (Appraisal work)
Differentiation Is there a clear understanding of how using the Vula app differs from existing practices of consulting and referring patients with burns?	**Enrolment** Do individuals "buy into" the idea of the Vula app?	**Skillset workability** How does the Vula app affect roles and responsibilities or training needs?	**Reconfiguration** Do individuals try to alter the Vula app?
Communal specification Do individuals have a shared understanding of the aims, objectives and expected benefits of the Vula app?	**Activation** Are doctors able to sustain involvement?	**Contextual Integration** Is there adequate resources and organizational support to use the Vula app?	**Communal appraisal** How do groups judge the value of the Vula app?
Individual specification Do individuals have a clear understanding of their specific tasks and responsibilities in the implementation and use of the Vula app	**Initiation** Are key individuals willing to drive the implementation?	**Interactional workability** Does the Vula app make the consultation and referral process easier?	**Individual appraisal** How do individuals appraise the effects on them and their work environment?
Internalization Do individuals understand the value, benefits and importance of the Vula app	**Legitimation** Do individuals believe it is right for them to be involved?	**Relational integration** Do individuals have confidence in the Vula app and each other?	**Systematization** How are the benefits or problems identified or measured?

Acceptance

What is the intention to use the Vula app burn injury consultation and referrals among front line health workers in a low-resource setting? (Study IV)

Study participants

Study IV was conducted in Dar Es Salaam, Tanzania at Muhimbili National Hospital, and three regional referral hospitals: Amana, Temeke and Mwananyamala. Health providers working in the emergency departments at the four facilities were invited to fill out a questionnaire regarding their attitudes towards using a smartphone app for burn injury consultations and referrals. The final sample of 59 health workers comprised doctors, nurses, health attendants, assistant medical officers, clinical officers and medical students. The questionnaire can be found in Appendix 5. A short introduction to the study and the app was given before completion of the questionnaire. The questionnaire first developed by Kifle et al. [162] was adapted for this study to mirror the technology, task and context. The 49 questions included measured 11 constructs relating to technology acceptance. The questions were asked on a seven-point Likert scale ranging from One = ‘‘strongly disagree’’ to Seven = ‘‘strongly agree.’’

Data analysis

To test the proposed hypotheses (Table 6) and the proposed model, structural equation modelling (SEM) was used. In order to test whether there were differences within the proposed groups (men/women, referral/referring, age group (24–29/30+), doctor/nurse, and self-rated burn care experience), constrained multigroup SEM analysis was conducted.

Table 6. Hypotheses included in the analysis.

Hypothesis	Definition
H1	Computer self-efficacy is positively related to their perception of ease of use of the app
H2	Facilitating conditions are positively related to their attitude towards the app the app
H3	Perceived compatibility is positively related to their perception of the usefulness of the app
H4	Perceived ease of use of the app is positively related to their perception of its usefulness
H5	Image is positively related to their attitude towards the app the app
H6	Voluntary use of the app is positively related to their attitude towards the app
H7	Social influences are positively related to their attitude towards the app the app
H8	Anxiety towards the use of the app is negatively related to their attitude towards the app
H9	Perceived ease of use of the app is positively related to their attitude towards the app it
H10	Usefulness of the app is positively related to their attitude towards the app

Ethical considerations

Ethical permits were obtained from ethical review boards for all studies within this PhD project. Study I was approved by the University of Cape Town Human Research Ethics Committee (Ref. N452/2015). Study II, by the Stellenbosch University Health Research Ethics Committee (Ref N15/04/027) and Study III by the Stellenbosch University Health Research Ethics Committee (Ref. N18/10/121). Study IV, by the Senate Research and Publication Committee (Ref. No. 2016-06-08/AEC/Vol.XI/29).

Study I which deals with patient data required caution in regards to safeguarding sensitive information. The data for this study was anonymised prior to data analysis, and disseminated results were presented on an aggregated level. In study II and III, which were mainly of qualitative nature, several consideration was made. First, before study participants consented to participate, they were assured that anything they shared during the interviews would not affect them negatively in any way, they were also told that they had the opportunity to withdraw from the study at any point — the names of the participants were not collected except on the consent forms. During transcription of the interviews, any name that was mentioned or other types of signifier were omitted. In Study IV, participants were also briefed on their rights to withdraw at any point, and no names were recorded on the questionnaire. In Study II-IV, participation was voluntary, and all participants consented to participate.

RESULTS

BURN CRITERIA ADHERENCE

Are patients with burns referred according to local burn criteria? (Study I)

Seven children did not have information on disposition and were excluded from the analysis. Of the 864 patients who were included in the analysis, 71% were referred to the burns unit. In this referred group, 94% fulfilled at least one of the referral criteria. Among patients who were not referred, 80% also fulfilled at least one criterion. Figure 6 shows disposition and whether the children matched the criteria for referral. The referral criteria most often met in both groups were “anatomical site” and “age under 2”. However, these two criteria were also the least common reasons for referral, with a referral rate of 78% and 70% respectively. Eight out of ten children matching the criterion “co-morbidity” were referred. The remaining criteria had a referral rate of 100%. Table 7 shows how many of the children fulfilled one or more of the criteria and those who were referred to the burns unit.

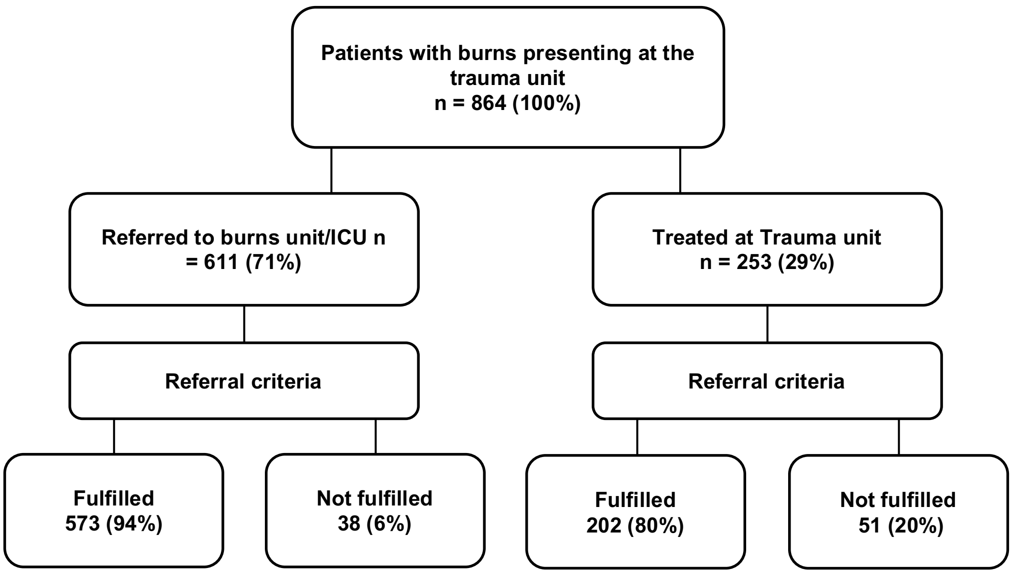


Figure 6 – Disposition of patients and fulfilment of referral criteria among 864 patients seen at the RCH trauma unit between Feb 1st 2015 – Sept 30th 2015.

Table 7 - Number of children fulfilling one or more criteria and the number of children subsequently referred to the burns unit n = 864.

	Referral criteria for transfer to burns centre	Number children fulfilling each criteria[a] n=864	(%)[b]	Number of children fulfilling at least one criteria and being referred* n = 611	(%)[c]
1	Age under two years	472	(54.6)	328	(69.5)
2	Partial-thickness burns >15 TBSA	52	(6.0)	52	(100.0)
3	Full-thickness burns >15 TBSA	8	(0.9)	8	(100.0)
4	Anatomical site	646	(74.8)	504	(78.0)
5	Inhalation injury requiring ventilation for more than 48 hours	4	(0.5)	4	(100.0)
6	Mechanism of injury	1	(0.1)	1	(100.0)
7	Existing Co-morbidity:	84	(9.7)	70	(83.3)
8	Severe associated injuries, e.g. polytrauma and crush syndrome	0	(0.0)	0	(0.0)

[a]Each child can fulfil more than one criteria, [b]Percentage of children fulfilling the criteria
[C]Percentage of children fulfilling the criteria and being referred

What are the demographic and clinical factors associated with referrals? (Study I)

The main difference between referred and not referred children was that referred children had significantly larger burns. Age differences were only found among patients younger than two years, where the children who were referred were slightly younger. In the group (older than two) girls were less likely to be referred than boys. However, girls older than two had significantly larger burns compared to boys in the same age group (median 8, compared to median 7—P 0.038).

Summary of results (Study I)

- Seven out of ten children were referred to the burns or the intensive care unit
- Of those admitted as inpatients, 94% fulfilled at least one of the criteria for referral
- Of those treated and discharged 80% fulfilled at least one of the criteria for referral
- “Age under two” & “anatomical site” was the most fulfilled criteria in both groups
- “Age under two” & “anatomical site” were the least common reasons for referral
- Referred children had significantly larger burns
- Girls older than two had significantly larger burns compared to boys

BARRIERS AND PROMOTORS

How do emergency doctors and specialists experience the usability of the Vula app for remote consultations and referrals of burn injuries? (Study II)

Findings From Think-Aloud Sessions

The emergency doctors completed the user-test without any major difficulties. Nonetheless, the video analysis revealed several usability issues relating to the pre-determined usability codes (Table 8).

