

Aus der Medizinischen Klinik und Poliklinik III (MKIII)
Klinik für Prävention und Versorgung des Diabetes

Direktor: Herr Prof. Dr. Stefan R. Bornstein

**Development of the First Diabetes Self-Management Smartphone Application (Kir'App)
For
Rwandan Diabetics**

DISSERTATIONSSCHRIFT

zur Erlangung des akademischen Grades

Doctor of Philosophy (Ph.D)

vorgelegt

der Medizinischen Fakultät Carl Gustav Carus

der Technischen Universität Dresden

von

Claudine Balahali Kabeza

Aus Kigali, Ruanda

Dresden 2021

1. **Gutachter:** Herr Prof. Dr. med. habil. Peter Schwarz
2. **Gutachter:** Frau Prof. Dr. Sophie Baumann
3. **Gutachter:** Frau Prof. Dr. med. habil. Ulrike Rothe

Tag der mündlichen Prüfung: 30.06.2021

Herr Prof. Dr. rer nat. habil. Henning Morawietz

Vorsitzender der Promotionskommission



Kir'App logo

Papers

Paper A: Kabeza, C.B., Harst, L., Schwarz, P.E.H., Timpel, P. (2019). Assessment of Rwandan diabetic patients' needs and expectations to develop their first diabetes self-management smartphone application (Kir'App). *Therapeutic Advances in Endocrinology*, 10, 2042018819845318. <https://doi.org/10.1177/2042018819845318>

Paper B: Kabeza, C.B., Harst, L., Schwarz, P.E.H., Timpel, P. (2020). A qualitative study of users' experiences after 3 months: the first Rwandan diabetes self-management Smartphone application "Kir'App." *Therapeutic Advances in Endocrinology*, 11, 2042018820914510. <https://doi.org/10.1177/2042018820914510>.

Contents

List of figures	7
List of abbreviations	8
1. Introduction	9
1.1. Background of the Study	9
1.2. Problem Statement	12
1.3. Study Aim	12
1.4. Research Objectives	13
1.5. Research and theoretical approaches used	14
1.6. Structure of the thesis	19
2. Publication 1: The Assessment of the Rwandan diabetics' needs and expectations to develop their first diabetes self-management Smartphone Application (Kir'App)	20
3. Kir'App, the first Rwandan diabetes self-management smartphone application	43
3.1. Kir'App description and development process	43
3.2. Functionalities (pages) of Kir'App	44
3.3. Some of Kir'App features in screenshots	46
4. Publication 2: A qualitative study of users' experiences after 3 months: the first Rwandan diabetes self-management Smartphone application "Kir'App"	50
5. Discussion	63
6. Conclusion and recommendations	68
6.1. Research objectives achievement	68
6.2. Limitations of the research project	69
6.3. Contribution to research fields and implication for practice of Kir'App	71
6.4. Recommendations	72
7. Summary	73
7.1. English version	73
7.2. German version	75
Bibliography	77
APPENDIXES	83
A. Appendix of study 1: Assessment of the Rwandan diabetics' needs and expectations to develop the first diabetes self-management smartphone application (Kir'App)	
A.1. Interview guide	84
A.2. Summary of recurrent themes and sub-categories with examples	86

B. Appendix of study 2: A qualitative study of users' experiences after 3 months: the first Rwandan diabetes self-management Smartphone application "Kir'App"	102
B.1. Comparison of themes.....	102
C. Autobiographic reflection.....	121
D. Acknowledgement.....	122
E. Dedication.....	122
F. Impact factor of journal with InCites Journal Citation Reports.....	123
Anlage 1 : Erklärungen zur Eröffnung des Promotionsverfahrens	124
Anlage 2: Einhaltung der gesetzlichen Vorgaben im Rahmen meiner Dissertation.....	125
Anlage 3: Ethical clearance to conduct the research project in Rwanda.....	126

List of figures

Figure 1: Kir'App development process through the user-centered design (UCD) concept15

Figure 2: Process of Kir'App utilization through the Health Access Process Approach (HAPA) model.....17

List of abbreviations

AADE	American Association of Diabetes Educators
AADE7™	Seven diabetes self-care behaviors by AADE
eHealth	Electronic health
GDP	Gross Domestic Product
HAPA	Health action process approach
Kir'App	Kira application
MARS	Mobile App Rating Scale
mHealth	Mobile health
Smartphone apps	Smartphone applications
UCD	User-centered design
USD	United Stated Dollar
US FDA	United States Food and Drug Administration

1. Introduction

1.1. Background of the Study

Global context

The last decades have seen a rapid growth in diabetes prevalence globally. In 2019, about 463 million adults aged between 20 - 79 years old were living with diabetes and 79% among them were living in low- and middle-income countries (International Diabetes Federation, 2019). In the same year, diabetes expenses took over \$760 billion USD, which was equal to 10% percent of the global health expenditure. Moreover it was estimated that 374 million people had a high risk of developing type 2 diabetes (International Diabetes Federation, 2019).

Like in any other chronic disease, self-management is one of the keys for a successful plan for diabetes care. Diabetic patients as the first stakeholders of their disease management report various challenges, including some related to lifestyle modification such as acceptance of a new diet plan, treatment adherence and regular exercising (Pokhrel et al., 2019; Whitemore et al., 2019).

The most commendable approach to address diabetic patients' health challenges when it comes to self-management was found to be patient empowerment. Whilst in the traditional health care setting, the medical staff are the providers of all the care needed by the patients; patient empowerment assigns that responsibility to patients and allows them to make decisions about their health care, which leads to behavior changes and improvement to the quality of life (Tol et al., 2015; Wong-Rieger and Rieger, 2013).

Recent studies have shown that mobile health (mHealth) technologies through virtual interactions with health care staff, self- and tele-monitoring contribute much in diabetics' empowerment and deal with almost all of their health challenges (Alcántara-Aragón, 2019; Krošel et al., 2016; Mallow et al., 2014; Cahn et al., 2018).

As defined by the United States Food and Drug Administration (US FDA), mHealth is a category of digital health or electronic health (eHealth), which consists in the delivery of health services via mobile and wireless devices through the means of smartphone applications (apps), short message service (SMS), text messaging and wearable technology. Additional categories include health information technology, wearable devices, tele-health and telemedicine and personalized medicine (US Food and Drug Administration, 2019).

The development of mHealth is being promoted by the considerable, universal rise in internet and smartphone users. At the end of 2019, approximately 4.1 billion people or 53.6% of the global population were using the internet (International Telecommunication Union, 2019), among them, 3.2 billion people were using smartphones. In 2020 the number of smartphone users has raised to 3.5 billion and is estimated to reach 3.8 billion in 2021 (O'Dea, 2020).

The increase in smartphone and internet users boosted the development of health applications with an estimate of 325,000 mobile health applications being available in the world in 2016 (Research2guidance, 2017). That amount was three times higher than the sum of 47,140 healthcare apps that were available on Google Play for Android users and 48,608 iOS healthcare apps that were available on App store for iPhones users from 2010 to 2015 (Clement, 2020a, 2020b).

Health or medical smartphone applications (apps) as defined by US FDA, are software run on a smartphone mobile platform with or without wireless functionality. The device contains component parts or accessories, which is used in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals (US Food and Drug Administration, 2019).

In the last five years, diabetes apps had a huge influence on the mobile health industry; it was the leading health target for the mobile app industry as reported by 70% of mHealth practitioners in 2015. And in 2017, more than 1500 diabetes-related apps were reported to be available for users. By the year 2022, diabetes is predicated to be at the first position in health conditions offering the best potential for mHealth apps market (Research2guidance, 2017). This predication can be explained by the advances already evidenced by numerous studies.

mHealth technologies have demonstrated much assistance when addressing psychosocial and emotional needs care by influencing diabetic patients' disease perception and acceptance. Self-management diabetes apps have also been proved to have a positive influence for patients in their self-care activities through control of their blood sugar, nutrition, physical activity, blood pressure, obesity and management of some diabetes complications such as retinopathy and foot screening (Krošel et al., 2016; Kebede and Pischke, 2019; Bonoto et al., 2017; Cassimatis et al., 2015). Moreover, concerning health benefits, mHealth technologies were found to be cost saving at a base level, as reported in a systematic review which included 5,902 studies (Iribarren et al., 2017). They allow health care cost reductions, as patients reduce their hospital visits, save their transport fees and offer more efficient work productivity by reducing the incidences of sick leave (Krošel et al., 2016; Udsen et al., 2017).

Although the advance and acceptance of diabetes management apps in mHealth technology are growing in assisting diabetics in the self-management of their disease, it has been shown that some apps are being readily presented to patients without prior assessment, even though their needs and background may be varied (Scheibe et al., 2015). Therefore it is recommended that the planning, the design and the implementation of all mHealth technologies, diabetes management apps included, should be user-centered by prior consideration of patients and clinicians' expectations (Krošel et al., 2016; El-Gayar et al., 2013; Scheibe et al., 2015; Conway et al., 2016; Chavez et al., 2017; Rossmann et al., 2019).

As with the assessment of users' expectations before the development of diabetes management apps, the evaluation of users' experiences after their introduction is also crucial. It allows the improvement of the apps' quality and safety through the inclusion or exclusion of some components with the aim of filling existing gaps, and this leads to a high users' engagement and better long-term health outcomes (Boyle et al., 2017; Georgsson and Staggars, 2017; Adu et al., 2018).

Regional and local contexts

In 2019, diabetes prevalence in African region was estimated to be 3.9% in 501.3 million of the African adult population aged between 20 - 79 years old (International Diabetes Federation, 2019). The latest statistics of the World Health Organization about Rwanda show that 2.8% of the Rwandan population had diabetes; 3% being females and 2.7% males (World Health organization, 2016). The Index Mundi has recently estimated that prevalence to be 5.10 in 2019 (Index Mundi, 2019).

Rwanda is a small country located in the Central and East of the African continent. It has a population of 12.626 950 million on 26,338 square meters of land. Its gross domestic product (GDP) per capita is 820 USD (2019 estimates). Rwandans' life expectancy at birth is 68 years. It has one doctor per 10,055 inhabitants and one nurse per 1,094 inhabitants (World Bank, 2020; Rwanda Health Ministry, 2018).

In 2018, Sub-Saharan Africa saw an increase from 10% to 30% in smartphone penetration in a period of four years (Global System for Mobile Communication Association, 2019). The following year, African countries were the majority on the list of countries with the fastest growing internet use; Western Sahara being the first on the list with a growth of +364% and Rwanda being the ninth with a growth of +50% (Kemp, 2019).

The Rwandan National Statistics Institute reported that the increase in the use of smartphones has facilitated the access to the internet to about 75% of the Rwandan population (National Institute of Statistics Rwanda, 2017).

1.2. Problem Statement

Like everywhere in the world, the increase in smartphones users raised the permeation of mHealth technology in Africa. The Middle East and North Africa (MENA) region comes at the first place with an existence of more than 18 informational and utility smartphone applications used in the management of diabetes (Alhuwail, 2016).

In Rwanda, despite the level of diabetes knowledge that was proven to be low among the general population (Mukeshimana and Nkosi, 2014), among the healthcare providers (Bagweneza et al., 2019), and among the diabetes patients (Habtu et al., 2019) and moreover, the traditional medicine to be the most practiced (Schierenbeck et al., 2018), only a few telemedicine applications using video conferencing have been in use in general medicine (Combi et al., 2016).

Also, concerning mHealth technologies for diabetes management, only some propositions about their introduction in Rwandan primary health care have been published (Asiimwe-Kateera et al., 2015; Lygidakis et al., 2019).

Surprisingly, despite the existence of such propositions, until the publication of the first study of this project, there was no other study evidencing any existence of technology using smartphones in the self-management of diabetes in Rwanda.

Therefore, this research project was conducted in order to develop the first diabetes self-management smartphone application in Rwanda.

1.3. Study Aim

To develop the first diabetes self-management smartphone application (Kir'App) for Rwandan diabetics.

1.4. Research Objectives

This thesis comprises three research objectives related to the study aim:

1. Assessment of the Rwandan diabetics' needs and expectations to develop their first diabetes self-management smartphone Application (Kir'App).

This opening study objective had two secondary objectives:

- (1) to identify functions which needed to be delivered by a potential diabetes self-management smartphone application (Kir'App) in order to assist Rwandan diabetic patients in their daily disease management; and
- (2) to translate participants' expectations into recommendations for the development of the intended diabetes self-management smartphone application (Kir'App).

2. The second objective consisted in the development of the first Rwandan diabetes self-management Smartphone Application (that I called Kira which means: *be healthy*).

The idea of Kir'App as the first Rwandan diabetes self-management Smartphone Application was to develop an App that was exclusively user-centered. Therefore I literally developed its content and designed its functionalities based on the results of the previous assessment of the needs and expectations of Rwandan diabetics.

Following the results of the previous study and under the supervision of my thesis supervisor who is an expert in diabetes prevention and management, I wrote a multi-thematic document of about 140 pages on different topics on diabetes self-management according to the standards of diabetes care as provided by the International Diabetes Federation and other recognized diabetes care organizations.

However, even if Kir'App was fully developed based on the needs and expectations of Rwandan diabetics, we also respected common international standards on the development of mobile health Apps by using Mobile App Rating Scale (MARS) criteria as a checklist for the development of the content and the functionalities of Kir'App (see details in chapter 3).

Once the content was ready, I also worked with a Rwandan professional translator to translate the content in Kinyarwanda (national language spoken in Rwanda) then I presented both the content and the desired functionalities to a professional App developer who developed the digital part of Kir'App.

3. As the third objective of this research project, we evaluated Kir'App users' experiences after three months of use.

Once the first prototype of Kir'App was ready to use, it was presented to the participants of the previous study to assess if it met their needs and expectations.

This second study had three secondary objectives:

- (1) to assess positive aspects of Kir'App identified by users after three months of use,
- (2) to assess negative aspects of Kir'App identified by users after three months of use, and
- (3) to identify the users' suggestions for improvement of Kir'App.

1.5. Research and theoretical approaches used

The overall research methodology of this research project used a qualitative research approach and the data were thematically analyzed using Mayring's method of qualitative content analysis and deductive and inductive methods.

The semi-structured face-to-face in-depth interviews we used to collect data provided us with deep and detailed insights in the attitude, feelings and behaviors of our study participants. They were encouraged to express their thoughts freely and this helped us to discover some areas in diabetes care that needed to be more considered in Rwandan standards and protocols of diabetes care.

The use of user-centered design in the process of Kir'App development

Since Kir'App was going to be the first diabetes self-management App in Rwanda, we worked to maximize the benefits of client-centered design for its development.

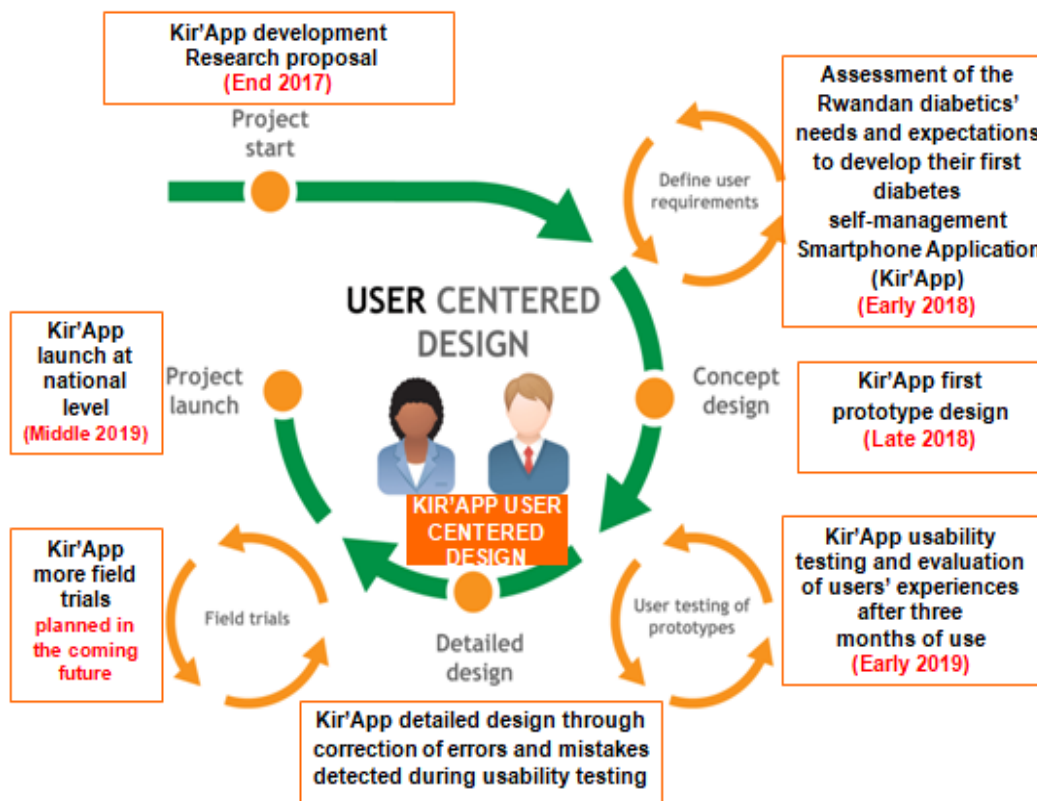


Figure 1: Kir'App development process through the user-centered design (UCD) concept

According to the *Encyclopedia of Human-computer interaction*, user-centered design (UCD) is a general term used to describe any design process in which designers let the end-users influence how a design takes shape; either by assessing their needs and involving them at the time of requirements gathering and usability testing or by involving them as their partners throughout the design process (Abrams et al., 2004).