Usability-Related Aspects

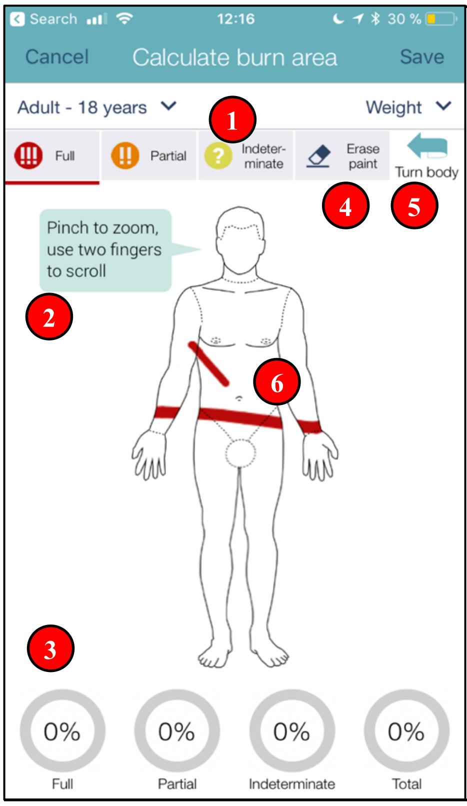
Usability related aspects focus on the user interface and the user-system interaction. Most of these problems related to navigation, i.e. moving through the system or user interface. Almost all of these problems were concentrated to the drawing function of the app. Examples of problems can be found in figure 7. Most of the time, the problems were minor and was easily corrected by the user. In a few cases, however, these problems resulted in the user not completing the task as it was intended. A few doctors did not see that the body could be turned over, and therefore failed to indicate the burn on the posterior side. Despite causing some frustration, most users expressed that the drawing function was one of the strengths of the app and an effective way to communicate burn surface and depth.

> *"it is easy to use, it's not hard. You can erase nicely and just come back to it, and it calculates as you do it" - User 24*

Usefulness of content

One of the most relevant features of the app was the ability to send pictures, and overall taking and sending pictures worked well. However, users had some other comments in regards to the relevance of some of the content of the app, or its accuracy and correctness. Many users expressed that they were often unable to provide the information asked for in the app, such as the patients' weight or height. Another common remark was that they were often limited by the pre-defined options and suggested there should be more free-text options.

> *"I would rather like this part again to rather to be, type in because this is like limited choice" - User 16*



Usability problems

1. Users not understanding that burn depth can be changed or understanding which button is active.
2. Users not seeing the text box about zooming and scrolling.
3. Users pressing the percentage indicators thinking these are buttons.
4. Users having problems finding the erase button.
5. Users not knowing the body can be turned around.
6. Users using one finger instead of two when scrolling and zooming and drawing a line by mistake.

Figure 7: Usability problems identified in the drawing section of the Vula app

The user test also revealed problems related to the accuracy of some of the information in the app. One example is when the doctors had to select what had caused the burn. Many were unsure whether hot coffee should be recorded as a hot liquid or hot water.

> *"ok cause of burn, I would choose hot water burn, coffee is basically hot water, but I find that a bit ambiguous" - User 2*

Safety- and Technology-Induced Error Codes

The last theme concerned slips, mistakes, and workarounds made by the users. Some users made mistakes without realising that resulted in a different outcome than was expected. Some users ended up with different burn surface calculation when using the drawing function. For example, one user did not draw the burn as indented by the app and only marked the edges of the burn, which resulted in a 0% TBSA. The user subsequently thought something was wrong with the calculation and as a workaround, estimated the burn to be 9% and typed it in the "burn percentage" text field. Due to being unaware that the body could be turned around, some users only indicated there was a burn on the posterior side. This subsequently resulted in a smaller burn surface area. In most cases, the underlying cause of these slips, mistakes, and workarounds was often due to not understanding user instructions, the meaning of icons or terminology, or visibility of system status.

Table 8:Usability codes, definitions, frequency of problems and number of users experiencing problems

Codes	Definition	Frequency of Problems	Number of users experiencing problems (n =24)	
Usability Codes			n	(%)
Navigation	Relates to aspects of moving through a system or user interface.	30	14	(58)
Overall ease of use	Coded when the user makes comments of the overall ease of use of the system	27	9	(38)
Consistency	Relates to aspects of the consistency in the user interface	23	10	(42)
Meaning of icons/terminology	Relates to aspects of understanding language or labels used in the interface.	20	12	(50)
Lack of user instructions[a]	Relates to aspects of lack of user instructions	17	10	(42)
Visibility of system status	Relates to aspects of understanding what the system is doing.	15	11	(46)
Layout	Relates to aspects of the layout of screens or information on those screens	6	5	(21)
Understanding instructions	Relates to aspects of understanding user instructions.	5	5	(21)
Graphics	Relates to aspects of graphics of the system.	4	3	(13)
Font	Relates to aspects of font size or text readability.	1	1	(4)
Speed/response time	Relates to aspects of system speed or response time.	1	1	(4)
Usefulness of Content Codes				
Accuracy/correctness	Relates to aspects of the accuracy or correctness of information or advice provided by the system	19	14	(58)
Overall usefulness[a]	Coded when a user makes comments of the overall usefulness of the system	5	3	(13)
Relevance	Relates to aspects of the relevance of information and features to the user carrying out their task.	30	13	(54)
Safety and Technology-Induced Error Codes				
Mistake	Coded when a review of the data indicates the user has made a mistake that is not corrected.	7	4	(17)
Slip	Coded when a review of the video data indicates the user has made a mistake but corrects the mistake.	34	20	(83)
Workaround	Coded when the user is not using the approach to carrying out work that is recommended by the healthcare organization or computer system.	8	8	(33)

[a]New code added to the original coding scheme.

User satisfaction

Overall, the app scored relatively high on all constructs, with "ease of use" scoring the highest (Table 9). While the usefulness scored high, item 5,10 and 12 which relates to receiving a reply scored lower. Quality of work-life also scored high, indicating that the doctors perceived the app to be using the app had a positive impact on work life. The lowest score was given to the construct "user control", especially the items 18 and 19, which relates to error prevention.

Table 9: Health-Information Technology Usability Scale (Health-ITUES)

	Item	Concept	Score (1-5)
	Quality of work-life (Cronbach α= .76)		**4.42**
1	I think the app has improved the emergency staff's ability to care for burns	System impact - career mission	4.67
2	I think the app has been a positive addition to burn care at the hospital	System impact - organizational level	4.46
3	The app is an important part in the acute management of burns	System impact - personal level	4.13
	Perceived usefulness (Cronbach α= .92)		**4.14**
4	Using the app makes it easier to receive expert advice on management of burns	Productiveness	4.5
5	Using the app enables me to receive burn management advice more quickly	Productiveness	3.70
6	Using the app makes it more likely that I have sufficient knowledge on how to manage acute burns	Productiveness	4.00
7	Using the app is useful for receiving information about burn management	General usefulness	4.13
8	I think that the app presents a more equitable process for burn management	General usefulness	4.38
9	I am satisfied with the app for receiving information on burn management	General satisfaction	4.13
10	I can receive information on burn management in a timely manner because of the app	Performance speed	3.88
11	Using the app increases receiving information about burn management	Productiveness	4.33
12	I am able to receive advice on burn management whenever I use the app	Information needs	3.88
	Perceived ease of use (Cronbach α= .74)		**4.64**
13	I am comfortable with my ability to use the app	Competency	4.71
14	Learning to operate the app is easy for me	Learnability	4.63
15	It is easy for me to become skilful at using the app	Competency	4.67
16	I find the app easy to use	Ease of use	4.54
17	I can always remember how to log on and use the app	Memorability	4.67
	User control (Cronbach α= .55)		**3.73**
18	The app gives me error messages that clearly tell me how to fix problems	Error prevention	2.67
19	Whenever I make a mistake using the app, I recover easily and quickly	Error prevention	3.87
20	The information (such as on-screen messages and other documentation) provided with the app is clear.	Information needs	4.33

Interviews with burns consultants

While the app allows the burns consultants to select from a set of pre-defined options for advice, treatment medication and dressings, most consultants would rather initiate a chat to give the advice., and one consultant was even unaware this function. While one of the consultants said that in general pre-defined options are good, the options in the Vula app were currently not very helpful.

> *It irritates me that I need to tell them the dose. So, if I choose morphine, I have to write the dose. That's standard protocol, the nurse or doctor should know this, or use another app, or it should be in this app. [Consultant 1]*

Similar to what the emergency doctors expressed, the ability to exchange images was the most important part of the app. However, one consultant stressed that it is important that the doctors clean the wounds before taking and sending the pictures, and suggested that the app should have instructions about this.

Summary of results (Study II)

- Most users finished all tasks related to the test without major problems
- The drawing feature and the ability to send photos was perceived to be very useful
- Most of the usability-related problems were concentrated to the drawing function
- Some said that the pre-defined choices were too limiting and wanted more options for free text.
- The app scored high in the Health-ITUES questionnaire, with ease of use scoring the highest.
- The burns consultants did not always use the app as it was intended and found that the pre-defined advice were not always very useful.

What promotes and hinders the embedding and integration of the Vula app for burn injury consultations and referrals in the emergency centre? (Study III)

Three overarching themes were identified across the transcripts, relating to aspects that hindered or promoted the use and integration of the app for burn injury consultation and referrals.

Themes

It is better than sitting on the phone	**It is all word of mouth**	**You do what you can with what you have**
Sub-themes	**Sub-themes**	**Sub-themes**
It's easy because it's on our phones	What do I do with this patient? - Just Vula It	It all comes from your own pocket
The app saves time – if you get a reply	Making sense of how it works	We have the resources to carry out management - but only the basics
The app promotes higher quality referrals	There is always resistance to change	Using the app is a way to learn

It's better than sitting on the phone. In general, the doctors used their phones for all sorts of work-related task, such as looking up information and for communication. The doctors expressed that they often preferred the Vula app compared to traditional phone consultations. One of the most important benefits was that it was time-saving. First, they did not have to find a phone to call from, and secondly, they could bypass the hospital switchboard and reach the specialist directly.

> *"It makes our life easier because we have got a load and we have got a short amount of doctors so, we need to spread ourselves, and this saves time and helps you spread yourself" – Participant 5*

However, whether they saved time would depend whether they received a reply within a reasonable timeframe. Here, the doctors had varying experiences, where some said the specialists were quick to reply, while others said they always had to call and ask if they had seen their request.

"Not once, not had to phone them anyway, and say please look at your phone I have sent a Vula referral" – Participant 2

The doctors also brought up that the drawing feature and fluid calculation was very useful and that it was quicker than doing it on a standard paper sheet. Some also expressed that using the app was a more reliable means of calculating the burn surface area compared to doing manually. Using the app to calculate not only made it easier but also made them feel more confident in their assessment.

"so instead of you having to colour in on the clerking sheet and working out formulas now, it's just so much easier colouring in. [...] I think we kind of doubt ourselves sometimes a lot as professionals so I think it is also just a good way to reassure you" – Participant 6

While the app was perceived as time-saving in some respects, the doctors were still required to write referral letters and take notes for record-keeping, which was said to increase workload in other respects. None of the participants used the camera function in the app, and instead used the native camera app on the phone and later imported the photos to the app. This was because taking photos of the burns and filling out the information in the app did usually not occur at the same time. This, however, meant that the photos would end up in their photo gallery, which was not only inconvenient but problematic from a data security perspective.

The participants also said that the app promoted higher-quality referrals. The app helped the doctors to structure the referral and to remember what information was relevant to the specialist. The doctors also said that by using the app, the referrals where more objective compared to a verbal description over the phone.

"We all have different ways of describing things [...], but if you can actually send a photo via the app and provide all the other information, there is a visual thing that the other person can use to also see what you are seeing" – Participant 6

While the doctors said they usually agreed with the specialist's decision, they also acknowledged their own responsibility to provide the necessary information in order for the specialists to make a proper assessment. Some other benefits with the app were that it led to better documentation and that it felt more professional compared to using other text and image-based communication apps such as WhatsApp.

"So it almost, enforces a level of professionalism, because this is all a trail that is being left. If you demean your colleague that is documented, you've got proof [...], and at the same time it also enforces a very high level of consultancy, because again if you give the incorrect management advice, its documented, its traceable" – Participant 10

Word of mouth. Knowing about the app and how to use it was often through word of mouth. While some had been told to use it by their superiors during induction, the majority had only found out about it from colleagues.

"your exposure to Vula is all word of mouth, if I have an eye problem and I ask like a friend, what do you think I should do, they will be like just Vula it." – Participant 4

Since the app was perceived as very user-friendly, there was no need for formal training on how to use it. Although, some thought it would be good to provide information and guidelines on how to use the app in practice, such as what specialities the app could be used for. There were also uncertainties in regards to what specialities were active on the app. For example, during the interviews, it became apparent that almost no one knew that they could refer children with burns via the app. In general, many said it depends on how active the specialist departments were in using and promoting the app. While some departments were very enthusiastic about the app, and would only take referrals through the app, other departments were said to be more indifferent. Many doctors said that they would only start using the app for a specific speciality if they knew that other colleagues had had positive experiences.

You do what you can with what you have. Many doctors talked about that how nowadays they are in a way expected to use their phones for work, but that it all comes from your own pocket. While using your own phone and airtime for work purposes was not a barrier to use the app, it was still something that was perceived as being problematic and not sustainable in the long run. Still, the doctors also recognised that resources were limited and there was a willingness to use their phones to be able to provide better services to their patients.

"I mean no one gives us extra data every month to use the app, it all comes from your own pocket, so in that way there hasn't been any kind of help from outside" – Participant 9

Another problem concerned the boundary between personal and professional use and the need for being online during off-hours if a referral had not yet been resolved. While most doctors would still rather use their own phones than having a communal device, they said that there should be free wireless internet in order to minimise the costs.

> *"The problem is that the personal-professional interface is very blurry because it's still my personal phone with my data and my battery life that I am using for non-personal reasons, but I love the fact that I do not need to carry a second thing or walk to a computer or telephone." – Participant 5*

The doctors were also asked about the capacity to carry out burn care in relation to the advice they received from the specialist. In general, resources were scarce, but it also was dependent on where they worked. While the advice they received from the specialists was generally perceived to be reasonable, it was often brought up that it was important that the specialist understood the doctors' capabilities and available resources when giving the advice.

> *"We don't have all this specialised burn dressings, so if they are going to need something more, we can't provide that, so I think it is also just important that the person that you are referring to understand" - Participant 3*

Finally, all participants brought up that the benefits of using the app went beyond the ability to speed up work and that in the poor communities where they worked, the patients now had access to better care because of the app. Many of their patients did not have the money to travel into town to see the specialists, and it was also difficult to arrange transport with an ambulance.

> *"The patient also benefits because they like I said, they don't have to travel for that same specialist care, and they are still receiving it at their level, at their hometown, in their own hospital" – Participant 8*

If patients could be treated locally, it was both good for the patient, and also for the whole health system. However, this perception came from what they could see themselves; no one had seen any formal evaluation.

Furthermore, most doctors said they did not have much training in burn care, thus using the app was not only support at the moment but also offered a learning opportunity that they would otherwise did not have access to.

> *"for us to leave and go out to learn is a bit also difficult, so that is a reason why these apps, Vula, and whatever other apps we use is actually beneficial to us. Because even though we are still part of town, we actually feel like we are in a rural area, isolated from others" – Participant 7*

At the same time, it was brought up that they wanted more feedback on their referrals from the consultant. One reason they wanted feedback was to learn, but also to know what happened to the patient.

> *"feedback, I think that is something might be a good thing, like feedback on the patient that you sent [...] especially so that it can better you management, of the patient, the next time" – Participant 3*

Summary of results (Study III)

Promotors

- Doctors were already accustomed to using their smartphones for work-related tasks.
- Uptake was promoted because of the app being perceived as easy to learn and use
- Vula app was considered to streamline the referral process and introduce higher quality consultations and referrals, leading to improved decision making and helped doctors provide better patient care.
- The match between the management advice or referral decision and the resources and capabilities were perceived to be reasonable to the participants
- The app offered a valuable learning opportunity.

Barriers

- The inconsistent use of the Vula app across specialist institutions led to uncertainties regarding who was active on Vula.
- The informal means of introduction, mainly peer-learning, may pose a barrier and could contribute to resistance among certain doctors.
- Lack of technical infrastructure was described as a potential barrier in the long run.
- Notes and referral letters still had to be written, which was said to increase workload in some respects.
- Limited opportunities for the doctors to provide feedback on the system

ACCEPTANCE

What is the intention to use the Vula app burn injury consultation and referrals among front line health workers in a low-resource setting? (Study IV)

All except three of the fifty-nine participants own smartphones. The participants who owned smartphones all used them for work purposes such as communication, searching for information and using different medical apps. The participants were positive towards using the app, as they rated high on concepts from the technology acceptance model (TAM) such as usefulness, ease of use, attitude and behavioural intention (Table 10). When testing our proposed hypotheses we found correlations between: CO-PU, PEOU-PU, IM-ATT, SI-ATT, ANX-ATT, PEOU-ATT, PU-ATT, and ATT-BI (Table 11).

Table 10. Number of items, item mean and reliability statistics (Cronbach's Alpha) of each construct

Construct		No. of items	item mean	Cronbach's Alpha
Perceived ease of use	PEOU	4	6.44	0.89
Perceived usefulness	PU	6	6.16	0.89
Compatibility	CO	2	6.03	0.53
Image	IM	3	5.44	0.93
Self-Efficacy	SE	7	3.84	0.58
Voluntariness	VO	2	3.49	0.60
Behavioural intention to adopt	BI	3	5.87	0.87
Anxiety	ANX	8	4.40	0.48
Social influences	SI	5	5.18	0.80
Facilitating conditions	FC	4	4.41	0.10
Attitude towards using technology	ATT	5	6.38	0.86

Table 11: Univariate analysis of relationships between constructs and differences between gender, type of hospital, age, occupation and self-rated experience in burn care