We used the first spectrum of UCD design process by taking into considerations Rwandan diabetics' needs, expectations and experiences before and after the development of Kir'App. Its content covers diabetes knowledge and information through means of texts and images Findings were thematically analyzed using Mayring's method of qualitative content analysis. We exclusively followed the UCD concept as originally introduced by Donald Norman in 1988. He recommended to designers to place the users at the center of their design and to ease the

task for them by ensuring that they are able to learn to use their product and utilize it as intended with minimal effort (Massaro, 1990; Abras et al., 2004).

Norman summarized his recommendations in four basic suggestions:

1. Make it easy to determine what actions are possible at any moment.
2. Make things visible, including the conceptual model of the system, the alternative actions, and the results of actions.
3. Make it easy to evaluate the current state of the system.
4. Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state.

Additionally to the user-centered design, we also applied the Health Action Process Approach (HAPA) model in the analysis of the data we obtained from the assessment of needs and expectations of Rwandan diabetics before we developed Kir'App and later in the evaluation of users' experiences with Kir'App.

The HAPA model is a psychological theory of health behavior change developed by Ralph Schwarzer which suggests that for a health behavior to be adopted, initiated and maintained at least two phases are necessary; the motivational phase and the volitional phase (Schwarzer, 1992).

The motivational phase is characterized by pre-intenders and intenders and it is the initial phase when people form an intention to perform a behavior. Their intention depends (1) on how confident and capable they are in enacting the behavior (self-efficacy) (2) on which outcome their engagement to perform the behavior might produce (outcome expectancies) (3) and/ or on their risk perception of their engagement or lack of engagement in behavior performance.

The volitional phase is an active phase represented by actors. It describes how their intentions are translated into behavior through three stages; (1) the action planning (here the time, the place and the way of performing the behavior are stated) (2) the coping planning (it consists in elaboration of strategies to avoid the anticipated barriers to the performance of the behavior) (3) the action control (here actors become aware of standards, self-monitor their progress and put efforts into the performance of the behavior) (Schwarzer, 1992 ; Preece et al., 2017).

The use of HAPA model in the process of Kir'App development

The HAPA model had twofold mixed use in the health behavior change of the participants of this research project; first in the general acceptance of Kir'App as an innovative healthcare software artifact and second as the first diabetes self-management smartphone app designed to help them improving their diabetes care (this second aspect is discussed in the published articles).

Kir'App was developed to assist Rwandan diabetics in the self-management of their disease. The HAPA model helped us first to analyze the personal predisposition of each of our study participants to change their health behavior by adopting a new healthcare device (Kir'App) in the self-management of their disease.

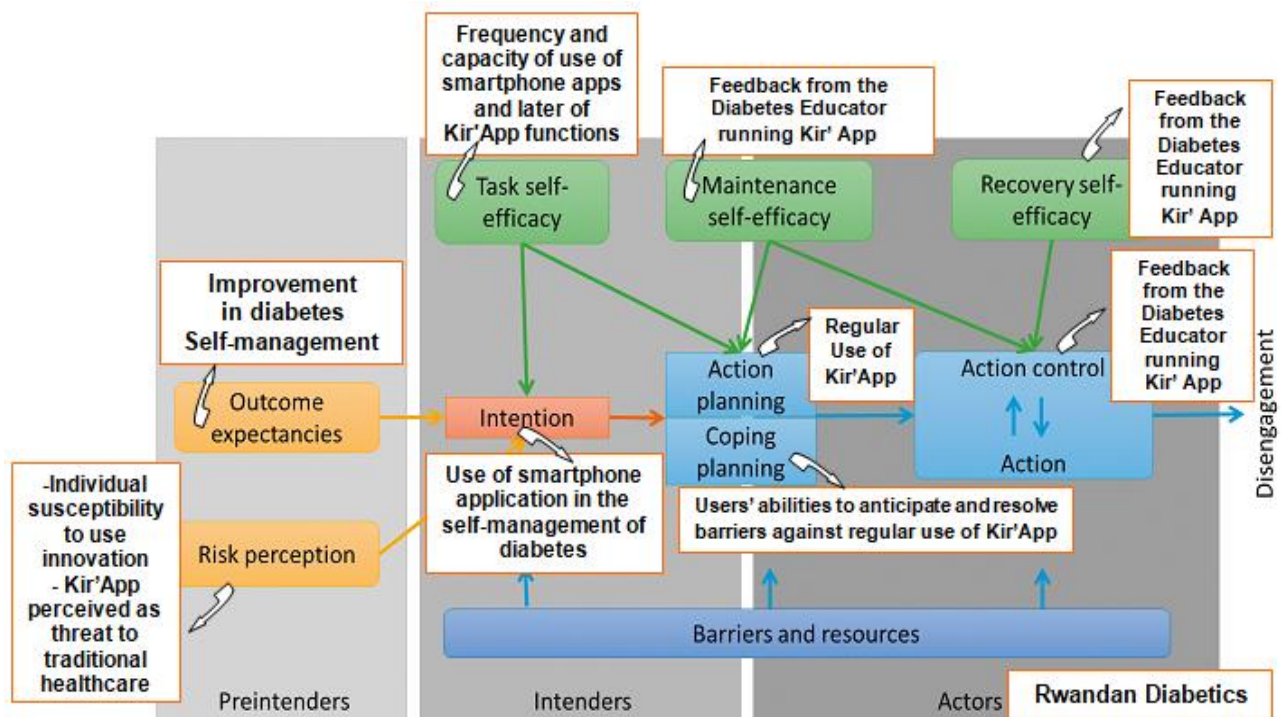


Figure 2: Process of Kir'App utilization (white) through the Health Access Process Approach (HAPA) model

In the process of Kir'App development, the motivational phase was instigated by a direct question that was asked at the beginning of each interview (*Would you like to have a smartphone application to assist you in the self-management of diabetes?*).

The positive answer to that question directed the researcher to investigate how confident the participants were in their ability to use smartphone applications through questions that assessed first their frequency and capacity to use other smartphone apps and later on, the impact Kir'App was having in the self-management of their disease (self-efficacy).

The outcome expectancies that were waited by the participants from Kir'App as the first App to assist them in the self-management of their disease were mainly based on the improvement of diabetes self-care activities as they expressed it through the interviews about their needs and expectations from Kir'App.

Beside the perceived susceptibility of some individuals to use innovation, the possibility of Kir'App assistance to become an obstacle between the patient and their healthcare providers by interfering with the traditional medical care was another perceived risk. That risk was averted by designing Kir'App functionalities that support both the patient and their healthcare provider to have shared satisfaction in terms of diabetes care.

Based on the information obtained in the motivational phase, Kir'App functionalities were developed in a way the users could easily adapt themselves in the volitional phase of HAPA. In the volitional phase, which was represented by Rwandan diabetics using Kir'App, we evaluated how their primary intentions to use a smartphone app in the self-management of their disease were translated into practice.

Through the usability testing and evaluation of users' experiences after 3 months of Kir'App use, we assessed our study participants' ability to plan their regular use of Kir'App (action planning), their capacity to anticipate and resolve possible barriers that hindered them to use Kir'App (coping planning) and their awareness of the involvement of individual effort in the use of Kir'App, and in self-assessment of the progress achieved to ensure that Kir'App was bringing improvement in their diabetes self-care activities.

The maintenance and recovery of self-efficacy and the action control of the use of Kir'App are being controlled through the interactions between the users and the diabetes educator who runs Kir'App.

1.6. Structure of the thesis

The body of this thesis is structured as follows:

Chapter 1: this chapter starts with background of the study that provides an insight on the global, regional and local contexts of the research problem. This is followed by statement of the research problem, study aim, research objectives and a summary of the research and theoretical approaches used.

Chapter 2 presents the first article that has been published on the first objective of this research project; *“The Assessment of the Rwandan diabetics’ needs and expectations to develop their first diabetes self-management Smartphone Application (Kir’App)”*.

Chapter 3 describes the process of Kir’App development and gives a brief summary of Kir’App content. That summary offers a glimpse into the App functionalities that were developed according to the results of the opening study objective.

Chapter 4 contains the article of the study conducted after the introduction of the first prototype of Kir’App to study participants; *“A qualitative study of users’ experiences after 3 months: the first Rwandan diabetes self-management Smartphone application “Kir’App”*

Chapter 5 discusses the implications of the main results of this research project as presented in the two above cited articles and compare Kir’App to international standards and researches.

Chapter 6: this is a conclusion and recommendation chapter that reviews the achievement of the study objectives, the contribution to knowledge, the implications for practice of Kir’App, the limitations encountered and the recommendations for future research.

References and appendixes: this section contains references, summary of the project written both in English and German, student’s autobiographic reflection, acknowledgement, dedication, interview guide, summary of the recurrent themes identified in the two studies with examples, information on the impact factor of the journal, copy of ethical clearance, approval to open doctorate proceedings and declaration.

2. Publication 1: The Assessment of the Rwandan diabetics' needs and expectations to develop their first diabetes self-management Smartphone Application (Kir'App)

This chapter presents the first publication as originally published.

The original publication is available at:

<https://journals.sagepub.com/doi/full/10.1177/2042018819845318>

Corrigendum to “Assessment of Rwandan diabetic patients’ needs and expectations to develop their first diabetes self-management smartphone application (Kir’App)”

Ther Adv Endocrinol Metab
2020, Vol. 11: 1
DOI: 10.1177/
2042018820973813
© The Author(s), 2020.
Article reuse guidelines:
sagepub.com/journals-permissions

Kabeza CB, Harst L, Schwarz PEH, et al. Assessment of Rwandan diabetic patients’ needs and expectations to develop their first diabetes self-management smartphone application (Kir’App). *Ther Adv Endocrinol Metab* 2019; 10: 1–21. Original DOI: 10.1177/2042018819845318

In the above referenced article, the correct abstract is:

Abstract

Background: Knowledge of and coping with diabetes is still poor in some communities in Rwanda. While smartphone applications (or apps) have demonstrated improving diabetes self-care, there is no current study on the use of smartphones in the self-management of diabetes in Rwanda. The main objective of this study was to assess the needs and expectations of Rwandan diabetic patients for mobile-health-supported diabetes self-management in order to develop a patient-centred smartphone application (Kir’App).

Methods: Convenience sampling was used to recruit study participants at the Rwanda Diabetes Association. Twenty-one patients participated in semi-structured, in-depth, face-to-face interviews. Thematic analysis was performed using Mayring’s method of qualitative content analysis.

Results: The study included 21 participants with both type 1 (female = 5, male = 6) and type 2 (female = 6, male = 4) diabetes. Participants’ age ranged from 18 to 69 years with a mean age of 35 and 29 years, respectively. Eight main themes were identified. These were (a) diabetes education and desired information provision; (b) lack of diabetes knowledge and awareness; (c) need for information in crisis situations; (d) required monitoring and reminder functions; (e) information on nutrition and alcohol consumption; (f) information on physical activity; (g) coping with burden of disease, through social support and network; (h) app features.

Conclusion: This study provides recommendations that will be used to design the features of the first Rwandan diabetes self-management smartphone application (Kir’App). The future impact of the application on the Rwandan diabetic patients’ self-management capacity and quality of life will be evaluated afterwards.

Assessment of Rwandan diabetic patients' needs and expectations to develop their first diabetes self-management smartphone application (Kir'App)

Claudine B. Kabeza , Lorenz Harst, Peter E. H. Schwarz and Patrick Timpel

Abstract

Background: Knowledge of and coping with diabetes is still poor in some communities in Rwanda. While smartphone applications (or apps) have demonstrated improving diabetes self-care, there is no current study on the use of smartphones in the self-management of diabetes in Rwanda.

Methods: The main objective of this study was to assess the needs and expectations of Rwandan diabetic patients for mobile-health-supported diabetes self-management in order to develop a patient-centred smartphone application (Kir'App).

Results: Convenience sampling was used to recruit study participants at the Rwanda Diabetes Association. Twenty-one patients participated in semi-structured, in-depth, face-to-face interviews. Thematic analysis was performed using Mayring's method of qualitative content analysis.

Conclusions: The study included 21 participants with either type 1 (female = 5, male = 6) or type 2 (female = 6, male = 4) diabetes. Participants' age ranged from 18 to 69 years with a mean age of 35 and 29 years, respectively. Eight main themes were identified. These were (a) diabetes education and desired information provision; (b) lack of diabetes knowledge and awareness; (c) need for information in crisis situations; (d) required monitoring and reminder functions; (e) information on nutrition and alcohol consumption; (f) information on physical activity; (g) coping with burden of disease, through social support and network; (h) app features. This study provides recommendations that will be used to design the features of the first Rwandan diabetes self-management smartphone application (Kir'App). The future impact of the application on the Rwandan diabetic patients' self-management capacity and quality of life will be evaluated afterwards.

Keywords: diabetes, Kir'App, Rwanda, smartphone application

Received: 18 September 2018; revised manuscript accepted: 1 April 2019

Diabetes care in Rwanda

Approximately 425 million adults (age 20 to 79 years) have diabetes worldwide.¹ In 2045, this number is expected to rise up to 629 million. In Africa, the number of patients with diabetes is expected to rise from 16 to 41 million (+156%). According to the World Health Organization, 2.8% of the Rwandan population are estimated to have diabetes.²

Rwanda's community-based health insurance system covers 80% of the population (2015–2016) and is further improving towards universal health coverage of the country. The healthcare system also covers country's poorest citizens through its home-grown development programme that aims to lift the living standards of poor families and to facilitate their access to healthcare.^{3,4} Although Rwanda's national programmes ascertain general

Ther Adv Endocrinol Metab

2019, Vol. 10: 1–21

DOI: 10.1177/
2042018819845318

© The Author(s), 2019.
Article reuse guidelines:
sagepub.com/journals-
permissions

Correspondence to:
Claudine B. Kabeza
Department for Prevention
and Care of Diabetes,
Faculty of Medicine Carl
Gustav Carus, Technische
Universität Dresden,
Fetscherstraße 74, 01307
Dresden, Germany
claudine.kabeza@gmail.com

Lorenz Harst
Faculty of Medicine Carl
Gustav Carus, Technische
Universität Dresden,
Dresden, Germany

Peter E. H. Schwarz
German Centre for
Diabetes Research
(DZD e.V.), Neuberger,
Germany Helmholtz
Centre Munich, University
Hospital, Munich, Germany
Faculty of Medicine,
Technische Universität
Dresden, Dresden,
Germany

Patrick Timpel
Department for Prevention
and Care of Diabetes,
Technische Universität
Dresden, Dresden,
Germany

Claudine B. Kabeza
College of Medicine
and Health Sciences,
University of Rwanda,
Rwanda

access to healthcare, knowledge and perception of diabetes mellitus is still inadequate in some communities of the country.⁵

Evidence on diabetes self-management

Strategies to provide education and support, for example, diabetes self-management education (DSME) programmes, for patients with type 2 diabetes mellitus (T2DM) incorporate ongoing self-monitoring of glucose levels and other diabetic outcomes as well as setting of behavioural goals. Behaviour change on the basis of these goals is the primary aim of DSME interventions,⁶ for example, regular intake of fruit and vegetables or increased levels of physical activity. Recent evidence from a pre–postparallel group design study indicates that self-management reduces diabetes mellitus (DM)-associated comorbid conditions as well as healthcare utilization and, therefore, overall cost.⁷ According to a meta-analysis of eight studies, DSM improved DM-related quality of life.⁸ Mezuk and colleagues found significant improvements of glycated haemoglobin (HbA1c) through self-management in a group setting in which lay healthcare workers served as coaches.⁹ All in all, evidence suggests that patient empowerment and behaviour change through self-management support is crucial for the success of DSM.

Self-management demands continuous medical support, as well as monitoring of disease-specific parameters. It is therefore regarded as the ideal target for telemedicine interventions.^{10–12} The International Diabetes Federation (IDF) published six categories of mobile applications (or apps) used in diabetes management.¹³ This includes tracking of medical parameters (e.g. blood pressure, blood glucose, body weight, etc.), nutrition (healthy food choices) and fitness data (physical activity) to support improved self-management and healthy lifestyle. They also call for a strengthening of patient relationships with their friends and families using social networks and blogs. Recent analysis shows mixed results for quality, reliability and privacy of available apps, making it hard for clinicians to recommend appropriate ones to their patients.¹⁴ In Rwanda, Kateera and colleagues have published a study proposing the introduction of mobile health (mHealth) approaches in the management of noncommunicable diseases, including diabetes.¹⁵



Figure 1. The HAPA model.¹⁸ Several preconditions have to be met for preintenders to become intenders and start planning an activity. The same is true for maintaining this activity (action stage). HAPA, Health Action Process Approach.

Theory-grounded development and implementation of behaviour-change interventions

Due to the varying backgrounds, needs and preferences of patients with chronic diseases, the whole process of planning, design and the implementation of the included technologies should be user-centred.^{16,17} Therefore, knowing and understanding the individual’s predispositions towards health behaviour change is of high importance when planning and for innovation. Theories and models of behaviour change provide guidance in this endeavour. Developed by Ralph Schwarzer in 1992, the Health Action Process Approach (HAPA) combines evidence-based theories, such as the Theory of Reasoned Action, the Theory of Planned Behaviour and the Health Belief Model. Its major contribution to health behaviour research is the inherent recognition that behaviour change has to be maintained over time. Both the intention (action planning) as well as keeping up the healthy behaviour (action) depend on several predictors, as shown in Figure 1.

A meta-analysis on the effectiveness of the Health Action Process Approach (HAPA) in predicting health behaviour change in chronically ill patients showed an overall fit of the model. Small-to-moderate effects were found for self-efficacy beliefs in the planning as well as in the volitional phase, whereas risk perception (vulnerability) showed only small effects. No effect was found for social support.¹⁹ Physical activity among adults with T2DM can be predicted by the

Table 1. Objectives of our study.

Primary objective	To identify needs and expectations of Rwandan diabetic patients for a potential diabetes self-management smartphone application (Kir'App).
Secondary objectives	To identify functions which need to be delivered by a potential diabetes self-management smartphone application (Kir'App) to assist patients in their daily disease management. To translate participants' expectations into recommendations for the development of the intended diabetes self-management smartphone application Kir'App.

HAPA, with self-efficacy again being among the most important predictors.²⁰ There is also evidence that the use of apps has a positive effect on the social-cognitive predictors of the HAPA for individuals engaging in physical activity.²¹ Based on this evidence, the HAPA is a suitable starting point for the interpretation of the results of the current study.

Objective

The objectives of the study are presented in Table 1.

The presented research is part of a research project called 'Kir'App Rwanda diabetes study' aiming to develop the first Rwandan diabetes self-management smartphone application.

Method

Study design

A qualitative study design was employed.

Target population

The target population of the study were Rwandan patients with type 1 and type 2 diabetes registered with the Rwanda Diabetes Association (RDA) at the time of the study.

Participants and eligibility criteria

The inclusion criteria for participating in the study were defined as being Rwandan, aged 18 years and above, living with type 1 or type 2 diabetes, registered with the RDA and having daily access to a smartphone.

Data collection tool and pilot test

Semistructured face-to-face in-depth interviews (February to March 2018) were used to collect

the data. The interview guideline was developed based on the methodology of in-depth interviews²² the authors' research background and experience in diabetes care as well as IDF guidelines and protocols for diabetes care.¹

The interview guideline consisted of two parts. In the first part, participant characteristics, including biographical data as well as self-rated smartphone knowledge and frequency of use were assessed. The second part covered nine questions assessing needs and expectations of Rwandan patients with diabetes for a potential diabetes self-management smartphone application (Kir'App). It covered the following topics: willingness to use a health app, possible functions of the app and expected support in daily life or in the management of the disease. The interviews were done in two steps.

First, a discussion was initiated on the general topics presented above. In cases where respondents were hesitant with their answers or replied too broadly, questions designed to prompt more detailed answers were asked. These were questions pertaining to concrete functions of self-management systems derived from literature, for example, assistance with the maintenance of physical activity.²³

A professional translator was consulted for the translation of the interview guideline from English to Kinyarwanda. After translation, a pilot test involving five Rwandan diabetic patients was carried out to validate the guideline. It was adjusted according to their feedback. The final interview guideline is provided in the appendix section.

Sampling method

As there is no database of Rwandan diabetic patients owning smartphones in the RDA, convenience sampling was used to recruit study

participants. During a period of 2 months, a researcher attended the Rwanda diabetes clinic (located within the RDA) and invited every patient fulfilling the eligibility criteria to participate in the study.

Sample size

Redundancy within the answers hinted towards theoretical saturation when interviews with 21 participants had been conducted.

Interview setting and procedure

The face-to-face interviews were conducted at the RDA. After the self-introduction of the researcher, the purpose of the study was explained and a consent form was signed prior to the interview. The permission to record during the interview was obtained and when necessary, the researcher took some additional notes. The average duration of each interview was 1 h.

Ethical implications

Permission to conduct the study was obtained from the RDA and from the Institutional Review Board of the College of Medicine and Health Sciences of the University of Rwanda (no 021/CMHS/IRB). Participants were informed about their voluntary participation in the study and their right to withdraw their consent at any time. They were not compensated for their time with incentives. Participants signed the informed consent forms before the interviews were conducted. Anonymity and confidentiality were assured by coding participants' names and the storage of the transcript in a locked cabinet.

Analysis

Interview transcription, coding and reporting. Each interview was audio-recorded, transcribed and analysed, applying inductive category formation suggested within Mayring's method of qualitative content analysis.²² For the final codebook (see Appendix, Table A1), paraphrases from the transcript were used to describe each theme and subcategory.

First, transcription was performed by one researcher (CB). The authors (CB, LH and

PT) then familiarized themselves with the transcripts and afterwards, two of them (CB and PT) independently aimed to identify initial codes (themes). In a first iteration, underlying patterns and recurring schemes were identified within the answers to all guiding questions of the in-depth interviews. Those patterns formed the first broad categories. In a second iteration, some of these categories, appearing to cover different facets of a broader theme, were subsumed and thereby became subcategories.

After discussion and relabelling of both themes and subcategories, examples taken from the transcripts were added. This process was carried out independently by three authors (CB, LH and PT). Conflicting presumptions about themes and subcategories were discussed until agreement could be achieved or a third author settled the ties. No software was used for coding.

Reporting of study results is in line with the consolidated criteria for reporting qualitative research²⁴ as well as recommendations following the Standards for Reporting Qualitative Research.²⁵

Results

Participants suffered from either type 1 (female = 5, male = 6) and type 2 (female = 6, male = 4) diabetes and were aged between 18 and 69 years (mean age of 35.29 years). Three individuals refused to take part due to lack of time. No participant dropped out before the end of the interviews.

The characteristics of participating patients are summarized in Table 2. All participants ($n = 21$) reported that they would like to have a smartphone application supporting them in their diabetes management, either being strongly supportive ('it would be wonderful'; 'yes, it would be fantastic') or simply open minded ('Yes, if it can help me managing my disease, why not?'). A qualitative content analysis of the transcripts resulted in seven inductively formed themes. A summary of identified themes and subcategories is provided in Table 3. A more conclusive table summarizing the seven themes, their subcategories and one to four examples each can be found in the appendix section.

Table 2. Description of study participants.

Characteristic	<i>n</i>
Participants, <i>n</i>	21
Age	
Range	18–69
Mean	35, 29
SD	17, 71
Sex	
Male	10
Female	11
Marital status	
Single	11
Married	9
Widowed	1
Type of disease	
T1D	11
T2D	10
Diabetes duration, years (time since diagnosis)	
<1	1
1–5	7
6–10	8
11–15	3
16–20	2
Educational level	
Primary school	2
Secondary school	16
Higher education (university)	3
Work status	
Permanent job	7
Temporary	3
Student	5
Jobless	4
Retired	2

Table 2. (Continued)

Characteristic	<i>n</i>
Self-rated smartphone knowledge/skills	
Excellent	6
Very good	4
Good	8
Poor	3
Frequency of smartphone usage	
<Once a day	1
Once a day	1
>Once a day	19

SD, standard deviation; T1D, type 1 diabetes; T2D, type 2 diabetes.

(1) Diabetes education and desired information provision

The theme refers to the provision of information, specialized education on diabetes in general and the coping with the disease.

(a) General information on diabetes, management and complications

Participants wished to receive information from the application that can help close their gaps on diabetes knowledge.

‘...the application should teach us the difference between type 1 and type 2 diabetes because most people of my age don’t know which type of diabetes they are living with. The application should also teach us more about the medications we take and why some people use tablets when others are using insulin although we all have type 2 diabetes? It should also teach us about side effects of medications...’ (P11)

(b) Medical parameters (e.g. blood pressure, blood glucose, body weight, etc.)

Some participants expressed their will to receive specialized knowledge on medical parameters of DM.

‘My blood glucose levels sometimes reach 400 mg/dl, I wish the application [would] tell me what caused it to raise that high and [...] teach me how I should lower it.’ (P4)

Table 3. Summary of recurrent themes and subcategories.

Theme	Subcategory
(1) Diabetes education and desired information provision	(a) General information on diabetes, its management and complications (b) Medical parameters (e.g. blood pressure, blood glucose, HbA1c, body weight, etc.) (c) Medical devices (d) Frequently asked questions by newly diagnosed patients (e) National/regional update and initiatives as well as services
(2) Lack of knowledge/awareness	(a) Lack of knowledge on living with diabetes (b) Prejudice and myths (social media knowledge) (c) Lack of knowledge on Web 2.0
(3) Crisis intervention	–
(4) Monitoring and reminder functions	(a) Blood glucose or sugar recording and trend visualisation (b) Reminder functions
(5) Nutrition and alcohol consumption	(a) Composition of a diabetes plate (b) Information on nonalcoholic beverage choices (c) Information on alcohol intake (d) Pleasure of eating
(6) Physical activity	(a) Type of exercise to do (b) Motivation for physical activity (c) Frequency and duration of physical activity
(7) Coping with burden of disease	(a) Emotional support (b) Social support
(8) App features	(a) Information delivery (b) Available languages
HbA1c, glycated haemoglobin.	

(c) Medical devices

Participants asked for support to monitor disease-specific parameters.

‘You know many diabetics like me don’t have glucose meters [...]. We take our medication without knowing our levels of blood sugar and we only come here to the clinic once [...] [a] month to check it or whenever we don’t feel okay.’ (P21)

(d) Frequently asked questions by newly diagnosed patients

Others underlined the special value of a target-group-specific repository of information for those being newly diagnosed with diabetes.

‘There are some people who are newly diagnosed with diabetes and who have a million questions

about it, [...] so the application should have a function [called] “frequently asked questions”.’ (P13)

(e) National/regional update and initiatives

Information on national or regional initiatives on diabetes care as well as local services (e.g. diabetes meetings) were asked for by the participants:

‘I wish the application to inform me about activities concerning diabetes that are taking place in Rwanda [...]. Activities [...] being organized for patients because now we don’t attend many due to lack of information.’ (P5)

(2) Lack of knowledge and awareness

This theme comprised characteristics of the individual end user, mainly knowledge gaps.

(a) Lack of knowledge on living with diabetes

Participants' responses indicated knowledge gaps concerning the everyday life with diabetes, especially concerning disease-related behaviour.

'I didn't know that someone could develop foot problems because of diabetes. Right now, I have athlete's foot and I've never thought that it could be linked to my diabetes [...]. I wish the application [would] teach us about foot problems in diabetes, [so] I can learn how to take care of them and [...] use it to teach other diabetics.' (P7)

(b) Prejudice and myths

Participants described false and misleading information being considered as true.

'The application can teach type 1 diabetics about how to live their love life with their diabetes. Most of them are ashamed to tell [...] their partners. Some people didn't go to school or don't know much about diabetes, they think that the person can contaminate them.' (P6)

(c) Lack of knowledge on Web 2.0

One participant referred to gaps in digital knowledge and limited trust in technology.

'I've seen some [diabetes self-management application] on Google Play but it requires a subscription; they are being connected to your bank account and they draw money from it. I was [...] scared of hackers, I abandoned the idea of subscription.' (P15)

(3) Crisis intervention

The third theme refers to information provision and immediate guidance in case of disease complications in order to prevent inadequate behaviour in stressful situations. No subcategory was found here.

'The application should teach us how to behave once you have hypos or highs because sometimes you become stressed which can raise your blood sugar levels more.' (P12)

(4) Monitoring and reminder function

Theme 4 refers to the continuous monitoring of disease-specific (medication, physical activity,

nutrition) parameters to be facilitated by the app. A second subcategory refers to reminder functions.

(a) Blood glucose or sugar recording and trend visualisation

The subcategory refers to digital monitoring and display of changes in diabetes parameters.

'Another thing I wish the application to offer would be a kind of diary to record the results of our blood glucose, A1c, blood pressure and body weight checking. A diary in which we can write possible mistakes, which may have caused the results of these health check-ups to be high or low compared to the normal values.' (P2)

(b) Reminder functions

Participants wish for automated reminders for appointments, physical activity, insulin use and food intake.

'The application can remind me to check my blood sugar and to take my insulin injection [...] and to exercise. It should also remind me of my doctor's appointments.' (P13)

(5) Nutrition and alcohol consumption

The theme refers to information provision on food and drink choices as well as alcohol intake. Four subcategories were found.

(a) Composition of a diabetic plate

Participants expressed a need for information on the kind of food being complementary with the disease.

'I wish the application to teach me what quantity of which food to put on my plate and the content [...] in terms of glucose and other nutrients.' (P3)

(b) Information on nonalcoholic beverage choices

This subcategory refers to diabetes-appropriate choices of beverages:

'[...] for example, I personally like soda very much and after I was diagnosed with diabetes I had to stop [drinking] it and whenever I used to pass by shops

[...] I felt my heart aching remembering that I couldn't drink [sodas] anymore. But is it true?' (P7)

(c) Information on alcohol intake

This subcategory refers to information on the acceptable kind and amount of alcohol, as well as possible interactions of insulin with alcohol.

'I wish to have a special page about beers diabetics can drink [...]. Or a page on how to still enjoy life besides having diabetes, because some people [...] [think] that beers and medications should never be mixed.' (P18)

(d) Pleasure of eating

This subcategory refers to dietary food intake and the consequences for pleasure while eating. For instance, participants report that they 'hate to always drink water' (P11), or refuse to go to parties because they cannot drink soda.

'Maybe the application can also give us tips on how to enjoy our food, because diabetics are known to always eat bitter.' (P11)

(6) Physical activity

The theme refers to information on the right kind and amount of exercise, as well as to motivational input for uptake and maintenance of physical activity.

(a) Kind of sport to do

The first subcategory refers to the kind of physical activity for people living with diabetes.

P17: 'The application can teach us about acrobatic games that are safe for diabetics. I used to be a player of acrobatic games but when I was diagnosed with diabetes, I stopped it and this frustrates me [...].'

(b) Motivation for physical activity

Participants report discouragement and lack of motivation for physical activity. They also ask for continuous support of behaviour change.

'The doctor told me to exercise at least 40mins a day, he said I have to walk quickly but I am not able to do so, that's why I don't exercise at all.' (P14)

(c) Frequency and duration of physical activity

This subcategory refers to information on the right amount of physical activity. Participants ask for tracking and performance-based recommendations.

'Then I decided to exercise twice a week after my job [...] but I don't know if it is enough.' (P20)

(7) Coping with burden of disease

This theme refers to emotionally supportive content and the ability to connect with others suffering from diabetes, easing the burden of disease.

(a) Emotional support

The subcategory refers to supportive content for emotionally distressing situations.

'I wish the application could give me advice about how to control my emotions (anger, bitterness, stress, sorrow, etc.).' (P2)

(b) Social support

The subcategory refers to social support when dealing with diabetes. Participants wish to be able to get in contact with other patients with diabetes, for example, in a forum to 'share goals and dreams' (P17).

'Can the application put me in contact with other people for example when I am feeling down so they can help me feel better (a kind of disease partner who is not necessarily sick but who knows diabetes well and who can help me)?' (P8)

(8) App features

Participants had difficulties imagining possible app functions. However, many referred to interactive information delivery options and the integration of different languages.

(a) Information delivery

This subcategory refers to content to be delivered *via* text, images, audios and videos.

'Videos are better, because you can see and understand what the doctor is explaining. At my age, reading may be tricky. I think that having both may be better.' (P5)

'Sometimes we cannot even raise our hand when we are in a hypo, so the idea of having an audio would be to instruct us on what to do in case of a hypo crisis. Otherwise you can neither read nor watch a video.' (P3)

(b) Available languages

This subcategory refers to desired languages to be supported by the app. Participants either wish to include local language, Kinyarwanda, or to also include English.

'Kinyarwanda is better because even if you think you speak English, you may start reading and be confused with medical or scientific terminology, though you needed to understand everything well.' (P7)

'It would be great to have an option to change the language like for Facebook (the application should be both Kinyarwanda or in English for the choice of the use).' (P3)

According to the qualitative analysis, the following functions were either mentioned by the participants (see above) or can be deducted from their mentioned needs and expectations:

- (1) Education provision tool using Kinyarwanda and English (including informational content on disease in general, medication and medication adherence, physical activity and nutrition, and their respective impact on coping with the disease and disease-related complications);
- (2) Monitoring system for disease-related parameters such as HbA1c as well as medication and nutrition intake and amount of physical activity;
- (3) Reminder functions based on monitored data, for example, for medication adherence and physical activity behaviour, as well as disease management, for example, appointments with physicians;
- (4) Crisis intervention function providing easy-to-access information in case of hyper- and hypoglycaemic events;
- (5) Social network function providing access to other patients and self-help groups, in order to offer social support as a coping mechanism for the burden of disease;

- (6) Combine written content with images and support it with both audio- and video-based information delivery.

Discussion

The assessment of expectations and needs of Rwandan patients with diabetes will be used to develop the first diabetes self-management smartphone application (Kir'App) for Rwandan patients with T2DM.

Eight main themes were identified: (a) diabetes education and desired information provision; (b) lack of diabetes knowledge and awareness; (c) need for information in crisis situations; (d) required monitoring and reminder functions; (e) information on nutrition and alcohol consumption; (f) information on physical activity; (g) coping with burden of disease; and (h) app features. Table 4 summarizes the study participants' expectations that will guide the App development (functionalities and content) and table 5 shows the suggested future use of this study results.

Theory-grounded user-centred development

A recent systematic review concludes that mHealth studies for behaviour change in low- and middle-income countries are insufficiently based on behaviour-change theories.²⁶ Evidence on the HAPA shows that while all patients with T2DM should be presented with means to increase their self-efficacy, support during behaviour-change processes depends on the stage a person is at.²⁷ Accordingly, our results are discussed in reference to the single predictors and stages included in the HAPA.¹⁸

Risk perception, outcome expectancy and health literacy. Outcome expectancies cover most of the answers received in the semistructured interviews. As indicated in theory, outcome expectancies are said to increase the success rate of coping responses.²⁸ Outcome expectations and pretreatment self-efficacy predict greater intention to engage in health behaviours,²⁹ as they allow for carrying out plans.³⁰ Among the expectations towards the potential smartphone application is a special feature for the provision of education on diabetes in general and coping strategies with disease-related complications. Participants also expect the application to provide response to their lack of

Table 4. Study participants' expectations guiding the app development: functionalities and content.