Path	Standardized	All (59)	p	Men (21)	Women (38)	p	Referral (30)	Referring (29)	p	24-29	30+	p	Doctor (30)	Nurse & others (27)	p	Experienced	inexperienced	p
SE ->PEOU	Yes	-0.14	0.36	-0.16	-0.06	1.00	0.07	-0.29	0.99	-0.20	-0.12	1.00	0.08	-0.51	1.00	NA	NA	NA
	No	-0.08	1.00	-0.06	-0.03	1.00	0.01	-0.30	0.99	-0.09	-0.09	1.00	0.03	-0.44	1.00	NA	NA	NA
FC ->PEOU	Yes	0.42	0.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	No	0.22	0.99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CO -> PU	Yes	0.94	**0**	NA	NA	NA	0.89	0.96	**0.03**	NA	NA	NA	NA	NA	NA	NA	NA	NA
	No	0.95	**0.01**	NA	NA	NA	0.43	1.21	**0.03**	NA	NA	NA	NA	NA	NA	NA	NA	NA
PEOU -> PU	Yes	0.70	**0.00**	0.47	0.78	1.00	0.92	0.60	0.99	0.62	0.75	1.00	0.58	0.85	1.00	0.91	0.43	0.99
	No	0.38	1.00	0.24	0.43	1.00	0.43	0.39	0.99	0.41	0.46	1.00	0.16	0.24	1.00	0.42	0.24	0.99
IM -> ATT	Yes	0.55	**0.00**	0.48	0.57	0.12	0.41	0.83	**0.00**	0.53	0.58	0.62	0.53	0.62	0.19	0.60	0.47	0.51
	No	0.41	**0.00**	0.22	0.48	0.12	0.16	0.89	**0.00**	0.37	0.45	0.62	0.29	0.53	0.19	0.45	0.34	0.51
VO -> ATT	Yes	-0.26	0.13	-0.34	-0.24	1.00	-0.39	-0.23	1.00	-0.34	-0.17	1.00	-0.40	-0.18	1.00	-0.29	-0.20	1.00
	No	-0.16	1.00	0.11	-0.15	1.00	-0.11	-0.17	1.00	-0.17	-0.09	1.00	-0.16	-0.11	1.00	-0.14	-0.09	1.00
SI -> ATT	Yes	0.65	**0.01**	0.39	0.63	0.07	0.56	0.52	0.17	0.61	0.51	0.77	0.36	0.79	0.07	0.48	0.64	0.58
	No	0.65	**0.01**	0.27	0.85	0.07	0.36	0.77	0.17	0.70	0.60	0.77	0.31	1.14	0.07	0.55	0.70	0.58
ANX -> ATT	Yes	0.36	**0.02**	0.11	0.42	0.99	0.15	0.45	1.00	0.56	0.30	0.33	0.11	0.40	0.29	0.17	0.75	0.07
	No	0.47	**0.04**	0.09	0.70	0.99	0.09	0.69	1.00	0.80	0.35	0.33	0.11	0.54	0.29	0.22	1.00	0.07
PEOU -> ATT	Yes	0.58	**0.00**	0.80	0.68	1.00	0.84	0.63	1.00	0.58	0.63	1.00	0.64	0.68	NA	0.70	0.45	1.00
	No	0.83	**0.00**	0.63	0.99	1.00	1.05	1.02	1.00	0.79	0.78	1.00	1.05	0.80	NA	1.00	0.58	1.00
PU -> ATT	Yes	0.83	**0.00**	0.81	0.84	**0.03**	0.97	0.72	0.48	0.90	0.81	NA	0.99	0.64	1.00	0.82	0.90	0.99
	No	1.45	**0.00**	0.95	1.62	**0.03**	1.70	1.43	0.48	0.85	0.77	NA	0.75	0.71	1.00	1.00	0.88	0.99
ATT-> BI	Yes	0.41	**0.00**	0.62	0.36	0.73	0.48	0.40	0.97	0.78	0.52	0.65	0.86	0.51	0.74	0.43	0.76	0.50
	No	0.44	**0.00**	0.47	0.37	0.73	0.40	0.41	0.97	0.81	0.67	0.65	0.95	0.82	0.74	0.64	0.87	0.50

Abbreviations: SE – Self-Efficacy; PEOU – Perceived ease of use; FC – Facilitating conditions; CO – Compatibility; PU - Perceived usefulness; IM – Image; ATT – Attitudes; VO – Voluntariness; SI – Social influence; ANX – Anxiety; BI – Behavioral intention.

With regards to differences between men and women, type of facility, doctors/nurses, and their experience in burn care, we found that the correlation between usefulness and attitude was stronger for women compared to men. There was also differences between referral and referring hospitals in the constructs Compatibility-Perceived usefulness and Image-Attitude. When testing the modified model by Kifle et al [162], there were significant correlations between Perceived usefulness—Attitude and Compatibility—Perceived usefulness (Figure 8).

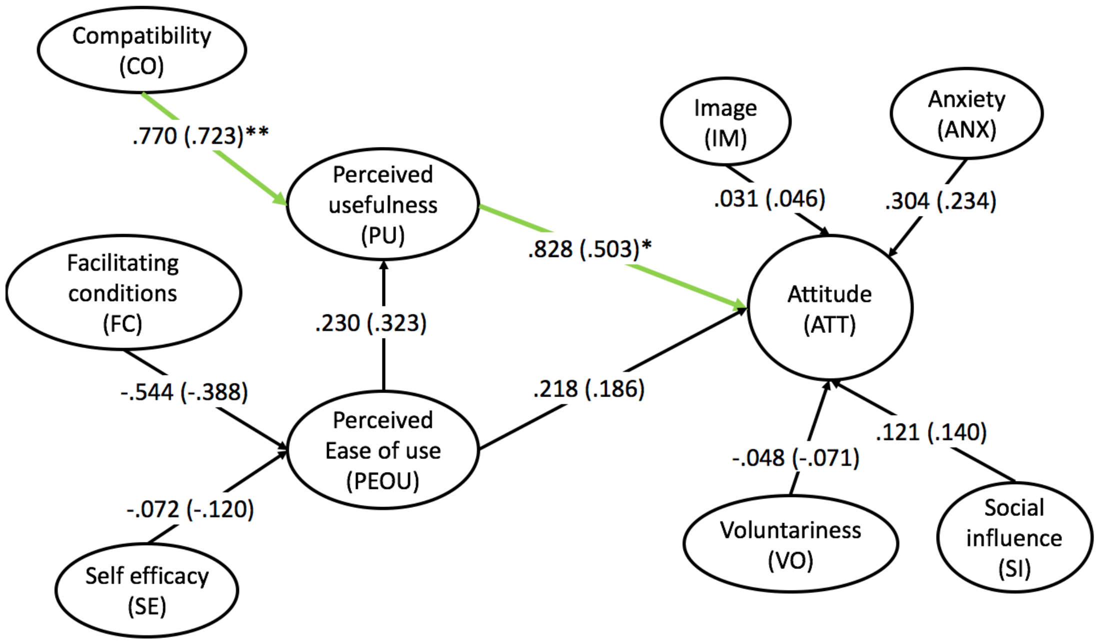


Fig 8: Hypothesis model *Significant at 0.05 ** Significant at 0.01

When asked about giving comments about using the app the participants suggested that wireless internet should be provided, but also smartphones or tablets. It was also raised that taking photos of patients was a concern.

Summary of results (Study IV)

- Most participants owned smartphones and used them for work purposes
- The participants rated high on the core concepts from TAM suggesting they were positive towards using the app
- There was a significant relationship between compatibility and perceived usefulness of the app, and this correlation was stronger for referring hospitals
- The correlation between perceived usefulness and attitudes was stronger for women
- The correlation between image and attitudes were stronger for referring hospitals
- Participants suggested that phones and internet should be provided to facilitate use

DISCUSSION

BEYOND THE REFERRAL CRITERIA

One reason for using smartphones for teleconsultations in burn care is to reduce inappropriate referrals. The first study in this thesis was conducted to assess whether patients with burns are referred according to local burn criteria. The main finding was that many children were not admitted despite meeting the referral criteria. The most common criteria met were “age under two” and “anatomical site”. Many of the children that met these criteria had minor burns and were likely considered not to be in need of in-patient care. While it is impossible to tell whether referral guidelines were consulted at all, it is reasonable to assume that the referring health provider referred these patients thinking they were to be admitted to the burns unit. Burn referral criteria are intended to provide recommendations for clinicians in the process of identifying who will need transfer to a burns centre or not. Several studies have previously indicated that patients are not referred when indicated, or referred to burns centres without meeting any criterion for referral [38–42, 144]. While under-referral can lead to poor outcomes for the patient, over-referral put unnecessary pressure on the burns centres [40].

With a better understanding of burn pathophysiology, burn guidelines have evolved to better identify those in need of specialist burn care [163]. However, burn guidelines also need to take into consideration the context, such as available resources [164]. One reason many patients arrive at burns centres and do not match the referral criteria is that the referring clinician misdiagnosed the burn [44–48]. For example, studies consistently show that non-specialists frequently overestimate burn size, and have difficulties determining the depth of the burn. It is worth mentioning that burn depth are inherently difficult to assess as they evolve during the first 48 to 72 hours [165], and even burns specialist have difficulties making the correct assessment [34].

Considering that most of the children in study I had previously been assessed at a local clinic or emergency room, it raises the question whether these patients could have had their initial treatment at their local clinic instead, and followed up later at the burns clinic if necessary. While even minor burns may benefit from specialist care, this might not always feasible in remote settings or those with a high patient load and constrained resources.

There are also some problems with using burn criteria as the sole guidance for burns referrals. One is that despite being evidence-based, developed and refined by experts, they still cannot fully account for the complexity of all burns, the local context, burden of burns and the available resources at any given time. For example, in many regions of the world [166, 167], including South Africa [168, 169], burn incidence varies with season. Thus, one can assume that during some months, the burden of burns will exceed the number of available beds in the burns unit, some patients will inevitably have to be cared for at other care facilities.

Another issue with burn guidelines is that if the burn is not accurately diagnosed, the true extent of the burn will not correctly match the criteria. While some of the referral criteria are easy to apply if such information is available, such as age-related criteria, co-morbidity or location of the burn. Other criteria such as surface area or depth can be more challenging because it hinges on the ability of the clinician to assess the burn accurately. Furthermore, previous research has also demonstrated that non-specialists are not comfortable in managing burns and therefore rather refer [35]. In light of this, it has been discussed that in order to relieve burns centres, but also save costs and time for patients, there should be outreach programs supported by telemedicine [170].