Study participants' expectations guiding the app development: Functionalities and content	
(1)	Information, specialized education on diabetes and skills for coping with the disease
(2)	Knowledge about diabetes burdens in everyday life and crisis situations
(3)	Information on food, drink choices and alcohol intake
(4)	Right type, amount and motivational input for physical activity
(5)	Monitoring and reminder functions for diabetes parameters (health check-ups), doctor's appointments and medication taking
(6)	Emotionally supportive content and the ability to connect with other people living with diabetes
(7)	Bilingual support using both Kinyarwanda and English
(8)	Information delivery combining written content, images, audio and videos according to users' preferences

Table 5. Future use of this study's results.

Future use of this study's results
The findings of this study will:
(1) be used to develop the first diabetes self-management smartphone application (Kir'App) for Rwandan patients with T2DM;
(2) inform the Ministry of Health of Rwanda as well as the Rwanda Diabetes Association about the needs of Rwandan diabetic patients in terms of diabetes education and management;
(3) raise awareness among diabetic patients' associations, social movements, and decision makers about the needs of Rwandan diabetic patients, providing help for the necessary advocacy;
(4) open a way for Rwandan diabetic patients to verbalize their needs and facilitate development of their healthcare.
T2DM, type 2 diabetes mellitus.

knowledge and awareness about coping with the diabetes burden in everyday life, which is often impaired by common diabetes myths and rumours. This is noteworthy as disease-related literacy is an important predictor for risk perception.³¹ Furthermore, patients with knowledge deficits or low health literacy are expected to benefit most from mHealth interventions.³²

Health literacy is the basis for a successful self-management, as also stated by Saha and colleagues.³³ This is supported by guidance published by the American Diabetes Association, the American Association of Diabetes Educators, and the Academy of Nutrition and Dietetics.³⁴ A survey of people in Rwanda revealed that general knowledge and perceptions of T2DM was low, highlighting the need for education campaigns.⁵ Therefore, adequate education corresponding to the individuals'

level of health literacy is needed, even more so as increased health literacy has been shown to improve self-efficacy and therefore coping behaviour in an Iranian sample of diabetes patients.³⁵

Diabetes self-management, monitoring and crisis intervention. Study participants also wished to have a diabetes self-management application with the capacity to assist them with crisis intervention. By providing information in case of disease complications, such as episodes of low and high blood sugar values, patients can be empowered to prevent wrong behaviour in stressful situations. As for community-based strategies, Gallé and colleagues found proof for benefits from improved diabetes self-management on the management of hypoglycaemic crisis.³⁶ For diabetic patients enrolled in a telehealth programme, Chen and colleagues found improvement in problem solving through a

teleconsultant service.³⁷ Overall, crisis intervention may refer to recovery self-efficacy, as well as action control predictors of the HAPA. It is well known that during the phase of intention and action planning, coping strategies for potential setbacks need to be included.¹⁸ However, evidence is missing for what conditions are required to maintain a new behaviour and to prevent relapse, as well as how to re-establish the new behaviour after relapse.³⁸

An automated monitoring system that facilitates continuous monitoring of disease parameters, such as blood glucose tracking, was among the most cited potential features in the present study. In a cross-sectional study by Borges and colleagues, 111 participants were in favour of using continuous glucose monitoring provided it was easy to use and did not produce information overload.³⁹ Both preconditions support the importance of early-user integration in the design process of the Kir'App. Also, feedback and monitoring are among the most frequently applied behaviour-change techniques in theories applied to mHealth interventions.²⁶

Along with a monitoring of disease parameters, patients expressed the need for knowledge on behaviours related to everyday life with diabetes, such as foot care, for example. For rural diabetic patients in Montana, Ciemins and colleagues found higher adherence rates for regular foot care when applying a telehealth self-management programme.⁴⁰ Such cues to action are important in behaviour-change theories as well,⁴¹ which is why Schwarzer subsumes them under barriers and resources in the HAPA.¹⁸

Participants wish for an application feature that offers specific information on food, nonalcoholic drink choices and alcohol intake to facilitate their daily diabetes-related nutritional choices. The potential of telehealth applications to improve dietary behaviour are, again, supported by Chen *et al.*,³⁷ as well as by a randomized controlled trial carried out by Fernandes *et al.*⁴² Again, the presented findings support the link between health literacy and self-efficacy. Within theory, task self-efficacy describes the extent to which an individual is convinced to be able to successfully take up a particular behaviour.⁴³

Enhanced motivation through emotional and social support. In order to comply with diabetes-specific physical activity recommendations, participants expected the application to give them information

on the right type, amount of and motivational input for physical activity. This strongly relates to maintenance and recovery self-efficacy during the action planning and action control.¹⁸ Dobson and colleagues found improved patient adherence to diabetes and health behaviours, as well as better HbA1c values when using motivational text messages to support DSM.⁴⁴ In the present study, patients expressed their loneliness and they found that it could be addressed by an application feature that offers emotionally supportive content and the ability to connect with other people living with diabetes. This is an especially important contribution, given that Koetsenruijter and colleagues found a strong association between social support by emotional networks (family and friends) and successful diabetes self-management.⁴⁵

Our findings are supported by the qualitative results of Desveaux and colleagues calling for a balanced consideration of self-efficacy, competing priorities, previous behaviour change, and beliefs about Web-based solutions.⁴⁶

Implications

In a systematic review comparing 55 healthcare systems of sub-Saharan African countries in the management of diabetes, Rwanda was assessed among countries with health partnerships and systematic care that facilitate patient access to diabetes information, care and adherence to treatment.⁴⁷ Decentralization, focus on community health and insurance scheme are traditionally seen as strengths for the Rwandan health system.⁴⁸ These aspects may be a support to test, evaluate and roll out the innovative self-management application developed in the Kir'App Rwanda Diabetes study project.

The expectations and needs of Rwandan diabetic patients were collected using a strongly user-centred study design. Coresearch, defined as research in partnership with older people, is said to enrich results derived from research based on older peoples' interpretations of their own lives.⁴⁹ This method is said to foster an improved understanding of heterogeneous target populations and presents a promising approach for partnerships at the community level.⁵⁰ In addition to the fact that there is no current diabetes app available for Rwandan diabetes patients, qualitative findings from patients in Canada describe how currently available apps inadequately address the needs of patients.⁵¹

Limitations

Qualitative methods such as focus groups or in-depth interviews are commonly used for user-centred design processes in the domain of health technologies.⁵² However, the study design, using a semistructured interview guide for qualitative research, has well-known limitations. Although a pretest was conducted, back-and-forth translation from English to Kinyarwanda may have led to misinterpretations or loss of information. Additionally, analysis was theme based and interpretative. Therefore, the individual backgrounds of the researchers may have had an impact on the final results. In order to address this risk of confirmation bias, analysis of data was independently carried out by two of the authors and coding was later supervised by another.²²

As databases for patients with diabetes are missing, convenience sampling in a professional setting, the RDA, was used. Using this method, patients not attending this association at all were missed, or if not attending on a regular basis, were less likely to be included. This especially applies to patients living in rural communities, having limited health literacy (indicated by not visiting the RDA on a regular basis) or those being unaware of their conditions. Although attempts were made to recruit diverse patients, those that refused to take part may have provided additional insights. Therefore, participants of the interviews may be generally more responsive to health services and studies.

Data were collected from 21 individuals, derived from a highly heterogeneous study population (Table 2) in terms of age, sex, time since diagnosis and working status, and cannot be generalized to a larger population.

The study aimed to assess needs and expectations of Rwandan diabetic patients as potential users of the first Rwandan diabetes self-management app. Though specific functions would have been a valuable help to design this first app of its kind in Rwanda, participants may have been overstrained to imagine possible functions, as they never used a comparable app or device before.

Conclusions

The outcomes of this study have provided recommendations that are currently being used to

develop the first Rwandan diabetes self-management smartphone application, Kir'App. Kir'App is expected to strengthen the empowerment of Rwandan diabetic patients using smartphone applications in their diabetes self-management capacity. The expectations and needs of patients with diabetes is the strong focus on functions and design of a future smartphone application and is in line with the present call for user-centred development of health interventions. The qualitative insights provide a prototype of the first diabetes self-management smartphone application (Kir'App). The respondents highlight the importance of combining knowledge-oriented components with monitoring functions. They call for connecting their own living with diabetes with both social support derived from peers, as well as regional/national initiatives.

Acknowledgements

The authors wish to thank the Rwanda Diabetes Association for facilitating the process of the research. We also thank Rwandan diabetes patients for participating in our study and for providing rich insight. The authors also wish to thank Kristin Kemple for her linguistic editing.

Author Contributions

CK and PS contributed to the initial conceptual planning of the project and design of questionnaire. CK researched data. CK, PT and LH contributed to the analysis and interpretation of data. PT and LH contributed to the discussion, reviewed and edited the manuscript. CK, PT and LH wrote the manuscript. PS approved the version to be published.

Funding

This work was supported by the Ministry of Education of Rwanda and the German Academic exchange service (DAAD).

Conflict of interest statement

The authors declare that there is no conflict of interest.

Supplemental material

Supplemental material for this article is available online.

ORCID iD

Claudine B. Kabeza  <https://orcid.org/0000-0002-1218-5941>

References

1. International Diabetes Federation. *IDF diabetes atlas*. 8th ed. Brussels, Belgium: International Diabetes Federation, 2017; 9.
2. World Health Organization. *Rwanda*, http://www.who.int/diabetes/country-profiles/rwa_en.pdf (2016 accessed July 20, 2018).
3. Fenny AP, Yates R and Thompson R. Social health insurance schemes in Africa leave out the poor. *Int Health* 2018; 10: 1–3.
4. Makaka A, Breen S and Binagwaho A. Universal health coverage in Rwanda: a report of innovations to increase enrolment in community-based health insurance. *Lancet* 2012; 380: S7.
5. Mukeshimana MM and Nkosi ZZ. Communities' knowledge and perceptions of type two diabetes mellitus in Rwanda: a questionnaire survey. *J Clin Nurs* 2014; 23: 541–549.
6. Haas L, Maryniuk M, Beck J, *et al.* National standards for diabetes self-management education and support. *Diabetes Care* 2014; 37(Suppl. 1): S144–S153.
7. Turner RM, Ma Q, Lorig K, *et al.* Evaluation of a diabetes self-management program: claims analysis on comorbid illnesses, health care utilization, and cost. *J Med Internet Res* 2018; 20: e207.
8. Cunningham AT, Crittendon DR, White N, *et al.* The effect of diabetes self-management education on HbA1c and quality of life in African-Americans: a systematic review and meta-analysis. *BMC Health Serv Res* 2018; 18: 367.
9. Mezuk B, Thornton W, Sealy-Jefferson S, *et al.* Successfully managing diabetes in a community setting: evidence from the YMCA of Greater Richmond Diabetes Control Program. *Diabetes Educ* 2018; 44: 383–394.
10. Kruse CS, Soma M, Pulluri D, *et al.* The effectiveness of telemedicine in the management of chronic heart disease – a systematic review. *JRSM Open* 2017; 8: 2054270416681747.
11. Herold R, Hoffmann W and Van den Berg N. Telemedical monitoring of patients with chronic heart failure has a positive effect on total health costs. *BMC Health Serv Res* 2018; 18: 271.
12. Hanlon P, Daines L, Campbell C, *et al.* Telehealth interventions to support self-management of long-term conditions: a systematic metareview of diabetes, heart failure, asthma, chronic obstructive pulmonary disease, and cancer. *J Med Internet Res* 2017; 19: e172.
13. Jacques Rose K, Petrut C, L'Heveder R, *et al.* IDF Europe position on mobile applications in diabetes. *Diabetes Res Clin Pract* 2017; 149(2019): 39–46.
14. Loy JS, Ali EE and Yap KY-L. Quality assessment of medical apps that target medication-related problems. *J Manag Care Spec Pharm* 2016; 22: 1124–1140.
15. Asiimwe-Kateera B, Condo J, Ndagijimana A, *et al.* Mobile health approaches to non-communicable diseases in Rwanda. *Rwanda Journal Series F: Medicine and Health Sciences* 2015; 2: 4.
16. Slater H, Campbell JM, Stinson JN, *et al.* End user and implementer experiences of mHealth technologies for noncommunicable chronic disease management in young adults: systematic review. *J Med Internet Res* 2017; 19: e406.
17. El-Gayar O, Timsina P, Nawar N, *et al.* A systematic review of IT for diabetes self-management: are we there yet? *Int J Med Inform* 2013; 82: 637–652.
18. Schwarzer R. *Self-efficacy / thought control of action*. Washington; London: Hemisphere Pub. Corp., 1992; 217–243.
19. Zhang C, Zhang R, Schwarzer R, *et al.* A meta analysis of the health action process approach. *PsyArXiv*. Epub ahead of print 29 May 2018. DOI: 10.31234/osf.io/4pc27.
20. Rohani H, Sadeghi E, Eslami A, *et al.* (2018) Predictors of physical activity among adults with type 2 diabetes mellitus, Isfahan, 2015: structural equation modeling approach. *Int J Prev Med* 2018; 9: 66.
21. Bassett-Gunter R and Chang A. Self-regulatory self-efficacy, action control, and planning: there's an app for that! *Telemed J E Health* 2016; 22: 325–331.
22. Mayring P. Qualitative content analysis. *Forum Qual Soc Res* 2000; 1.
23. Goyal S, Nunn CA, Rotondi M, *et al.* A mobile app for the self-management of type 1 diabetes among adolescents: a randomized controlled trial. *JMIR Mhealth Uhealth* 2017; 5: e82.
24. Tong A, Sainsbury P and Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health Care* 2007; 19: 349–357.
25. O'Brien BC, Harris IB, Beckman TJ, *et al.* Standards for reporting qualitative research:

- a synthesis of recommendations. *Acad Med* 2014; 89: 1245–1251.
26. Yoon-Min C, Seohyun L, Shariful ISM, *et al.* Theories applied to m-health interventions for behavior change in low- and middle-income countries: a systematic review. *Telemed J E Health* 2018; 24: 727–741.
 27. Lippke S and Plotnikoff RC. Testing two principles of the Health Action Process Approach in individuals with type 2 diabetes. *Health Psychol* 2014; 33: 77–84.
 28. Marlatt GA and George WH. Relapse prevention: introduction and overview of the model. *Br J Add* 1984; 79: 261–273.
 29. Yeager CM, Shoji K, Luszczynska A, *et al.* Engagement with a trauma recovery internet intervention explained with the Health Action Process Approach (HAPA): longitudinal study. *JMIR Ment Health* 2018; e29.
 30. Mohebi S, Azadbakht L, Feizi A, *et al.* Review the key role of self-efficacy in diabetes care. *J Educ Health Promot* 2013; 2: 36–36.
 31. Kowall B, Rathmann W, Stang A, *et al.* Perceived risk of diabetes seriously underestimates actual diabetes risk: the KORA FF4 study. *PLoS One* 2017; 12: e0171152.
 32. Whitehead L and Seaton P. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. *J Med Internet Res* 2016; 18: e97.
 33. Saha S, Riemenschneider H, Müller G, *et al.* Comparative analysis of diabetes self-management education programs in the European Union Member States. *Prim Care Diabetes* 2017; 11: 529–537.
 34. Powers MA, Bardsley J, Cypress M, *et al.* Diabetes self-management education and support in type 2 diabetes: a joint position statement of the American Diabetes Association, the American Association of Diabetes Educators, and the Academy of Nutrition and Dietetics. *Diabetes Care* 2015; 38: 1372–1382.
 35. Reisi M, Mostafavi F, Javadzade H, *et al.* Impact of health literacy, self-efficacy, and outcome expectations on adherence to self-care behaviors in Iranians with type 2 diabetes. *Oman Med J* 2016; 31: 52–59.
 36. Gallé F, Di Onofrio V, Cirella A, *et al.* Improving self-management of type 2 diabetes in overweight and inactive patients through an educational and motivational intervention addressing diet and physical activity: a prospective study in Naples, south Italy. *Diabetes Ther* 2017; 8: 875–886.
 37. Chen L, Chuang L-M, Chang C-H, *et al.* Evaluating self-management behaviors of diabetic patients in a telehealthcare program: longitudinal study over 18 months. *J Med Internet Res* 2013; 15: e266.
 38. Kwasnicka D, Dombrowski SU, White M, *et al.* Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. *Health Psychol Rev* 2016; 10: 277–296.
 39. Borges U and Kubiak T. Continuous glucose monitoring in type 1 diabetes: human factors and usage. *J Diabet Sci Technol* 2016; 10: 633–639.
 40. Ciemins E, Coon P, Peck R, *et al.* Using telehealth to provide diabetes care to patients in rural Montana: findings from the promoting realistic individual self-management program. *Telemed J E Health* 2011; 17: 596–602.
 41. Riley WT, Rivera DE, Atienza AA, *et al.* Health behavior models in the age of mobile interventions: are our theories up to the task? *Transl Behav Med* 2011; 1: 53–71.
 42. Fernandes R, Chinn CC, Li D, *et al.* A randomized controlled trial of financial incentives for Medicaid beneficiaries with diabetes. *Perm J* 2018; 22: 17-080.
 43. Gough SCL, Kragh N, Ploug UJ, *et al.* Impact of obesity and type 2 diabetes on health-related quality of life in the general population in England. *Diabetes Metab Syndr Obes* 2009; 2: 179–184.
 44. Dobson R, Whittaker R, Pfaeffli Dale L, *et al.* The effectiveness of text message-based self-management interventions for poorly-controlled diabetes: a systematic review. *Digit Health* 2017; 3: 2055207617740315.
 45. Koetsenruijter J, Van Eikelenboom N, Van Lieshout J, *et al.* Social support and self-management capabilities in diabetes patients: an international observational study. *Patient Educ Couns* 2016; 99: 638–643.
 46. Desveaux L, Shaw J, Saragosa M, *et al.* A mobile app to improve self-management of individuals with type 2 diabetes: qualitative realist evaluation. *J Med Internet Res* 2018; 20: e81.
 47. Nuche-Berenguer B and Kupfer LE. Readiness of sub-Saharan Africa healthcare systems for the new pandemic, diabetes: a systematic review. *J Diabetes Res* 2018; 9262395.
 48. Samuels F, Amaya AB and Balabanova D. Drivers of health system strengthening: learning from implementation of maternal and child health programmes in Mozambique,



- Nepal and Rwanda. *Health Policy Plan* 2017; 32: 1015–1031.
49. Walker A. Why involve older people in research? *Age Ageing* 2007; 36: 481–483.
50. Buffel T. Older coresearchers exploring age-friendly communities: an ‘insider’ perspective on the benefits and challenges of peer research. *Gerontologist* 2018; 1–11.
51. Lithgow K, Edwards A and Rabi D. Smartphone app use for diabetes management: evaluating patient perspectives. *JMIR Diabetes* 2017; 2: e2.
52. Alpert JM, Krist Alex H, Aycock Rebecca A, *et al.* Designing user-centric patient portals: clinician and patients’ uses and gratifications. *Telemed J E Health* 2017; 23: 248–253.

Visit SAGE journals online
[journals.sagepub.com/
home/tae](http://journals.sagepub.com/home/tae)

 SAGE journals

Appendix

Table A1. Summary of recurrent themes and subcategories with examples.

Theme	Subcategory	Examples
(1) Education and desired information provision The theme refers to the provision of information, specialized education on diabetes in general and coping with the disease	(a) General information on diabetes, management and complications This subcategory refers to information that should be provided by the app in order to close general knowledge gaps on disease characteristics, management (through medication and behaviour change) and complications	<p>P5: 'I wish the application to help me to master in the care of my disease by giving me more information about diabetes and helping me to change behaviour in order to care after my disease.'</p> <p>P5: 'I need to know much about insulin. I think that even all those tablets we take are also insulin in different forms, but I would like to know if insulin injections taken on a long-term may cause damages in the human body. I know it's the only medication we must take, but are there precautions we should follow or respect while taking injections or other tablets? What are the short- or long-term complications which may occur? Right now, I have neuropathy; can't it be due to those insulin injections I am taking? There is also another problem we often discuss with other diabetics without finding answers: why are our bodies not producing insulin? I heard that it is because of malfunction of the pancreas (though I am not sure if that information is correct) but if it is, why can't our pancreas be treated and healed?'</p> <p>P11: 'First of all, the application should teach us the difference between type 1 and type 2 diabetes because most of people of my age don't know which type of diabetes they are living with. The application should also teach us more about the medications we take and why some people use tablets when others are using insulin although we all have type 2 diabetes? It should also teach us about side effects of medications, you know taking the same medicine for 10–20 years, I guess it causes some harm to the body. Because I know someone who was diagnosed with diabetes after me and the Dr. prescribed her immediately insulin. He told her that tablets are not good because they immediately go into the blood, and that insulin was better. I was really confused.'</p>
	(b) Medical parameters (e.g. blood pressure, blood glucose, HbA1c, weight, etc.) This subcategory refers to specialized knowledge on parameters of diabetes symptoms and progression	<p>P18: 'The application should have a special page about all the tests and health exams we need to do as diabetics and mention when and why we should do them. Imagine that I used to think that through the HbA1c test, both my eyes and kidneys were also screened.'</p> <p>P4: 'My blood glucose levels sometimes reach 400 mg/dl. I wish the application to tell me what caused it to raise that high and very importantly to teach me how I should lower it. Can it also have the capacity to show me my blood glucose levels?'</p> <p>P3: 'The application should teach me what are the normal values of HbA1c, the poor values to avoid and how to keep it in normal ranges.'</p>
	(c) Devices This subcategory refers to information provision on new medical devices to monitor diabetes parameters	<p>P5: 'I wish the application to inform me about newly discovered devices being available on the market that may help in diabetes care. You see, we use different glucose meters. I would like the application to tell us for example whenever there are some other available new glucose meters that can be more efficient, and maybe less expensive. Or maybe some other devices we don't know so far that can be used in diabetes care.'</p> <p>P16: 'In case I want to check my blood glucose levels, I wish an application that can show me my blood glucose levels by using my finger print only without being obliged to prick my finger to get a blood drop.'</p> <p>P21: 'You know many diabetics like me don't have glucose meters or we buy them and don't repair them once they have defects. We take our medication without knowing our levels of blood sugar and we only come here to the clinic once in month to check it or whenever we don't feel okay. Is that good? The application should teach us more about that.'</p>
	(d) Frequently asked questions by newly diagnosed patients This subcategory refers to a repository of information for those newly diagnosed with diabetes	<p>P13: 'There are some people who are newly diagnosed with diabetes and who have a million questions about it, even we ourselves still have many unanswered questions about it, so the application should have a function of 'frequently asked questions' with their answers for a rapid consultation in case of need.'</p> <p>P14: 'It's been only 1 year since I was diagnosed with diabetes and I have to confess that I have many unanswered questions about it. Maybe the application can make a kind of summary about everything a new diabetic has to know so by reading it we can have an overview of our disease.'</p>

Table A1. (Continued)

Theme	Subcategory	Examples
(2) Lack of knowledge/ awareness This theme comprised characteristics of the individual end user, mainly knowledge gaps	(e) National/regional update and initiatives, as well as services This subcategory refers to information on national and regional initiatives on diabetes care as well as local services	<p>P5: 'I wish the application to inform me about activities concerning diabetes that are taking place in Rwanda and that we can attend. And those ones taking place outside Rwanda even if I may not be able to attend them. Activities like meetings, workshops, conferences and sensitization activities about diabetes that are being organized for patients because now we don't attend many due to lack of information.'</p> <p>P1: 'Another idea that would be great would be an application that can indicate us possible pharmacies (in Kigali for example) where someone can buy insulin and syringes. Because someone can come from another province (for example, western) to Kigali and not knowing where to buy products he really needs for his diabetes care.'</p>
	(a) Lack of knowledge on living with diabetes This subcategory refers to knowledge gaps concerning the everyday life with diabetes, especially concerning disease-related behaviour	<p>P16: 'Sometimes there are some topics the Dr teaches me when I come to my regular appointments but I don't understand them well and I ask for more explanations to my mother and then we google them [for example, about the control of blood glucose levels, food and so on] and try to get answers. So, I think that if we had the application, it would help me to learn more.'</p> <p>P7: 'What is the problem with feet in diabetes? I didn't know that someone could develop foot problems because of diabetes. Right now, I have athlete's foot and I've never thought that it could be linked to my diabetes but now that you mention it, I will go back to the doctor and ask for a treatment. Now, I wish the application to teach us about foot problems in diabetes, I can learn how to take care of them and I can use it to teach other diabetics like me who may be unaware of that information.'</p> <p>P10: 'The application should teach us about type 1 diabetes and pregnancy. We are not sure if as type 1 diabetics we can have children, and if we get pregnant, can we keep taking insulin?'</p> <p>P4: 'The application should teach us about diabetes care in our everyday life, for example I smoke, I would like to know if it is good or bad for a diabetic.'</p>
	(b) Prejudice and myths (social media knowledge) This subcategory refers to false information being considered true	<p>P4: 'The application should also tell us about all possible diabetes myths [for example some people say that when you grow up, your diabetes shift from type 1 diabetes to type 2], in order to protect us against them since there are many outside here and sometimes the person telling it looks smart and you are tempted to believe him.'</p> <p>P6: 'The application can teach type 1 diabetics about how to live their love life with their diabetes. Most of them are ashamed to tell it to their partners. Because there are many known cases where the partner broke with the person after knowing that s/he had diabetes. Some people didn't go to school or don't know much about diabetes, they think that the person can contaminate them, others think that once they get married they can die or develop complications and that their lives would be worse or the healthcare would cost them much.'</p> <p>P3: 'The application should teach us about diabetes myths and how to behave as young diabetics. How to behave once a type 1 diabetic gets married, how to behave at your work or in your family and how to deal with alcoholism, drug abuse, adultery, fighting, etc.'</p>
(c) Lack of knowledge on Web 2.0 This subcategory refers to gaps in digital knowledge and trust in technology	<p>P15: 'I've seen some [application] on Google Play but it requires a subscription; they are being connected to your bank account and they draw money from it. I was not sure of them, scared of hackers, I abandoned the idea of subscription.'</p>	

(Continued)

Table A1. (Continued)

Theme	Subcategory	Examples
(3) Crisis intervention This theme refers to information provision in case of disease complications in order to prevent panicky behaviour		<p>P3: 'When I am in class and start feeling bad, I wish to be able to check the application and get to know if it is a hypo or a high episode I am going through.'</p> <p>P12: 'The application should teach us how to behave once you have hypos or highs because sometimes you become stressed which can raise your blood sugar levels more. It (the application) can also be my logbook where I can write my blood sugar levels and my doses of insulin of every day.'</p> <p>P9: 'I wish the application to teach me tips about food and drinks or anything else that can help me to keep myself from hypos and highs. I hate to have hypos because after the hypo episode, everyone knows that I have diabetes and I hate people to know that I have diabetes.'</p> <p>P14: 'Right now, I have a flu and whenever I have it, I lose appetite and can't eat anything which causes me to have high blood sugar levels that I treat with insulin and then I have low blood sugar levels. So the application should teach us about the management of diabetes in case we have other diseases like flu, malaria, that can interfere with our appetite and cause changes in our blood glucose levels. Those diseases have even some symptoms similar to hypo/highs and you can't guess if you have a hypo or high.'</p>
(4) Monitoring and reminder functions This theme refers to monitoring and reminder functions; the app should incorporate disease-relevant parameters, including medication, physical activity and nutrition	(a) BG/BS recording and trend visualization This subcategory refers to monitoring and display of changes in diabetes parameters to be done via the app	<p>P2: 'Another thing I wish the application to offer would be a kind of diary to record the results of our blood glucose, A1c, blood pressure and body weight checking. A diary on which we can write possible mistakes, which may have caused the results of these health check-ups to be high or low compared to the normal values. That diary would help us to do a kind of self-evaluation. Based on knowing the mistakes we did, next time we may take measures for correcting them referring ourselves to our diary.'</p> <p>P3: 'The application should [...] help me to keep all my previous health records in order to show them to the Dr so he can do a follow up of my progress.'</p> <p>P4: 'I usually use a diary to record my blood glucose results but when I have a fieldwork or when I go unexpectedly for a job mission I forget the diary but I never forget my smartphone, so it would be good to have a kind of electronic diary.'</p> <p>P13: 'Sometimes when you are not at home, it's challenging to measure your blood sugar in order to take your insulin. I know that there are applications that show people what is their heart beat and pulse. I wish we could also have an application that shows us our regular blood glucose levels without being obliged to use glucose meter and needles.'</p> <p>P15: 'I usually work much and use much energy since I am an IT technician, so at 11-12 a.m. when I take a break, I would like the application to show me the variation of my blood glucose levels. Then other times when I am not using much energy like when I am repairing a computer, the application can also help me to track the variation of my blood glucose levels. This way I can get to know how my blood sugar levels change depending on my daily activities and know how to adjust to it.'</p> <p>P16: 'I wish the application to track my physical activity, show me my heart beat and tell me when I have done enough exercise.'</p>
	(b) Reminder functions This subcategory refers to automated reminders for physical activity, insulin use and food intake to be provided by the app	<p>P2: 'It could also remind me when to do exercise during the week days because I forget it most of the time and my mother has to remind me to do it with her only on Fridays after work, though I know I have to do it at least three times a day. So if I had an application in which I could set days of doing sport for example on Mondays, Wednesdays and Fridays, I think it would be great and help me more in controlling my blood sugar.'</p> <p>P3: 'The application should first remind me of the Dr's appointment.'</p> <p>P13: 'The application can remind me to check my blood sugar and to take my insulin injection at the same hour of every day. It should ring also at the same hour of every day to remind me to do exercise because I can be busy and forget to do it so the application should remind us that even when busy, we should find 30 min for exercise. It should also remind me of doctor's appointments.'</p> <p>P14: 'The application should remind me when it's time to check my blood sugar and the estimated time my insulin medication will run out so I can buy another one on time because sometimes I just forget to buy it and I experience shortage when I am not ready to buy another one (not having money for example) and I can spend a day or two without taking it which is bad.'</p>

Table A1. (Continued)

Theme	Subcategory	Examples
(5) Nutrition and alcohol consumption This theme refers to information provision on food and drink choices, as well as alcohol intake, to be delivered by the app	(a) Composition of a diabetic plate This subcategory refers to information provision on what kind of food is complementary with the disease	<p>P3: The application should teach us about types of food that don't contain much glucose. Sometimes I may take much quantity of rice and little quantity of beans whereas I should do the opposite. I wish the application to teach me what quantity of which food to put on my plate and the content of each possible food in terms of glucose and other nutrients.'</p> <p>P6: For the food, the application should show us which one is allowed. They usually teach us about how a diabetic plate must be prepared (how to divide it in 4 parts: with one side for banana, another one for beans, another one for vegetables and fruits) but we most of the time forget it, so the application should give us a list of different categories of food we can eat depending on the availability of food we have here in Rwanda.'</p> <p>P5: We need to have an application that can teach us more about diabetics' diet. Having a list of common food with their glucose content. You hear some people saying, potatoes contain much glucose, another one; rice is worse, another one; forget sweet potatoes for the good. That's the main problem I experienced when I was diagnosed with diabetes; suddenly I was not allowed to eat anything. I lost much weight and I was most of the times nearly fainting because of hunger. [...] And when I talk with other diabetics; that is the very first main challenge they say that they meet.'</p>
	(b) Information on nonalcoholic beverage choices This subcategory refers to information about diabetes-appropriate choice of beverages the app should provide	<p>P2: Sometimes it is really hard for example in case of a party taking place at home when others are drinking soda or juice and you wonder what to do; drinking them or mix them with water and do like you are enjoying the drinks like others? So most of the time I check my blood sugar and drink a soda. I also heard that drinking water reduces blood sugar, so sometimes when I have high blood sugar (in case of sorrow, stress, etc.), although I have taken my insulin shot, I wonder if I could drink water and reduce my blood glucose instead of taking another injection.'</p> <p>P7: [...] for example, I personally like soda very much and after I was diagnosed with diabetes I had to stop taking it and whenever I used to pass by shops with sodas in fridges I felt my heart aching remembering that I couldn't drink it anymore. But is it true? Can't we take some food or drink we like maybe once in a while and keep enjoying our life?'</p> <p>P8: The application can teach us about milk, because I love milk; I can take 1 litre of curdled milk a day. But the application should also tell us something about pasteurized milk. There are some people like me who can even take 3 litres of milk a day but we don't know if it can cause problems or if it can interfere with the pills or insulin we take.'</p>
	(c) Information on alcohol intake This subcategory refers to information about the acceptable kind and amount of alcohol the app should provide	<p>P13: [...] some people like drinking alcohol, the application should maybe direct us how much quantity they should drink, maybe a half bottle. For example, type 1 diabetics feel young and strong. Some drink alcohol and when you get drunk, you can easily fall down and get injured and some people aren't even aware of their injury when they are high, coming home, they sleep and the next day they deal with their hangover and the person may have to go to a hospital when the wound is infected and maybe get amputated in the future.'</p> <p>P18: I wish to have a special page about beers diabetics can drink and have fun with friends and still enjoy life. Or a page on how to still enjoy life besides having diabetes, because some people choose not to take insulin injection or pills when they are going to take beers, thinking that beers and medications should never be mixed. Other people cannot stop taking beers: should they die? Like me, I can take 5 bottles of Skol (malt) when I am with my friends, I know it's bad but what should I do, I like it.'</p> <p>P5: You hear also some men (diabetics) saying that the doctor said they can take Skol and you wonder which kind doctor advises his patients to take alcohol. They forget that even if alcoholic beverages are bitter but still have amount of carbohydrates which increase blood sugar levels.'</p>
	(d) Pleasures of eating This subcategory refers to the perceived cognitive effort of dietary food intake and the consequences for enjoyment when eating	<p>P21: Isn't there any way our everyday life could be improved? Why do we have to eat only bitter? Aren't there new researches about that? The application should inform us about that.'</p> <p>P11: Maybe the application can also give us tips on how to enjoy our food, because diabetics are known to always eat bitter. And when you are diagnosed at an old age, it is really hard to stop with your life time habits in terms of food.'</p> <p>P4: Sometimes I refuse to go to parties because I don't drink alcohol and when I think I can't take soda either I refuse to go as I hate to always drink water. Can the application teach me what else I might do to enjoy parties like others?'</p> <p>P19: I stopped to eat whatever contains sugar even fruits; I can't eat banana or pineapple, I only use the diabetic sweeteners. If the application could teach me which fruits are good and at which quantity I can eat them, it would be great.'</p> <p>P20: I stopped to eat quite everything because people and doctors were telling me to do so. I used to like rice, I can't eat it anymore. That is to cite one example; they tell us to eat pumpkins only. But can someone survive with that one kind of food? The application should tell us about all categories of food we are allowed to take.'</p>

(Continued)

Table A1. (Continued)