BARRIERS AND PROMOTORS TO USE SMARTPHONES IN BURN CARE

For the successful implementation of digital health initiatives, WHO concludes that digital health interventions must go beyond the technology itself [171]. This include, organisational processes, structures, roles, standards, legislation and at the same time considering human resources, educational needs, reimbursement and the specific culture of those who will be utilising the services. However, implementation efforts have often only focused on acceptance and individual adoption and failed to recognise the complex system where the technology is to be implemented. In resource-limited settings in particular, successful integration in routine use needs to address issues such as technical and human resources, infrastructure and organisational constraints [97].

The findings from study III suggest that the Vula app had been diffused rather than being disseminated. While diffusion is the informal and decentralised spread of ideas mediated by peers, dissemination is the formal and centralised effort to spread new knowledge, policies, and practices. Greenhalgh refers to the former as "let it happen" and the latter for "make it happen", with "help it happen" in the middle [124]. After interviewing the participants in Study III it soon became clear that there had been very few or no formal activities in order to implement the app. Instead the app was often introduced, used and diffused by the doctors themselves through talking to each other and teaching new user how to use the app. The drawback with such approach is when there is a lack of understanding of the system and its implications on the care process and the various actors involved. For example, several studies have recommended that for successful implementation of electronic consultation and referral systems there is also a need for improved coordination across specialities with mutually agreed referral protocols [172–175].

Both study II and study III revealed that emergency doctors appreciated using the app for consultations and referrals for several reasons. One being that it streamlined the referral process. This included saving time by not having to make traditional phone consultations, but also making the referral more comprehensive and structured because of the referral template, the drawing feature and the images. Streamlining the referral process has been one of the main arguments for using electronic referral systems [174]. Previous research on electronic consultation and referral systems have advocated for the use of templates [173, 174, 176]. The main reason being that critical information will not be omitted [176], but also for making feedback more timely and consistent [173]. However, it has been noted that some referrers find that templates can limit their ability to communicate findings clearly and that the templates are often accused of being designed to cater to the needs of the specialists rather than the referrers [172, 177–179]. In the usability study of the Vula app, some doctors said that some of the options were too limiting and suggested free-text fields under each drop-down list. Furthermore, since the Vula app is used for different specialities with variations in what information each speciality require, it is important to harmonise the language within the app in order not to cause confusion [174]. While there are different needs from both the specialist and the referring doctor, it is essential that in the development process that both parts are involved to increase user-satisfaction [173]. While the content and form of the burns part of the app was informed by input from burns and emergency medicine specialists, the findings from Study III indicated that the referring doctors had not been involved and had rarely been asked for their input. While there is room for improvement in regards to the content and form of the burns template in the Vula app, it was still regarded as a being better in comparison to traditional phone calls or text messages.

One often noted barrier to the effective use of digital interventions in LMIC is the availability of technical resources and infrastructure [96, 180]. This includes access to devices as well as the supporting infrastructure such as internet and electricity. The doctors in both study II and III all had smartphones and used them frequently for work. It was, however, noted in study III that using one's private phone was somewhat met with apprehension. There appeared to be a struggle between on the one hand having access to a service that made both their work easier and was beneficial to the patients, and on the other hand, having to use their own devices and pay for their data. In the Tanzanian context, access to technical resources is even more challenging as the participants in study IV eluded to. Similar concerns have also been raised in other studies from African countries [181–183]. Implementers, policymakers and hospital managers must be aware of this issue when introducing smartphone-based interventions. Here, public-private partnerships (PPPs) could offer means for achieving access and scale through leveraging different skills, resources and capabilities. For example, in South Africa, Vodacom, one of the mobile network operators, is offering their subscribers free access to ‘MAMA South Africa’, a service to support mothers enrolled in prevention of mother-to- child transmission of HIV programs [184]. WHO also recommends that implementers negotiate options for subsidising communication with mobile network operators and other partners [185].

Usability issues are one often cited barrier to successful integration of digital health interventions [186]. Usability testing has several purposes, such as observing how end-user interacts with the system, to test user-friendliness or to assess whether user needs are met [187]. While usability testing should be performed in the early development phase of new technologies, some issues may only appear after it is implemented. Study II revealed some usability problems and the findings from study III indicated that there had been very little user involvement to address these problems. The most number of issues were encountered in the drawing part, which is also the key feature for burns referrals. While these issues were easy to recover from in most cases, it becomes problematic if such a feature is difficult to use in a real situation. In the case of technologies that might be used infrequently due to the sporadic presentation of certain patients, it is important that these technologies can be used with no or minimal previous experience. Additionally, many of the users of the burns part of the Vula app may only use the app for a limited time due to being on a short term rotation within emergency medicine. Furthermore, in the acute setting where time is critical, apps must be easy to use and intuitive for first-time users. For example, such apps should be designed to use the same gestures, icons and terminology as other commonly used apps, and contain sufficient information on how to use it.

While one reason for using apps such a Vula is to decrease the number of patients with burns that are inappropriately transferred, another is to support frontline providers to diagnose and manage burns. In general, doctors have limited training and experience in burn care [188], and in study II-IV, the participants were young and had relatively little experience working as health providers. In terms of receiving management and referral advice, this has some implications. First, it is important that the advice is timely, understandable, but most importantly, actionable. Since the findings from study I, and similar studies suggest that many patients does not need in-patient care, apps such as Vula could support health providers when managing patients locally. However, at the same time, it's important to strengthen these facilities to ensure access to material and human resources with adequate training [189].

Secondly, the participants in study III said that the app offered a valuable learning opportunity. At the same time, some said that this was an under-utilised resource, and wanted more feedback on their referrals in order to enhance learning. Archibald et al. concluded that questions from electronic consultations can be collected to identify gaps in physician knowledge and skills [190]. However, in order to fully attain the educational benefits, it is important with specialist engagement, and that other stakeholders such as information technologists and policy makers work together to ensure that the platform and workflow support learning and knowledge sharing [191]. In the South African context, Blom et al. found that burns specialists saw education as an important part of their work, and that the Vula App would aid the experts when educating frontline clinicians [192].

In the Tanzanian context with less developed burn care, but also in remote areas where the distance to a burns centre is a barrier, patients may have to be cared for locally. In study IV, it was clear that the participants where positive towards using the Vula app. However, as they themselves mentioned, that would require assistance with the devices and access to internet. Another problem in Tanzania is the limited access to burn care [193], and patients with burns are often managed at facilities with limited resources. If the Vula app or similar systems would be available, there is also a need to strengthen the health facilities with both material resources and education [152, 194]. Finally, since burns specialists in Tanzania are scarce, successful implementation of the Vula app hinges on the availability and motivation of the few number of specialists that does exist.

METHODOLOGICAL CONSIDERATIONS

Patient records as a data source

Study I was limited by the inherent problems of any retrospective study, namely, incomplete data, but also difficulties in interpreting handwritten notes. Data on burn size, depth and co-morbidity were often missing. The patients who had missing information on variables related to the referral criteria were assumed in the analysis not to fulfil the criteria. In regards to missing data, there is no reason to expect any systematic differences. However, considering the fact that information on TBSA and depth was often missing, the result most likely underestimated the amount of patients that fulfilled the criteria. Finally, since the referral criteria were retrospectively applied to the clinical and the demographic data, it is impossible to know whether the criteria was used at all.

Sampling and sample size (Study II-IV)

In study II, III and IV, participants were enrolled using convenience sampling which could have resulted in sampling bias, and creating issues of transferability of the results. For study II and IV where the sampling took place at the study sites during work hours, almost everyone who was present and available agreed to participate. Study II had a sufficient sample size (24 participants) for think-aloud methodology where 5-9 users are deemed sufficient [195]. For study III the sample size was judged to be sufficient based on the recommendations by Malterud on information power [196]. Additionally, in study III, the 15 participants came from a sample of 40 doctors who fit the inclusion criteria (used the app more than three times). However, it is difficult to know how well this final study sample represented the sample from where they were drawn, since there were little data on characteristics of the doctors in the initial sample. However, the doctors who chose to participate represented the sample from where they were selected, in terms of men to women ratio and type of health facility where they worked. What is not known however, is whether these doctors differed in their experiences using the Vula app. For example, doctors with a more (or less) favourable experience may have been more inclined to participate. In terms of age, the sample do mirror that of health providers working in emergency care in the study settings. The young age of the majority of the doctors in studies II-IV also introduces some problems of transferability to other settings, especially in regards to technology use and acceptance. There is however inconclusive evidence on age as a predictor of use and acceptance of health information technology [197–199]. Nevertheless, in terms of age, the sample do mirror that of health providers working in emergency care in the study settings. Also, since all these studies were conducted in urban settings the results might not be fully transferable to rural settings.

For study IV the small sample size introduced some issues in the analysis where convergence was not achieved, hence the results must be interpreted in light of this. Furthermore, the small sample size and the fact that the studies were conducted in an urban area, these findings may not be generalisable beyond the study setting. In Study IV the questionnaire was in English, and while everyone spoke English it was not their first language. However, participants where encourage to ask if they did not understand any parts of the questions.

Qualitative data

A problem with the usability study is that since it was a specific app that was tested, these results are mainly applicable to the usability of the app itself. Nonetheless, the results reveal some important aspects of what doctors perceive to be important in terms of content and functionality of such an app. During the first twelve users test, the participants did not always "think aloud" and therefore, during the subsequent twelve tests, a second session was added where the interviewer asked question about the user interface. In study III a qualitative approach was suitable since the aim was to study the doctors experiences, especially with regards to interaction and activity [200]. The main strength of this study is that we have used a robust analytical framework in order to analyse perspectives on a mobile-based consultation and referral system in a resource-limited setting. Additionally, in order not to be constrained by the theoretical framework, we conducted an inductive analysis, both to better understand the links between the constructs, but also to uncover aspects that could not be identified through NPT. Reflexivity was considered throughout the process of design, data collection and analysis [200]. For example, a field journal was kept during data collection and analysis, and transcripts were read and re-read throughout the analysis stage to ensure that interpretation and formation of themes were grounded in the data. Furthermore, interpretations were continuously discussed in the research team to aid this process. A strength is also that the members of the research team are from different backgrounds.

IMPLICATIONS FOR RESEARCH AND PRACTICE

- Future research should investigate whether the use of the Vula app has an actual effect on over and under referral.
- Studies also need to investigate whether patients that are treated locally supported by mobile teleconsultation receive sufficient care and more importantly, the effect on recovery and long term consequences of burns.
- Study I indicated that a large number of patients that are transferred to the tertiary hospital but upon arrival were not deemed severe enough to require in-hospital care. This further indicate the need for supporting local hospitals through teleconsultations but also training and resources to manage minor burns.
- Front line health providers find the mobile teleconsultations to be a valuable tool for diagnostic and management advice. However, for successful integration, there needs to be adequate support in terms of resources and incentives. Examples include providing free internet access at hospitals.
- The confusion regarding processes that was highlighted in Study III indicate that there is need for improved co-ordination and collaboration between referring and receiving facilities.

CONCLUSIONS

Due to the challenges in assessing burns, identifying who is in need of a referral is not always straightforward. In Cape Town, most children are referred to the burns unit according to local burns criteria, although upon arrival, many burns are still not regarded severe enough to require in-patient care. Using mobile teleconsultations in burn care is, therefore, a way of assisting with diagnosis and initial management. Front line health workers perceived the Vula app to be easy to use and useful, but the results from study II also highlighted the importance of conducting user tests in the field with real users in order to identify usability problems. Additionally, apps specifically for burn injury consultations and referrals, may only be used sporadically and therefore it's even more important that such apps are easy to use. Study III further highlighted why the app was perceived to be useful; it streamlines the referral process, improves the quality of the referrals and is a valuable resource for learning. However, to support further integration of the app, some barriers need to be addressed. Clear information and improved coordination between primary and speciality care in regards to the use of the Vula app in practice. Supporting users with internet and incentives to use their personal devices, as well as ongoing evaluation and feedback will also be important to ensure successful integration. While Tanzanian health providers are positive to use an app like Vula, in such setting with considerably fewer resources, these barriers will likely be even more important to address prior to implementation.

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APPENDIX 1 – INJURY DATA COLLECTION FORM (STUDY 1)

Burn Unit or Trauma	Select if this patient records is based on burn unit registers or trauma registers. A patient could be admitted first to Trauma and then found in the burn unit, in that case it is filled in as a burn unit patient.
Case Number in project	Write your initials and then start counting from 001 e.g. John Doe = DO001
Hospital record number	Indicate numeric hospital record number Verify number is not already entered in the database.
Sex	▪ Male ▪ Female ▪ Unknown
Date of Birth	Write the date of birth in the format YYYY-MM-DD
Age	Age will be calculated automatically based on the date of birth and date of injury, but double check it if stated in the records. If Date of Birth or Date of injury is missing, but information on age is found in the records, add the age in “ADDITIONAL INFORMATION”.
Date of hospital attendance	YYYY-MM-DD The year has to be written with four numbers. If there is no info regarding this, leave blank and comment in “ADDITIONAL INFORMATION”.
Time period of attendance	Select in which time period the patient arrived at the hospital. If there is no info regarding this, select “unknown”.
Date of injury	YYYY-MM-DD The year has to be written with four numbers. If there is no info regarding this, leave blank and write the information that is there for example “morning” “afternoon”, “two hours ago” “a few days ago” etc, in “ADDITIONAL INFORMATION”.
Time of injury	HH:MM Write the time in 24-hour clock. If there is no info regarding this, leave blank and write the information that is there for example “morning” “afternoon”, “two hours ago” “a few days ago” etc, in “ADDITIONAL INFORMATION”.
Mechanism of burn	▪ Fire/flame ▪ Hot object ▪ Hot liquid ▪ Steam

	▪ Chemical ▪ Electrical ▪ Steam ▪ High pressure steam ▪ High voltage electrical (>1000V) ▪ Hydrofluoric acid injury ▪ Other (specify) ▪ Unknown Hot liquid includes hot food, fats and cooking oils. Try and fill in as precisely as possible, but if in any doubt, select Other (specify) and specify. You can also select for example “Hot liquid” and write down in “others” what is specified in the file, such as “coffee”
Intent	▪ Unintentional ▪ Intentional (assault) ▪ Intentional (self-harm) ▪ Other (specify) ▪ Unknown If any doubt, select Other (specify) and specify in OTHINTENT. If no information about the circumstances, select unknown. Intentional can only be selected when it’s written in the medical records that this is suspected. It’s important not to lose information at this stage as this is used for criteria definition.
Other intent	If there is no other relevant info, leave blank.
Circumstances	Write down any potential information found on the activity or place of injury if found in the records. If no information was found, leave blank.
Other (non-burn) injuries	If other non-burn injuries that occurred simultaneously to the burn are present, write them here with as many details as possible, they will be used for defining some of the criterias so this is key. If there are no other injuries write “none”
Abbreviated Injury Scale	▪ List numerical rating from 1-4 Refer to AIS Scale found on the trauma unit sheet. Complete only if information exists on the trauma sheet records. If the information is not found do not try and guess.
Treatment	▪ Dressings ▪ IV fluid ▪ Antibiotics ▪ Analgesia ▪ Other (specify) ▪ Nutritional supplementation ▪ Surgery/escharotomy

	▪ Graft/transplant ▪ Unknown Mark all treatments that apply. The patient should have received: within the first few hours for “dressings”, “IV fluids”, “antibiotics” or “analgesia”, and within the first few days for “nutritional supplementation”, “surgery” or “graft”. If in any doubt or not listed, select Other (specify) and specify. You can start filling up with trauma sheet data, and then complete with any information found in the burn unit records.
Disposition at Trauma Unit	▪ Treated and discharged ▪ Admitted to ICU ▪ Admitted to burn unit ▪ Transferred to other hospital ▪ Died ▪ Other (specify) ▪ Unknown If patient disposition is not listed, select Other (specify) and specify.

Body part(s) injured	▪ Head (excluding face)
	    o Face
	▪ Neck
	▪ Upper extremities (excluding hands)
	    o Hand(s)
	▪ Trunk/back (including butt)
	▪ Trunk/chest
	    o Perineum
	▪ Lower extremities (excluding feet)
	    o Feet
	▪ Genitalia
	▪ Indicate if the burn was circumferential, septic or includes major joints
	
	Mark all that apply based on records and on the sketch. Also write if the burn is circumferential, septic, or includes major joints.
	
	▪ If any comments write any useful information in “ADDITIONAL INFORMATION”.

Inhalation injury	▪ Inhalation injury ▪ Suspected inhalation injury ▪ Inhalation injury requiring intubation for more than 48hours. Verify whether there is possible inhalation: if written in records select “inhalation”. If the records mention a fire or

	scald burn in a closed environment with intubation, then write it down in "INHALATION COMMENT" and select "suspected inhalation injury". If records mention intubation within the first 24hours due to inhalation, and that intubation remains for more than 48hours select "inhalation injury requiring intubation for more than 48 hours".
Body Surface Burned (as mentioned in the trauma sheet)	Only if information exists in the trauma sheet records, otherwise leave blank. Do not try to guess based on a picture or description. If there is no info regarding this, write "no info". If there is any other useful information, add it in "ADDITIONAL INFORMATION".
TBSACategories	Select in which category the burn size resides based on the trauma unit information.
Burn depth (as mentioned in the trauma sheet)	▪ Partial ▪ Full ▪ Indeterminate ▪ No information Only if information exists in the trauma unit records, otherwise leave blank. Do not try to guess based on a picture or description, for example do not guess "Second degree" burns as partial and "third degree" as full. If there is any other useful information add it in "ADDITIONAL INFORMATION".
Body Surface Burned (as mentioned in burn unit records)	Only if information exists in the burn unit records, otherwise leave blank. Do not try to guess based on a picture or description. If there is no info regarding this, write "no info". If there is any other useful information, add it in "ADDITIONAL INFORMATION".
TBSACategories	Select in which category the burn size resides based on the burn unit records information.
Burn depth (as mentioned on the burn unit records)	▪ Partial ▪ Full ▪ Indeterminate ▪ No information Only if information exists in the burn unit records, otherwise leave blank. Do not try to guess based on a picture or description, for example do not guess "Second degree" burns as partial and "third degree" as full. If there is any other useful information add it in "ADDITIONAL INFORMATION".
Burn Unit comments	Write down any comments concerning the burn diagnosis that would be found in the burn unit record to help with understanding discrepancies that could be found between trauma diagnosis and burn unit diagnosis.