Theme	Subcategory	Examples
<p>(6) Physical activity This theme refers to information provision on the right kind and amount of exercise as well as motivational input for physical activity to be delivered by the app</p>	<p>(a) Type of sport This subcategory refers to the kind of physical activity one should pursue when having diabetes</p>	<p>P11: 'Which physical activity fits old people like me?' P17: 'The application can teach us about acrobatic games that are safe for diabetics. I used to be a player of acrobatic games but when I was diagnosed with diabetes, I stopped it and this frustrates me because I used to like it much.' P16: 'The application should show us which equipment diabetics are allowed to use in the fitness studio and the time they should spend using them. Which one is better to use in order to make us healthier? And of course the ones that might be dangerous for us and what we don't really need.'</p>
	<p>(b) Motivation for physical activity This subcategory refers to motivational input the app should deliver to the end user</p>	<p>P11: 'I am retired and have time for exercise but I lack motivation and become discouraged whenever I imagine what people would think if they see an old woman running on the street. I don't have people who motivate me. Sometimes I exercise at home and walk many rounds during 30min but it's not every day. I wish the application to give us motivation.' P14: 'The doctor told me to exercise at least 40min a day, he said I have to walk quickly but I am not able to do so, that's why I don't exercise at all. Maybe the application could teach us more flexible ways of exercising so we can be motivated to do it instead of abandoning it completely.' P20: 'It is really hard to exercise every day. You know it is really difficult to wake up every morning for exercise when you are 50-years old and you've never done it before. I tried and failed.'</p>
	<p>(c) Frequency and duration of physical activity This subcategory refers to information on the right amount of physical activity one should pursue to be delivered by the app</p>	<p>P16: 'I wish the application to track my physical activity, show me my heart beat and tell me when I have done enough exercise.' P20: 'Then I decide to exercise twice a week after my job. I do it for like 1 h. But I don't know if it is enough. The application should teach us about what is better to do.' P3: 'Sometimes we see other people exercising for example for 2h and we follow them. I wish the application to teach me what, as a diabetic, I am supposed to do before I am working out. The application should [...] teach [...] the right duration of physical exercise because for example I can go for a football game which lasts for 90min and may encounter some problems.'</p>
<p>(7) Coping with burden of disease This theme refers to functionalities of the app which allow for better coping with diabetes through emotionally supportive content and the ability to connect with others suffering from diabetes</p>	<p>(a) Emotional support This subcategory refers to supportive content for emotional distressing situations due to the disease, which should be provided by the app</p>	<p>P1: 'Receiving some recommendations and advice from the application would be very helpful. For example, some advice about behaviours to adapt in different situations, like now I am about to start university. The application can give me some advice for example about how to cope with the stress caused by the new environment; how to keep on respecting my schedule of taking my insulin injections on time and so on.' P2: 'I wish the application could give me advice about how to control my emotions (anger, bitterness, stress, sorrow, etc). Since I heard that most of them cause the blood sugar to raise. It should give me some advice for example to listen to music and sleep whenever I feel unhappy and so on.' P3: 'The application should teach us how to behave as a diabetic; for example, as a young girl how to avoid alcoholism, drug and adultery which hinder my health and my blood sugar and worsen my diabetes. How to behave with my friends who don't have diabetes or other people or my family in general. Because there are some diabetics who live isolated, always angry or depressed and don't live well with others. How to behave at home; some don't live relaxed at home with their siblings (or are never happy for/with them) or are jealous of them because they are sick and not them. Some refuse to do any chore at home pretending that they are sick and spend time in bed while their siblings are doing everything. They may not play with them as a kid, not eat the same food like them and use their disease to be capricious or disturb the family atmosphere because of their diabetes.' P6: 'You can teach young people with type 1 diabetes about having hope in life. As we know that diabetes can be hereditary, some of us just stack on that idea and live hopeless thinking that they can never get married because they don't want their children to live the same hell they are living. Whenever I meet some, I try to convince them of the opposite; showing them how a young type 1 like me became a happy married woman with one kid without diabetes and pregnant with a second one and that I live a happy life, but it is hard to convince them. So if the application could teach us about that aspect, it would be very great.'</p>

Table A1. (Continued)

Theme	Subcategory	Examples
	(b) Social support This subcategory refers to social support when dealing with diabetes, which should be incorporated into the functionalities of the app	<p>P11: 'I told you that I sometimes become discouraged to go for exercise alone because in my neighbourhood there are only young people busy with their jobs. There is no other people with diabetes or hypertension to motivate me; if the application could help us knowing each other; we can even organize meetings and share our experiences; our hope to live. Like I was diagnosed at an old age but there are young mothers and fathers who need to be encouraged to fight and keep living and see their children growing up.'</p> <p>P12: 'The application can give us a function to teach us to accept our disease, to strengthen our self-confidence and help us to keep strong. To remind us that despite of our disease we will become adults like others. Because sometimes when we meet with discouraging people, we feel down. I don't know if we can have a forum on the application where we can meet as diabetics but also invite other people so we can explain them about diabetes. Telling them that despite of our diabetes, we are also human beings. To tell them, that they should not despise us because we didn't choose to suffer from it.'</p> <p>P8: 'Can the application put me in contact with other people for example when I am feeling down so they can help me feel better (a kind of disease partner not necessary sick but who knows diabetes well and who can help me)?'</p> <p>P17: 'There should also be a function like a forum where we can share our contacts, address, picture and our goal or dream in life so we can get to know each other as diabetics. See, today I met a guy here at the clinic I use to meet in my neighbourhood without knowing he was also a type 1 diabetic. If we knew we had the same condition, I am sure we could have helped each other much.'</p> <p>P18: 'I think the app can connect us because like me I don't know many other diabetics and I think its causes me to be less informed.'</p>
(8) App features Although participants had difficulties imagining possible app functions, this theme refers to interactive information delivery options and the integration of different languages	(a) Information delivery This subcategory refers to content to be delivered via text, images, audios and videos	<p>P5: 'Videos are better, because you can see and understand what the doctor is explaining. At my age, reading may be tricky. I think that having both may be better.'</p> <p>P3: 'Sometimes we cannot even raise our hand when we are in a hypo, so the idea of having an audio would be to instruct us on what to do in case of a hypo crisis. Otherwise you can neither read nor watch a video.'</p> <p>P1: 'Having an audio to tell you what to do in case of hypos and high sugars would be great since you cannot read or watch a video properly when you are experiencing one of those crises but you can listen to an audio and follow instructions [...] The idea of using images to show you how to take care of my foot would also good.'</p> <p>P7: 'Videos are also better because when reading, you can get confused, but when you see the person speaking, you understand well.'</p> <p>P11: 'Videos are better because sometimes you can read and don't understand meaning and the context.'</p>
	(b) Available languages This subcategory refers to desired languages to be supported by the app. Participants either wish to include local language, Kinyarwanda, or to also include English	<p>P7: 'Kinyarwanda is better because even if you think you speak English, you may start reading and be confused with medical or scientific terminology, though you needed to understand everything well.'</p> <p>P3: 'It would be great to have an option to change the language like for Facebook (the application should be both Kinyarwanda or in English for the choice of the user).'</p> <p>P1: 'Having an option of either using it in Kinyarwanda, French or in English would be better.'</p> <p>P5: 'It's better to have the application in Kinyarwanda because many people, even if they went to school, they may not understand medical terms if they are in English.'</p> <p>P13: 'Some Rwandans don't know Kinyarwanda well, it will be better to put the application in both Kinyarwanda and English.'</p>
	BG, blood glucose; BS, blood sugar; HbA1c, glycated haemoglobin; IT, information technology.	

3. Kir'App, the first Rwandan diabetes self-management smartphone application

3.1. Kir'App description and development process

Kira Application (Kir'App), a friend in diabetes derives its name from the word “*Kira*” which means “*be healthy*” in Kinyarwanda (national language spoken in Rwanda). That word is famously known in Rwandan culture because it is said to everyone who sneezes to wish them to be healthy. Kir'App's interface color is orange to mean; *health, change, encouragement and determination*”.

Kir'App is a free client-centered diabetes self-management smartphone application which is available in both English and Kinyarwanda. The App is currently accessible for Android users on Google Play store (<https://play.google.com/store/apps/details?id=com.kirapp.dk.kirapp&hl=en>) and will soon be available on iOS platform for iPhone users.

Kir'App was developed following the recommendations of numerous studies stating that the planning, the design and the implementation of diabetes management apps should be user-centered by prior consideration of their needs and expectations (Krošelj et al., 2016; El-Gayar et al., 2013; Scheibe et al., 2015; Conway et al., 2016; Chavez et al., 2017; Rossmann et al., 2019).

The design of engagement approach of such devices was found to be more important than the features of their technology for successful use and for producing potential health benefits (Patel et al., 2015). And even though mHealth technology acceptance was proven to be high in some cases, their engagement was still low; thus the recommendation to include users' needs in their development for the improvement of their engagement and functionality (Conway et al., 2016).

Therefore for the respect of these existing recommendations, before developing Kir'App we first assessed Rwandan diabetics' needs and expectations from their first-to-be diabetes self-management Smartphone App.

However, even if in order to avoid influences and limitations of the existing Apps Kir'App was fully developed based on the needs and expectations of Rwandan diabetics, we ensured to follow basic international standards on the development of mobile health Apps by using the Mobile App Rating Scale (MARS).

The Mars scale is a simple, objective reliable and standardized tool used for the classification and assessment of the quality of existing mobile health apps and for the design and the development of new high quality health apps. It provides a checklist that helps to score apps on the criteria of:

- (1) Engagement (the app has to be fun, interesting, customizable, interactive e.g. sends alerts, messages, reminders, feedback, enables sharing and addressed to well-targeted to audience).
- (2) Functionality (the app functioning has to be easy to learn and have easy navigation, logic flow and gestural design).
- (3) Aesthetics (the app has to have graphic design, overall visual appeal, colour scheme and stylistic consistency).
- (4) Information quality (the app has to contain high quality information e.g. text, feedback, measures, references from a credible source)(Stoyanov et al.,2015 ; Messner EM et al., 2020).

3.2. Functionalities (pages) of Kir'App

Kir'App has 10 functionalities or pages. The first 8 pages contain mainly educative content that cover diabetes knowledge and information through means of texts and images. It also has reminder functions specific for each medical parameter needed to be checked up in diabetes, a logbook to help the user recording the results and an option to visualize their trends. Kir'App has also a location finder for pharmacies in Rwanda that sell diabetes medications and products.

The first 6 pages of Kir'App share 6 common features;

- (1) *"The must know"* (where the user finds detailed information on the specific topic of the page.
- (2) *"The frequently asked questions"* (with their answers on the topic)
- (3) *"The Myths or rumors"* (with their truths on the topic)
- (4) *"My diary"* (where the user writes comments, questions, feelings about their health and set goals)
- (5) *"Ask your questions and give your comments"* (the user uses this platform to ask questions or give comments on diabetes in general and on Kir'App content to the diabetes educator who runs the App).
- (6) and the *"References used"* (for all the information provided).

Page 1: “Teach me about diabetes”; is a page designed to introduce the user to the general knowledge on diabetes; from its history in the world to its complications in human body.

Page 2: “Food, drinks and diabetes”; teaches the user everything they need to know about food and drinks recommended in case of diabetes.

Page 3: “Physical activity and diabetes”; It’s a page that helps the user to understand what to do as physical activity in diabetes, why, how and when.

Page 4: “Blood sugar and diabetes”; allows the user to demystify blood sugar in diabetes and teaches them how to control it.

Page 5: “Feet and diabetes”; explains to the user details of why and how to take care of their feet in diabetes.

Page 6: “Diabetes health checkups”; teaches the user about every laboratory exam and health test they need to check up in case of diabetes.

Page 7: “Advise me”; it’s a page that goes in everyday life and advises the user on how to live well and happier with diabetes in every domain of personal and social life.

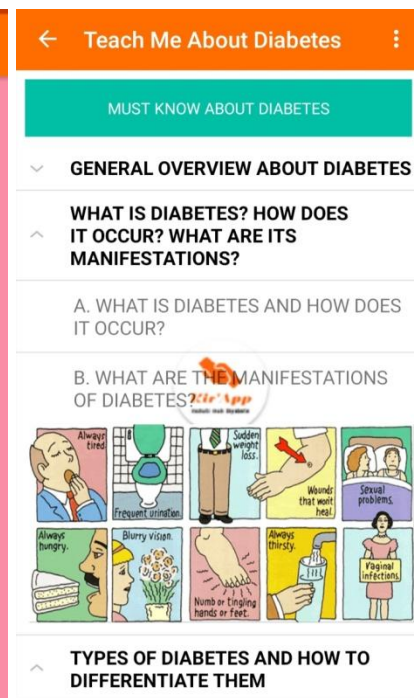
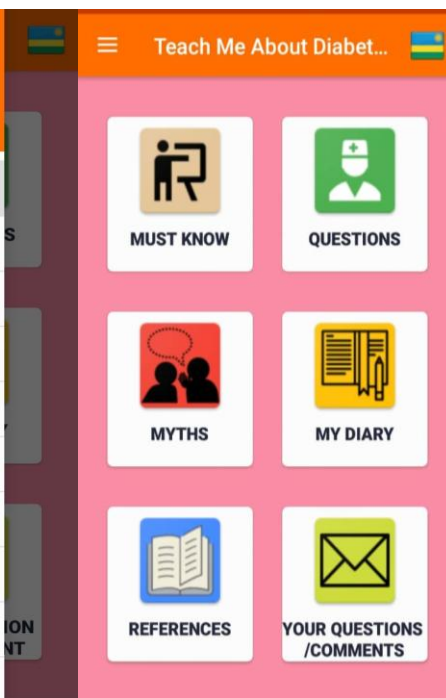
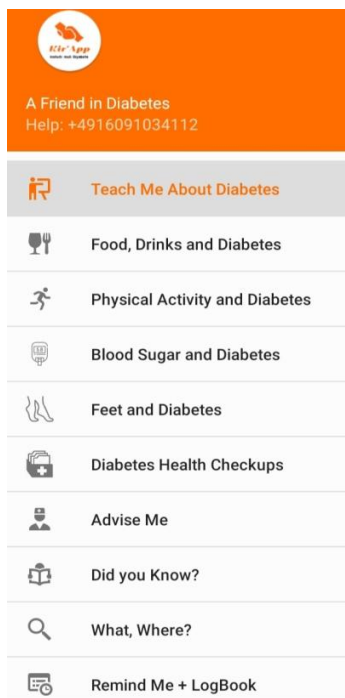
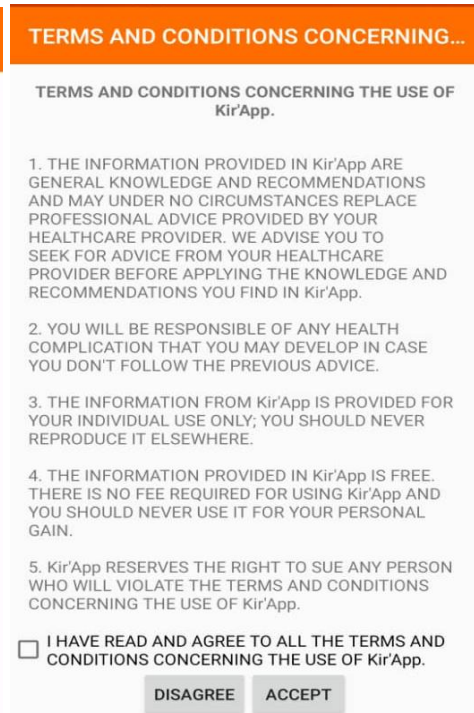
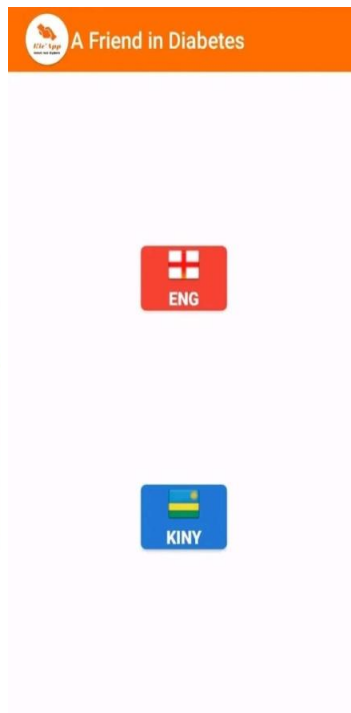
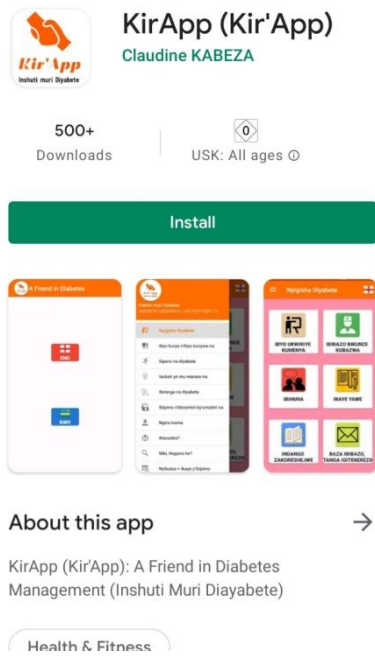
Page 8: “Did you know”; helps to raise diabetes awareness in non diabetes people, and to inform diabetics about diabetes news and updates in Rwanda and in the World.




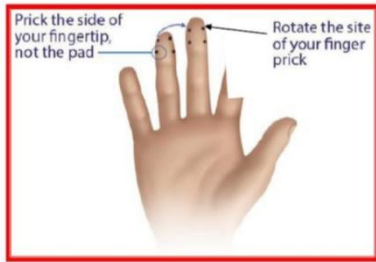
Page 9: “What, Where?; informs the user about diabetes events and important places they need to know such as nearest pharmacies with diabetes medications and products.



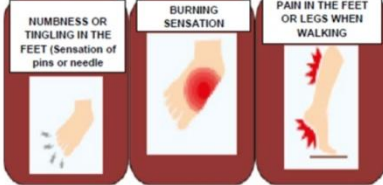






Page 10: “Remind me + Logbook”; it’s a page with reminders that are designed to remind diabetics about every activity they need to do to manage their disease, medical checkups included. It also offers options to convert and interpret lab results, logbooks to record information about each action for future use, and trends visualization of the results of medical checkups.