Pre-existing health illness	▪ HIV/AIDS ▪ TB ▪ Diabetes ▪ Epilepsy ▪ Depression ▪ Cancer ▪ Other (specify) ▪ None Mark all that apply. If there is additional co-morbidity, please select other and specify.
Drug therapy	▪ Steroids ▪ Other immune-suppressing medications (specify) ▪ Other (specify) ▪ Immunization (specify) ▪ None ▪ No information Mark all that apply. Write all information you find about the drugs that the patient was taking when arriving to the hospital. This is medication that the patient was taking prior to their injury, not the medication they were given in connection to the injury. If any information on immunization status, select only if up to date, if not specify it.
Allergy	▪ Known allergy ▪ Drug allergy/sensitivity (specify name) ▪ Other (specify) ▪ None ▪ No information Mark all that apply. Specify any allergies that are specified in the records.
Transport to Red Cross	▪ Self/Private ▪ Police ▪ EMS ▪ Taxi ▪ Other (specify) If patient was transported by other means, select Other (specify) and specify. If there is an EMS sheet found in the folder, select "EMS" and then add in "other" if EMS was used for inter-hospital transfer, for example "from Groote Schuur".
Disposition at Burn Unit	▪ Treated and discharged ▪ Admitted to ICU ▪ Admitted ▪ Transferred to other hospital ▪ Died

	▪ Other (specify) ▪ Unknown If patient disposition is not listed, select Other (specify) and specify.
Length of hospital stay	▪ No overnight ▪ Overnight – 3 days ▪ 4 days – 7 days ▪ Longer than 7 days Select appropriate if found in records.
Referral criteria	Both for the old guidelines and new guidelines. Selection is made automatically based on data entry. However, double check whether all results are correct. If it is not, write in the comment box “met” or “unmet” what you think is the appropriate answer. And then write in “ADDITIONAL INFORMATION” why you think the referral criteria should be overruled.

APPENDIX 2 –THINK-ALOUD PROTOCOL (STUDY 2)

Introduction to the study

1. This is a usability test of the Vula app for burns
2. This session will be divided into three parts.
3. First you will be given a scenario where you will use the app as you would in a real scenario. I will be acting as a patient and you will use the app to document the burns I have.
4. After that, I will let you use the app again and fill in the information as you would like in a real situation, but this time I'd like you to "think aloud" while you are doing it. With "thinking-aloud" I mean that you will say what you think, feel and do while performing the task.
5. Lastly, I will ask you about your experiences using the app and for other comments or suggestions.
6. Remember, we are not testing your abilities to use the app, but to identify usability problems of the app.
7. Here is the written information about the study and the consent form. Please take some time to read it through, and please ask i you have some additional questions before we start.

Session 1. - Scenario

The interviewer will act as a patient and the test subject will use the app as they would in a real situation. The test subject will be asked to use the app and ask the patient (Interviewer) for the information required. The patient will have fake burns drawn on the body indicating burn depth. During this first scenario the interviewee does not have to "think-aloud".

Session 2. Exploration - do the same thing again

- The interviewee is asked to go through the procedure once again but this time are allowed to "explore" the app. To do the same procedure as during the test scenario. This time they will be encourage to think-aloud while using the app.

Promoting questions

- What are you thinking now?
- Keep talking
- Can you describe what are you seeing now?

Observation

- In what order do the user fill out the information? from top to bottom or do they go back and forth?
- Do they struggle with filling out any of the fields?
- Do they express any frustration or other feelings ?

APPENDIX 3 – HEALTH INFORMATION TECHNOLOGY USABILITY EVALUATION SCALE (HEALTH-ITUES) (STUDY 2)

mHealth in burn care questionnaire

Thank you for taking some time to complete this questionnaire concerning the use of smartphones for burn diagnosis and management. We are interested in your experience using the app for burn injury management. The questionnaire is fully anonymous and will take about 10 minutes to complete.

Please estimate the number of (unique) occasions you have used the app on a patient?	I have ***never*** used the app	☐
	I have used the app ***5 times or more***	☐
	I have used the app ***less than 5 times***	☐

Please indicate on a scale from (1) "strongly disagree" to (5) "strongly agree" how much you agree to each of the following statements. If you are not able to answer a question, please indicate (not applicable).

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree	Not applicable
	(1)	(2)	(3)	(4)	(5)	
I think the app has improved the emergency staff's ability to care for burns	○	○	○	○	○	○
I think the app has been a positive addition to burn care at the hospital	○	○	○	○	○	○
The app is an important part in the acute management of burns	○	○	○	○	○	○
Using the app makes it easier to receive expert advice on management of burns	○	○	○	○	○	○
Using the app enables me to receive burn management advice more quickly	○	○	○	○	○	○
Using the app makes it more likely that I have sufficient knowledge on how to manage acute burns	○	○	○	○	○	○
Using the app is useful for receiving information about burn management	○	○	○	○	○	○
I think that the app presents a more equitable process for burn management	○	○	○	○	○	○

	Strongly disagree	Somewh at disagree	Neutral	Somewhat agree	Strongl y agree	Not applicable
I am satisfied with the app for receiving information on burn management	○	○	○	○	○	○
I can receive information on burn management in a timely manner because of the app	○	○	○	○	○	○
Using the app increases receiving information about burn management	○	○	○	○	○	○
I am able to receive advice on burn management whenever I use the app	○	○	○	○	○	○
I am comfortable with my ability to use the app	○	○	○	○	○	○
Learning to operate the app is easy for me	○	○	○	○	○	○
It is easy for me to become skillful at using the app	○	○	○	○	○	○
I find the app easy to use	○	○	○	○	○	○
I can always remember how to log on and use the app	○	○	○	○	○	○
The app gives me error messages that clearly tell me how to fix problems	○	○	○	○	○	○
Whenever I make a mistake using the app, I recover easily and quickly	○	○	○	○	○	○
The information (such as on-screen messages and other documentation) provided with the app is clear.	○	○	○	○	○	○

Please add any other comments you have about the app

A. What is your profession? I am a nurse ☐ I am a physician ☐

B. Highest level of training completed________________________________

☐ ☐ ☐

C. **Current occupation: Specialist Physician Nurse**

other___________

D. **Years of experience in emergency care ___________**

E. **How would you rate your experience with burn care?**

Extensive ☐ **Moderate** ☐ **Minimal** ☐ **None** ☐

F. **Do you use a smartphone for private use? Yes** ☐ **No** ☐

G. **Do you have any experience using smartphones for work purposes? Yes** ☐ **No** ☐

H. **If yes, for what**

purpose(s)____

I. **Age ____________**

J. **Gender: Male** ☐ **Female** ☐

Thank you for your time, your views will be of great value for the further development of the app.

APPENDIX 4 – INTERVIEW GUIDE (STUDY 3)

At the beginning of all interviews:

- Introduce yourself
    - My name is Anders and I am a PhD student from Sweden doing research on the use of the Vula app specifically for burn injuries. My background is in Public Health and I have been involved in research on burns here in South Africa for the last five years.
- Introduce study
    - In this study I am interested in the users experiences with the app specifically for burn injuries. The focus will be on your experiences with the app and what you think about using an app like this for burn care
    - The interview will take about 40 min to an hour.
- About audio recording/anonymity/confidentiality
    - I will be recording the interview if that is ok with you. The recordings will only be used to transcribe the interview, which I will do myself, and your name will not be captured in these transcripts

- Explain how data will be used
    - Any information I do capture such as your age or gender will only be presented on an aggregated level. And none of this information will be presented together in connection to anything you have said such as quotations.
- Obtain Consent

And before we start, I would also like to say that I have no professional relationship to the company behind the Vula app. And there are also no right or wrong answers.

First can you tell me a little about your current work situation.

- Where you work
- What department
- For how long you have worked there

  So, let's talk about burn care.
  Can you tell me about what happens from the point a patient with a burn comes in through

  the doors to the point when they are treated and discharged or referred?

- Who are usually involved?

--- Ok, now I would like to focus on your experience with the Vula App for burns ---

So first, could you take me through how a typical consultation with a burns patient could look like using the app?

- \- Do you always use the app when you see a burns patient, and if not what are the reasons for not using it?
- \- How long do you usually have to wait for the reply?

  - What do think about that?

  In what ways would you say using the app is different from other ways of consulting with specialists?

- the way you used to work before the app, in what ways would you say the app has changed the consultation?

  - What has become easier?
  - What has become more difficult?
  - How has it changed the speed of the consultation?
  - How do you experience the integration of the app in your work?

- When working with burns patients. Do you think that your role as doctor has changed after starting using the Vula app?

What training or information did you receive about the app? Was this sufficient to make you feel comfortable using the app?

- Of those involved in treating the patient in burn care, which profession do you think should be using the Vula app?

- \- What do you think about the specialists ability to make the assessment of the burn and to support you when managing patients with burns?

  - Do you usually agree with their assessment?

  - Are you usually satisfied with their decision to refer or not.

- \- How do you feel about carrying out the management based on the advice you

  receive?

  - Do you feel that you and the hospital have the resources to comply with the

  decision?

  From a wider perspective, why do you think the burns part of the Vula app was introduced?

- \- So for burns specifically, what would you say is the purpose of using the Vula app? (Aim and benefits)
- \- Would you say that your colleagues share this view?
- \- Let’s say a new doctor starts working here today – how are they introduced to the

  Vula app?

Can you describe the interest in using the app for burns amongst the people involved in burn care?

- - Who do you think if any, has been the strongest proponent of using the app?
- - Has there been any resistance towards using the app?

    - Why do you think others are not using the app frequently

    Do you feel there is support from the hospital management and colleagues to use the app? Such as information and help if there are any problems

- - What does the support from hospital and colleagues look like?
- - Do you think that you have the technical resources to use the app

If there are any issues with the app or the way you use the app, how do you solve these or who to turn to? And here I don't just mean technical issues, but also issues with the way that the whole systems works?

Depending on the result of the consultation (whether the patient needs to be treated or referred) do you feel that you and the hospital have the resources to comply with the answer?

- Have you received any feedback of the use of the app from others such as colleagues, the hospital management, burns specialsists or the company behind Vula?
- In what way do you think using the Vula app has benefited the patient? - Who do you think the app has benefitted the most?
- Ok, so now we are approaching the end of the interview. So now if you think of your experience with the app and what we have discussed, could you list a few positive aspects of using the app and a few negative aspects.
- And do you have any recommendations for improving the app or the way the app is used?
- Finally, is there anything else that you have thought of that we haven't covered during the interview?

Now I just have some background questions

- Age
- Years as doctor?
- Years at current work place
- Male/female

APPENDIX 5 – INTENTION TO USE QUESTIONNAIRE (STUDY 4)

Please complete the following anonymous information about yourself (tick the appropriate answer where required). This information is for background purposes only. Please complete the survey, even if you have no previous experience with smartphones (a phone with computer-like capabilities).

1. Age....................................... 2. Sex ....

3. Highest level of training/education completed ....

4. Current occupation:

☐ SPECIALIST (Specify level)………………………

☐ PHYSICIAN (Specify level)………………………

☐ NURSE (Specify level)………………………

Other, please specify ....

5. Years of experience in emergency care at current facility ……………. 6. in total ....

7. How would you describe your experience with burn care?
☐ EXTENSIVE ☐ MODERATE ☐ MINIMAL ☐ NONE

8. Do you use a mobile phone for private use? If no, go directly to the next page. ☐ YES ☐ NO

9. If yes, do you use a smartphone? ☐ YES ☐ NO

10. Do you have any experience of using smartphones for work purposes? ☐ YES ☐ NO

11. If yes, for what purpose(s) e.g. medical apps, communication or looking up information on the internet? ....

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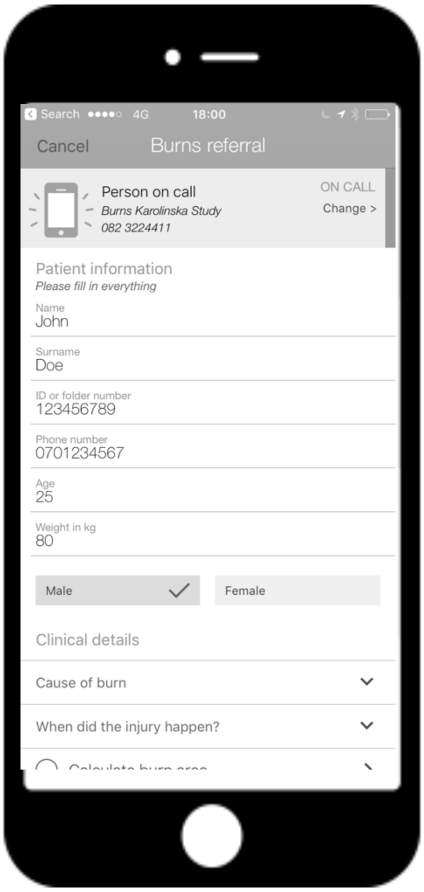
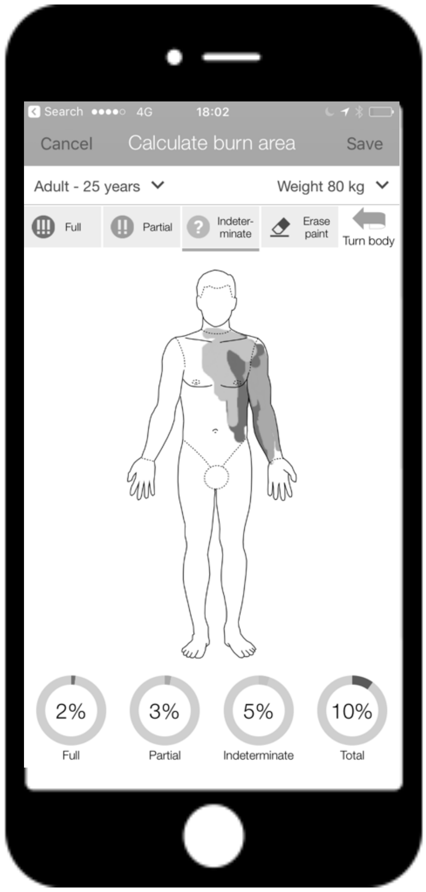
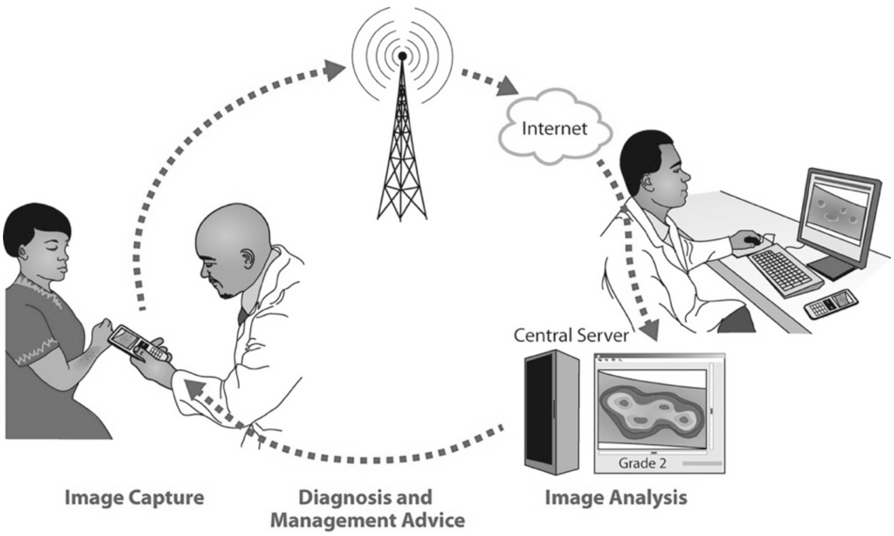
For this section, we would like you to imagine an mHealth system like the one illustrated on this page (yet to be implemented). It would allow you as a health care provider to use a smartphone app to capture information about a patient's burn injury, both text and images of the burn. The images, along with information about the injury, will be sent to a burns specialist who will review the information, and provide appropriate diagnostic and treatment information back to you as soon as possible.







For each statement below, please place an "X" in the box that best represents your view	**Completely disagree (1) – completely agree (7)** Completely disagree **1**	**2**	**2**	Neither disagree nor agree **4**	**5**	**6**	Completely agree **7**
Learning to operate a smartphone would be easy for me							
Learning to operate an app like this would be easy for me							
It would be easy for me to become skilful at using such an app							
My interaction with an app like this would be clear and understandable							
Using an app like this could improve the care I give to my patients							
If I were to use the app I could see more patients in the emergency room							
Using an app like this would increase my efficiency							
This app would be an improvement in the area where I see most of my patients (e.g., Emergency room)							
I would find an app of that kind useful in my job							
Using such an app would enable me to accomplish some tasks more quickly							
Using an app like this would be compatible with most aspects of my work							
Using an app like this would fit well with the way I like to work							
I think that using an app like this would fit well with the way I like to work							
If I were to use such an app I would gain more prestige among my peers							
Using such an app would be a status symbol in my department							
People in my organization who would use an app of that kind would have more prestige than those who do not							
I could use this app . . .							
…If I had used similar apps before							
…Even if I had never used an app like it before							
…If I only had the built-in "help" function for assistance							
…Even if there was no one around to tell me what to do as I go							

For each statement below, please place an "X" in the box that best represents your view	**Completely disagree (1) – completely agree (7)**						
	Completely disagree			**Neither disagree nor agree**			**Completely agree**
	1	**2**	**2**	**4**	**5**	**6**	**7**
…If I had seen someone else using it before							
…If someone showed me how to use the app beforehand							
…if I had a lot of time to use the application							
The department head does not require me to use apps like this							
Although it might be helpful, using an app like this, it is certainly not compulsory in my job							
I intend to use an app like this when it becomes available							
Over the ensuring months (if possible) I plan on experimenting with the app							
Over the ensuring months (if possible) I plan to regularly use such an app							
I am concerned about possible liability issues associated with the use of this app							
I do not like the loss of personal contact associated with using apps like this							
More research is needed on the effectiveness of apps like this before I would refer patients using the app							
If additional credentialing and licensure procedures were required that would discourage me from using apps like this							
I do not think an expert can adequately make an assessment of the patient when not being physically present							
I feel apprehensive about using an app like this							
It scares me to think that I could lose a lot of information using such an app by hitting the wrong button							
I hesitate to use such an app for fear of making mistakes I cannot correct							
People who influence my behavior may think that I should use an app like this							
People who are important to me at work may think that I should use an app like this							
The senior management of this facility will be helpful in the use of such an app							
In general, the facility management will be supportive of the use of an app of this kind							

For each statement below, please place an "X" in the box that best represents your view	Completely disagree (1) – completely agree (7) Completely disagree 1	 2	 2	 Neither disagree nor agree 4	 5	 6	 Completely agree 7
In general, the district health services management will be supportive of the use of such an app							
I have the resources necessary to use such an app							
I have the knowledge necessary to use an app like this							
An app like this is not compatible with the way we work							
A specific person (or group) should be available for assistance with difficulties concerning an app like this							
Using an app like this for burn emergency care is a good idea							
Using an app like this where I work is a good idea							
An app like this would make work more interesting							
Working with such an app would be fun							
I would like working with such an app							

Do you have any additional comments or suggestions?..

....

....

....

Please help us with suggestions of what you would consider important when implementing such a system. Is there anything in particular that
we should think about? ....

....