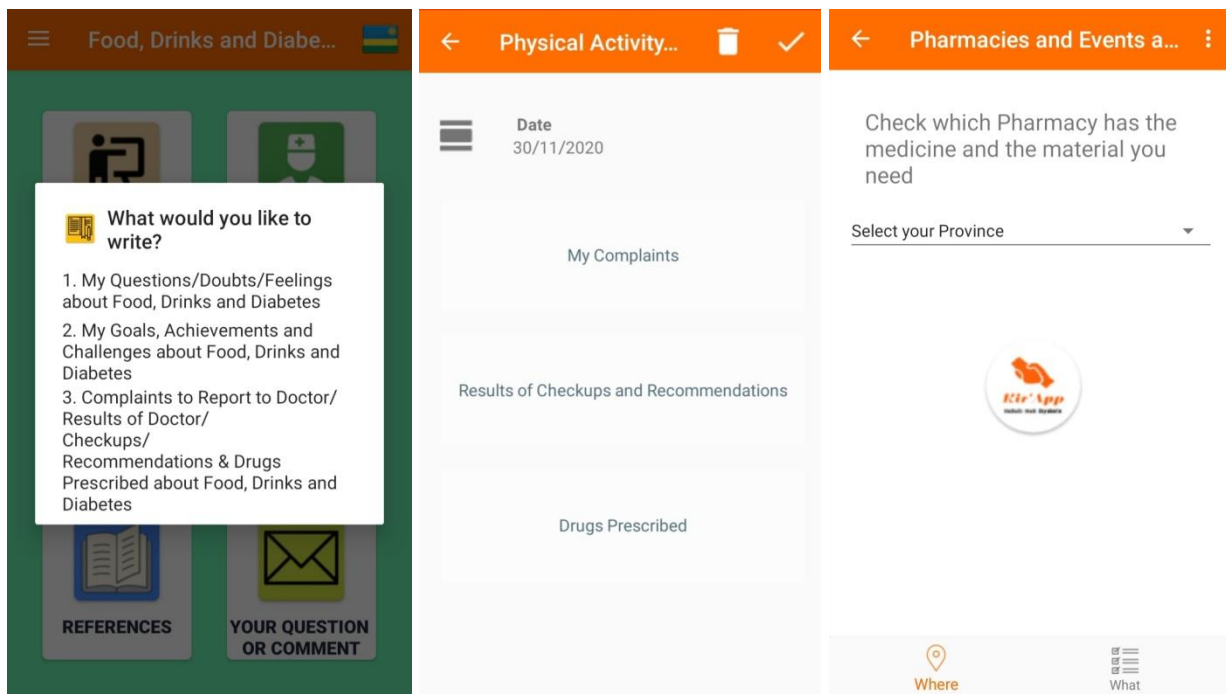
Before using Kir’App, users have to accept the terms and conditions that inform them that the information provided in Kir’App are general knowledge and recommendations and may under no circumstances replace professional advice provided by their healthcare providers. They are also notified that the information from Kir’App is provided for their individual use only; they should never reproduce it elsewhere. Details of Kir’App content can be accessed via <https://www.kirapp.org/>.

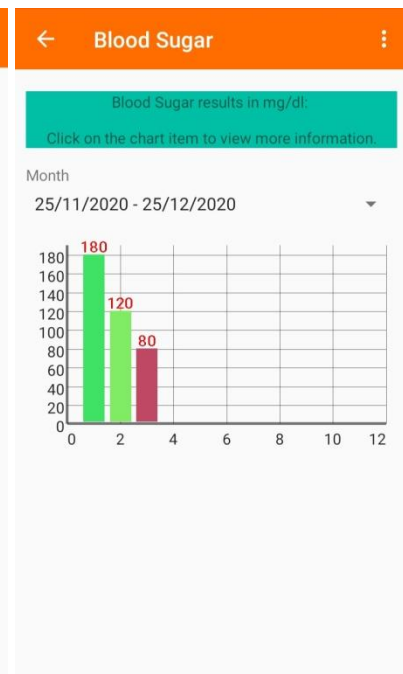
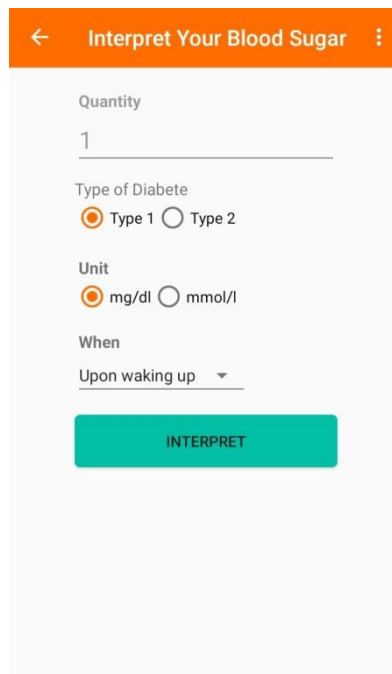
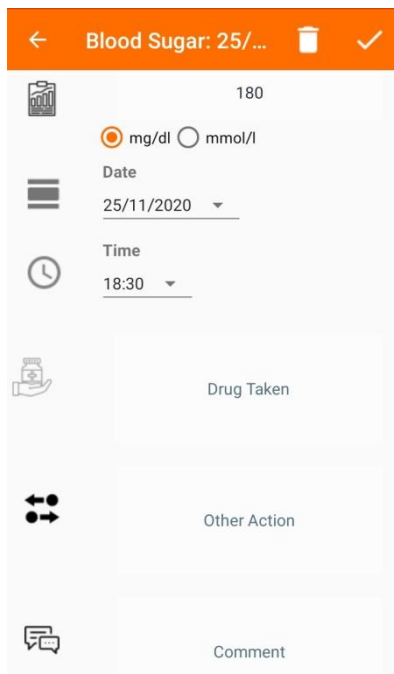
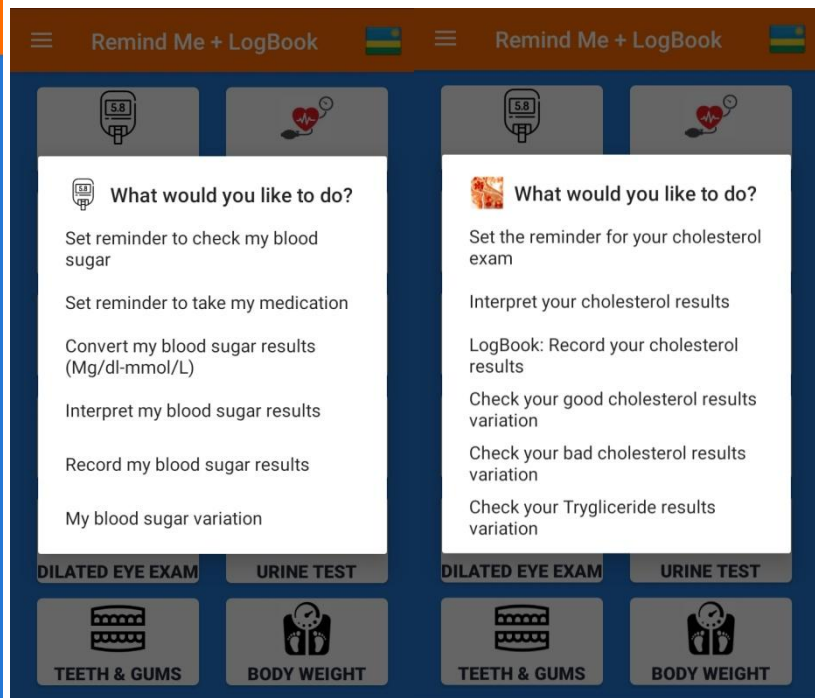
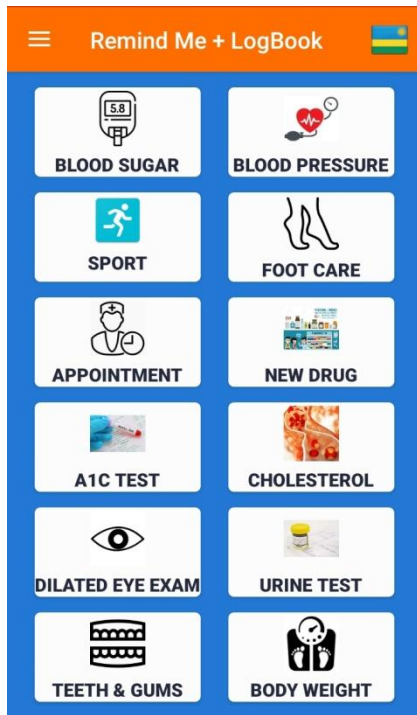
3.3. Some of Kir'App features in screenshots



<p>MUST KNOW ABOUT FOOD, DRINKS AND DIABETES</p>	<p>B.2.3. TYPES OF FIVE STRENGTH TRAINING ACTIVITIES YOU CAN TRY</p>	<p>MUST KNOW ABOUT BLOOD SUGAR AND DIABETES</p>
<p>^ NUTRITIONAL RECOMMENDATIONS IN DIABETES</p>	<p>1. WEIGHT MACHINES OR FREE WEIGHTS AT THE GYM</p>	<p>^ HOW TO USE A BLOOD SUGAR METER?</p>
<p>^ CLASSIFICATION OF FOOD AVAILABLE ON RWANDAN MARKET ACCORDING TO THEIR TYPES OF NUTRIENTS</p>		<p>A. GENERAL INSTRUCTIONS</p>
<p>^ HOW MUST A DIABETIC'S PLATE BE PREPARED?</p>	<p>2. RESISTANCE BANDS</p>	<p>B. HOW TO CHOOSE A GOOD BLOOD SUGAR METER?</p>
<p>FOOD PYRAMID FOR HEALTHY EATING HABITS</p> 		<p>C. WHERE TO PRICK ON THE FINGER TO GET A BLOOD DROP</p> 

<p>MUST KNOW ABOUT FEET AND DIABETES</p>	<p>MUST KNOW ABOUT DIABETES HEALTH CHECKUPS</p>	<p>MUST KNOW ABOUT DIABETES AND LIFE</p>
<p>^ FOOT PROBLEMS IN DIABETES</p>	<p>(HEMOGLOBINE GLYQUEE)</p>	<p>^ DIABETES IN EVERYDAY LIFE</p>
<p>A. WHO IS AT RISK FOR HAVING FOOT PROBLEMS IN DIABETES?</p>	<p>B. BLOOD PRESSURE MEASUREMENT</p> 	<p>A. YOU NEED TO HAVE THESE 2 PEOPLE IN YOUR LIFE</p>
<p>B. SEE YOUR DOCTOR AS SOON AS YOU FIND ANY OF THESE WARNING SIGNS</p>	<p>C. BLOOD TESTS TO MEASURE CHOLESTEROL AND TRIGLYCERIDES</p> 	<p>B. MAKE YOUR OWN "FIRST AID KIT"</p>
	<p>D. DILATED EYE EXAM</p> 	<p>C. DIABETES AND BAD MOODS</p>
	<p>E. URINE TEST</p> 	<p>D. DIABETES AND LONELINESS</p>
	<p>F. FEET EXAM</p> 	<p>E. DIABETES AND SELF-CONFIDENCE</p>
	<p>G. TEETH AND GUMS EXAM</p> 	<p>F. DIABETES AND LACK OF SLEEP</p>
	<p>H. BODY WEIGHT CHECK</p> 	<p>G. DIABETES AND LOSS OF MEMORY</p>
		<p>H. DIABETES AND TRIPS</p>
		<p>I. DIABETES AND SMOKING</p>
		<p>J. DIABETES AND ALCOHOL DRINKING</p>





4. Publication 2: A qualitative study of users' experiences after 3 months: the first Rwandan diabetes self-management Smartphone application "Kir'App"

This chapter presents the second publication as originally published.

The original publication is available at:

<https://journals.sagepub.com/doi/full/10.1177/2042018820914510>

A qualitative study of users' experiences after 3 months: the first Rwandan diabetes self-management Smartphone application "Kir'App"

Claudine B. Kabeza , Lorenz Harst, Peter E.H. Schwarz and Patrick Timpel

Ther Adv Endocrinol Metab

2020, Vol. 11: 1–12

DOI: 10.1177/
2042018820914510

© The Author(s), 2020.

Abstract

Background: Owing to the increasing popularity of smartphones in Rwanda, almost 75% of the entire population currently has access to the internet. Although it has been shown that smartphone applications can support diabetes self-management, there was no diabetes self-management application available in Rwanda until April 2019. Based on the findings of a prior study assessing the needs and expectations of potential users, 'Kir'App' was developed to fill that void. The aim of this study was to evaluate users' experiences after 3 months of use of the first Kir'App prototype.

Methods: The participants of the previous study were recruited to take part in the current study. Semi-structured, in-depth, face-to-face interviews were conducted. Findings were analysed thematically using Mayring's method of qualitative content analysis. Both deductive and inductive approaches were used to analyse transcripts according to the original categories and subcategories of the previous study.

Results: A total of 14 people with either type 1 or type 2 diabetes participated in the study. Age of participants ranged from 19 to 70 years, with a mean age of 34.4 years. Seven of the eight original themes and one additional theme were subjoined: diabetes education and desired information provision; increased diabetes knowledge and awareness; monitoring and reminder functions; nutrition; physical activity; coping with burden of disease; app features; use behaviour and usability. Overall, participants stated that the app increased their diabetes knowledge and assisted them with their diabetes self-management.

Conclusions: We found that the first prototype of Kir'App meets the overall needs and expectations of participating Rwandan diabetics. Having followed a strict user-centred design process, their qualitative insights will help to further improve the app.

Keywords: diabetes, experiences, Kir'App, Rwanda

Received: 7 November 2019; revised manuscript accepted: 3 March 2020.

Introduction

Telemedicine applications, in particular when app-based, allow for tailoring of content for each individual user,¹ continuous monitoring and direct feedback on the data provided by the user.^{2,3} Such app-based interventions cover basic components of diabetes self-management and education (DSME).⁴

Such applications regularly deliver cues to action due to their high degree of tailoring and individualized information provision, and therefore demand proactive use behaviour of their users.⁵ If the end user is unwilling to engage in continuous use of such apps and all their functionalities, the apps can never fulfil their purpose,⁶ which is to serve as a tool for DSME. While usability, that is, ease of use

Correspondence to:
Claudine B. Kabeza
University of Rwanda,
College of Medicine
and Health Sciences/
Rwamagana Campus,
Rwanda Department
for Prevention and Care
of Diabetes, Faculty of
Medicine Carl Gustav
Carus, Technische
Universität Dresden,
Fetscherstraße 74,
Deutschland, Dresden,
01307, Germany
claudine.kabeza@gmail.com

Lorenz Harst
Research Association
Public Health Saxony,
Centre for Evidence-Based
Healthcare, Faculty of
Medicine Carl Gustav
Carus, Technische
Universität Dresden,
Dresden, Sachsen,
Germany

Peter E.H. Schwarz
Department for Prevention
and Care of Diabetes,
Faculty of Medicine Carl
Gustav Carus, Technische
Universität Dresden,
Dresden, Deutschland
Germany German Centre
for Diabetes Research
(DZD e.V.), Neuberberg,
Germany Paul Langerhans
Institute Dresden of the
Helmholtz Centre Munich
at University Hospital
and Faculty of Medicine,
Technische Universität
Dresden, Dresden,
Germany

Patrick Timpel
Department for Prevention
and Care of Diabetes,
Faculty of Medicine Carl
Gustav Carus, Technische
Universität Dresden,
Dresden, Deutschland
Germany



of such applications,^{7,8} is one important factor prompting end user acceptance, so are performance expectancy and perceived usefulness.⁹ Both refer to the users' feelings that an application does what they hoped it would do and thereby helps them with their disease self-management.^{10,11}

Therefore, especially when aiming to design patient-centred applications required for DSME, incorporating expectations of potential users is a necessary step in the development process.¹² Esser and Goossens propose a framework for user-centred design that incorporates patient outcomes such as acceptance and compliance, as well as several background variables, including cultural factors.¹³ This is in line with the International Organization for Standardization (ISO) norm for human-centred design for interactive systems.¹⁴

For Rwanda, especially the highly centralized and hierarchical health care system and culture are relevant.¹⁵ Rwanda has a population of 12.21 million people, two-thirds of which live in rural areas. The median age is below 20 years.¹⁶ The estimated share of people living with diabetes is between 2.8 and 3.4%, adding to an estimated number of 155,000 undiagnosed cases. While there is little data on the routine care for diabetes in Rwanda, the WHO recommends comprehensive coverage by pharmacological treatments (insulin, metformin, etc.). However, especially oral tests for glucose tolerance and the HbA1c-level are lacking.¹⁷ Furthermore, a study on young diabetic patients showed that one-third of those have highly elevated HbA1c levels (above 14%) and already suffer from hypertension, a comorbidity which, given the appropriate treatment, can be prevented throughout the patient's life course.¹⁸ A study by Mukeshimana and Nkosi revealed knowledge gaps concerning the symptoms and pathogenesis of diabetes that were significantly correlated with the degree of education.¹⁹ Concerning cultural aspects, studies show that traditional medicine and its religious underpinnings still are of importance to the Rwandan population.²⁰

Almost 75% of the Rwandan population have access to the internet, a number which has increased, according to local authorities, due to the increased use of smartphones.²¹ Consequently, initiatives aiming to use mHealth applications for diabetes management are currently blooming.²²

Telemedicine applications, such as video conferencing, are already in use.²³

A whole set of methods can be applied to gain information from the potential user, all of them to be used before starting the development cycle as well as after having circulated the first prototype.²⁴

Therefore, a user-centred design process was chosen to develop the first self-management app for diabetes patients in Rwanda. Before beginning the development process, 21 in-depth interviews with patients suffering from both type 1 and 2 diabetes took place in order to gain insight into their expectations towards a potential application.²⁵ As DSME requires proactive health behaviour and therefore behaviour change, analysis of the interviews was structured using the Health Action Process Approach (HAPA) proposed by Schwarzer.²⁶ Within the HAPA, outcome expectations are important predictors for health behaviour change. The following outcome expectations were formulated by the patients in the initial interviews:

- (1) information, specialized education on diabetes and skills for coping with the disease;
- (2) knowledge about diabetes burden in everyday life and crisis situations;
- (3) information on food, drink choices and alcohol intake;
- (4) right type, amount and motivational input for physical activity;
- (5) monitoring and reminder functions for diabetes parameters (health check-ups), doctor's appointments and taking medication;
- (6) emotionally supportive content and the ability to connect with other people living with diabetes;
- (7) bilingual support using both Kinyarwanda and English;
- (8) information delivery combining written content, images, audio and videos according to user preference.

Following a user-centred design process, the results of the previous study were used to develop a prototype of the first diabetes self-management app in Rwanda (Kir'App).

Aim of the study

This study aimed to evaluate user experience after 3 months use of Kir'App. The overall aim was to check whether the outcome expectations

assessed during the previous study were met by the initial prototype of Kir'App.

Study objectives

- (1) To assess positive aspects of Kir'App identified by users after 3 months of use.
- (2) To assess negative aspects of Kir'App identified by users after 3 months of use.
- (3) To identify the users' suggestions for improvement of Kir'App.

Following these objectives, we aimed to explore whether the outcome expectations gleaned from the first interviews were met by the initial prototype of Kir'App.

Methods

This study was done as a follow up of a previous study on the assessment of Rwandan diabetics' needs and expectations considering a diabetes self-management app.²⁵

Study design

For the assessment of the first prototype from a user perspective, in-depth interviews with diabetes patients having used Kir'App over a period of 3 months were conducted. The interviews were face-to-face and followed a semi-structured interview guideline. In-depth interviews are a common method used in user-centred design processes.²⁴

First, biographical data and self-rated intensity of smartphone as well as app use were collected. Participants were then interviewed about their experiences with Kir'App after 3 months of use. This part of the interview was guided by three questions concerning perceived positive and negative aspects as well as challenges. Lastly, participants were asked for suggestions on how to improve the app.

While using the app, participants had the opportunity to ask questions to the diabetes expert running the app. These questions were again categorized, applying inductive thematic analysis.

Participants

To find out whether their expectations were met by the first prototype of Kir'App, participants of

the previous study were asked to participate again in the current study.

Participants were recruited from patients attending the Rwanda Diabetes Association, which is visited by diabetics from different areas of the country, both urban and rural. Their age groups were diverse. They were chosen randomly without prior assessment of either their education level or their diabetes-related health literacy.

Participants had to be Rwandan, aged 18 years or older, living with type 1 or type 2 diabetes, registered with the Rwandan Diabetes Association and having daily access to a smartphone. Of the 21 participants taking part in the first study, only 14 were available and participated. Of the seven who did not participate, one had left the country, one wished not to participate without further reason, two no longer possessed smartphones (one stolen, one broken) and three had iPhones (Kir'App is available only on Android platforms). Participants were not compensated for their participation, either monetarily or with incentives.

Study procedure

Permission to conduct the study was obtained from the Rwandan Diabetes Association and from the Institutional Review Board of the College of Medicine and Health Sciences of the University of Rwanda. Ethical approval No 021/CMHS IRB/2018.

A researcher installed Kir'App on the participants' phones, along with a brief explanation of how the app works and the functionalities it includes. Data collection for the current study took place 3 months after initial use of Kir'App at the Rwandan Diabetes Association. Written consent to participate was sought before each interview, along with the assurance that it could be withdrawn at any time during the interview. All interviews were audio-recorded; however, any information on the identity of the participants was stored separately from the records in order to ensure anonymity. Interviews lasted 10–15 min. All interviews were transcribed and subsequently translated into the English language.

Along with the interviews on users' experiences of Kir'App, a standardized usability test of the app was conducted. The results will be published elsewhere.

Data analysis

The transcripts were analysed following Mayring's method of qualitative content analysis.²⁷ As the overall study aim was to see if the expectations of potential Kir'App users had been met after actual use of a prototype, the original categories from the first study²⁵ had to be matched. As such, the initial approach was deductive, analysing the transcripts according to the original categories and subcategories. Wherever new patterns emerged from the text material, new categories and subcategories were formed in an inductive manner, since no background information existed to structure these new results.

Matching (deductive approach) and formation of the new categories (inductive approach) were performed by three researchers (CB, PT, LH) independently. Results were discussed until consensus was reached.

Study results

Demographics of study participants

The 14 participants had a mean age of 34.4 years [standard deviation (SD) = 16 years, median age = 25.5 years]; 8 were male and 6 were female (57.1% versus 42.9%) and most (9) had type 1 diabetes (Table 1). Most patients (11 out of 14) had been diagnosed at least 6 years ago. The majority of participants (11 out of 14) rated their smartphone skills as 'very good' or 'excellent'. Most participants used their smartphones more than once a day.

Results of in-depth interviews

In the following, the results from in-depth-interviews on user experiences are presented according to the categories developed in the first Kir'App study.²⁵ As none of the 14 participants mentioned an impact of app content on consumption of beverages in general and especially alcohol intake, the corresponding theme was relabelled to only cover issues of nutrition. It is now devoid of any subcategories, since no text answers matched the subcategory 'pleasure of eating'. Relabelling was also done for the category and subcategories concerning diabetes-related knowledge, as participants now reported increased knowledge rather than a lack thereof.

The theme 'coping with burden of disease' now contains three subcategories, as answers revealed feelings of patient empowerment fostered by use

of the app. The theme 'crisis intervention' was no longer mirrored in the results and was therefore dropped. A whole new theme now covers use behaviour and usability aspects mentioned by the participants.

In the following, each category and subcategory is described and exemplified in detail (Table 2).

Diabetes education and desired information provision. This theme refers to the availability of materials for diabetes education in the App.

General information on diabetes, management and complications. Users stated that the app supported them to fill gaps in their knowledge about diabetes.

'[. . .] the first time when you asked me which type of diabetes I had, I said type 2 then went to ask my doctor and came back to tell you I was type 1. [. . .] The detailed explanations I found in Kir'app helped me to understand all types of diabetes [. . .]' [P5]

Medical parameters (e.g. blood pressure, blood glucose, body weight etc.). Users expressed satisfaction with the individualized feedback on different medical parameters they received from the App.

'Kir'App interprets my blood sugar results and shows me which action to take immediately [. . .] I can even calculate my BMI using the calculator in Kir'App [. . .] so I can keep in mind what my limit must be' [P2]

Frequently asked questions by newly diagnosed patients. Users were pleased that the app provided a forum for posting inquiries about their individual experiences with diabetes, in addition to the section for frequently asked questions.

'I like [. . .] the part of frequently asked questions found on every page. [. . .] It's so helpful to click and find your question and its answer there. [. . .] even if you don't find it [the question] there [. . .] you can even use the different forums and ask [your questions] immediately.' [P6]

National/regional update and initiatives. Users found it helpful to have information in the app about local services (e.g. pharmacies) needed in their daily diabetes management.

'Another thing that I liked in Kir'App is the list of pharmacies with available medicine and materials

Table 1. Description of study participants.

Characteristic	value/n
Participants (n)	14
Age	
Range	19–70
Mean	34.4
SD	16.0
Median	25.5
Gender	
Male	8
Female	6
Marital status	
Single	9
Married	4
Widowed	1
Type of diabetes	
T1D	9
T2D	5
Diabetes duration in years (time since diagnosis)	
1–5	3
6–10	8
11–15	2
16–20	1
Educational level	
Secondary school	7
Higher education (university)	7
Work status	
Full time job	5
Temporary	2
Student	6
Retired	1
Self-rated smartphone knowledge/ skills	
Excellent	6

*(Continued)***Table 1.** (Continued)

Characteristic	value/n
Very good	5
Good	2
Poor	1
Frequency of smartphone usage	
Once a day	1
More than once a day	13

needed by diabetes people in every district of Rwanda.’ [. . .]

Increased knowledge and awareness. The theme reveals users’ experiences with the app in compensating for their knowledge gaps.

Increased knowledge on living with diabetes. Users reported the app helped them to increase their level of knowledge about diabetes self-care behaviours.

‘I also learnt about warning signs in case of foot problems, now I know that some signs that we consider as normal like having very hot or very cold feet can alert some danger and that I have to go to see my doctor whenever I feel it.’ [P9]

Prejudice and myths. Users reported that Kir’App helped them to uncover and discard false information (rumours and myths) on diabetes.

‘I’ve always wanted to ask my doctor about a rumour I heard about the effect of diabetes on sexual performance [. . .] when reading the first page of Kir’App [. . .] I saw a picture of a man with diabetes complications on different parts of his body even on sexual organs. This disease is terrible.’ [P13]

Monitoring and reminder function. This theme refers to monitoring and reminder functions of diabetes care parameters available in the app.

Blood glucose or sugar recording and trend visualization. In this subcategory, participants express their experiences with recording and monitoring of diabetes-related clinical parameters, and how this impacted their disease management.

‘[. . .] I have a record of quite all my blood sugar numbers of the last 3 months and with the option to check their variation, I can see where it went up or

Table 2. Summary of themes and subcategories.

Theme	Subcategory
Diabetes education and desired information provision	General information on diabetes, its management and complications; Medical parameters (e.g. blood pressure, blood glucose, HbA1c, body weight etc.); Frequently asked questions by newly diagnosed patients; National/regional update and initiatives as well as services
Increased knowledge and awareness	Increased knowledge on living with diabetes; Prejudice and myths (social media knowledge)
Monitoring and reminder functions	Blood glucose or sugar recording and trend visualisation; Reminder functions
Nutrition	Composition of a diabetic plate
Physical activity	Type of exercise to do; Motivation for physical activity; Frequency and duration of physical activity
Coping with burden of disease	Emotional support; Social support; Shared-decision-making/empowerment
App features	Information delivery; Available languages
Use behaviour and usability	

down [. . .] and get to manage well my blood sugar levels [. . .]' [P7]

Reminder functions. Users were pleased to have several automated reminders for a variety of tasks relevant to diabetes care.

'Some days are very hectic and I become much stressed which makes me forget my regular health checkups but with Kir'App reminder, I don't forget them anymore. The good thing with this reminder is that I can set alarms for different activities like blood sugar testing, taking drug, A1c checking, eye check, doctor appointment, buying a new drug and many others and each will ring at its own time.' [P4]

Nutrition. This theme refers to the availability of information about the appropriate diet for patients with diabetes.

Composition of a diabetic plate. The content in Kir'App on how to prepare a diabetic plate helped the users to control their eating habits.

'Kir'App taught me how to balance my food. Now it has been some weeks that I no longer get high blood sugar episodes because of food.' [P1]

Physical activity. The theme refers to the provision of information on the kind and amount of exercise required when coping with diabetes. It also covers the motivational advice given within the app.

Kind of sport to do. Participants describe how the information about the adequate type of exercises provided in the app changed their physical activity.

'[. . .] I have started to alternate the two categories of sport [aerobic exercise and strength training] a diabetic person has to do as described in Kir'App.' [P1]

Motivation for physical activity. Some users reported change in their exercise behaviour due to the motivational messages within the app.

'I used to neglect to do sport[s] mainly because of my age but when I got to know its benefits on my health, I got encouraged to do it.' [P8]

Frequency and duration of physical activity. Users found recommendations in the App about the right amount of physical activity required.

'[. . .]Two times a week I play volleyball or do jogging as aerobic exercises and at least once a week I lift weights in gym-tonic (fitness studio) as strength training.' [P1]

Coping with burden of disease. Theme 6 refers to the emotional support the app content provides and the current inability of the app to connect diabetics with each other. It also covers the empowerment users felt when being able to participate in shared decision making with their doctor concerning their individual diabetes care.

Emotional support. The participants felt that the app assisted them in coping with situations of emotional distress.

'I am widow since now 8 years, my husband left me with three kids and I am always worried about their future when I think about dying and leaving them alone. I was glad to find in Kir'App some advice given to parents who live with diabetes. [. . .]'. [P10].

Social support. Users wished the app could put them in contact with other people living with diabetes.

'It would be good to have a social media forum in Kir'App [. . .] where type 1 could meet, exchange ideas and share experiences of our everyday life.' [P11]

Shared-decision-making/empowerment. The information and knowledge found in the app empowered users to make shared decisions in their healthcare together with their physician.

'I usually have good numbers of blood sugar levels. But for example, I didn't know anything about A1c and other health checkups we need to do regularly. When I read about them in Kir'App, [. . .] I told the new one [doctor] that I needed to do all necessary health checkups and she prescribed me all of them.' [P8]

App features. The theme refers to experiences of the participants with the app features provided for

information delivery and to the availability of content in different languages.

Information delivery. Users appreciated the content organization of the app and its information delivery through texts and images but regretted the absence of audios and videos.

'I like much how appealing Kir'App is. It has beautiful colours that attract attention. I like also how well organized it is; information about every topic (food, sport, feet, etc.) has its own page [. . .]'. [P7]

'It is good Kir'App has images that go with the texts but it would be better if it could also have some videos. For example in physical activity; having some videos that show how to do all these exercises shown on images would be great.' [P9]

Available languages. Users were pleased to have the app content in their local language, Kinyarwanda.

'I appreciated having all this helpful information about my disease in Kinyarwanda. Nowadays we use much English, but being able to understand things that concern your life in a language you understand well is a very good thing.' [P14]

Use behaviour and usability. This theme refers to the users' general experiences with the usability of the app and to their individual use behaviour.

'In general, using Kir'App is like seeking pieces of advice from a friend, you cannot come just like that, get what you want and go back. You need to give it time because, the more you spend time using it, the more you get more interesting information and the more you understand more about diabetes and get ideas about your self-care.' [P6]

Discussion

The present study applies a user-centred design approach to validate previously identified (sub) categories representing needs and expectations of Rwandan patients towards their first diabetes self-management smartphone application (Kir'App). In general, the majority of categories and subcategories were identified again when analysing the transcripts. Interestingly, 'use behaviour and usability' was the only category that appeared in addition to the original ones. This underlines the

importance of an iterative user-centred design process, as issues with usability and specific usage patterns can only manifest when a first prototype of an application can be tested.¹⁴ The availability of diabetes health education and frequently asked questions was appreciated by Kir'App users in general, which fits the qualitative results on user perceptions of mobile health apps gained by Peng and colleagues.²⁸ Especially the need for diabetes-related information early after diagnosis, when symptoms are not well known to the patient, is an important component of DSME,⁴ and can be delivered by an app.²⁹ Fittingly, the provision of the desired information was mentioned as the most common use of Kir'App. Furthermore, users said to have gained knowledge about diabetes in general, and on strategies to live with it, which corresponds to survey results on reasons for technology use among adolescents with type 1 diabetes.³⁰ In a systematic review, Rush and colleagues show that virtual education approaches can improve clinical indicators as well as surrogate parameters such as disease-related knowledge and quality of life in patients with a variety of chronic diseases, among them diabetes.³¹

Users claimed that reminder functions, recording and trend visualization of medical parameters, especially blood sugar, offered by Kir'App helped them to be more aware of and accountable for their diabetes self-management activities, which is in line with results of pilot test of a self-management app provided by Dobson and colleagues.³² These results are especially important for further analysis of the effectiveness of the app, as a meta-analysis by Cui and colleagues has demonstrated that using apps for self-management can improve glycaemic control.³³ Including a positively rated and well-used reminder function into a self-management app, therefore, is of vital importance. Tracking of food intake and physical activity by using diaries were rated important by the participants, which is in line with review results by Williams and colleagues.³⁴ Goyal and colleagues demonstrated that the logbook function within their app significantly increased self-management behaviour, which, in turn, led to decreased levels of HbA1c over a time period of 12 months.³⁵

Kir'App users stated to have found useful pages in the app with advice for daily life, not only for themselves but also for relatives and family members. The pieces of advice were appreciated as a means of coping with the burden of disease as

they provided emotional support. The involvement of family members and peers in diabetes self-management interventions has been found to be important in several current reviews.^{36,37} Interactive forums and social media functions are nevertheless missing from the app, yet have proven effective in reducing HbA1c due to the support they can provide.³⁸

Users also appreciated having the app in both English and their mother tongue, which, as they say, allows them to better understand the information and therefore leads to more comfortable app use. This proves that having potential users participate in the design process of future digital diabetes interventions is worthwhile, as it helps overcome language and cultural barriers.³⁹ The fact that some participants stated now being able to better distinguish myths from facts about diabetes further underlines this point.

However, some users pointed out how complicated it could be for people with poor education to use the app. Indeed, low health as well as overall literacy can be an obstacle to telemedicine use,⁴⁰ yet can be overcome by the use of visual rather than text material and, where necessary, simple language, as suggested by the German guideline for evidence-based health information.⁴¹

As self-management applications should support behaviour change as modelled in the HAPA,²⁶ it is encouraging that the app actually helped participants not only in forming an intention to be more physically active but also in making the transgression from intention to action. As participants stated that the app also helped them to log physical activity levels, it also served as a tool for self-monitoring as a form of action control, which is an important predictor for the maintenance of healthy behaviour according to the HAPA.⁴² In general, outcome expectancies and whether they are met is an important variable in the process of behaviour change. As such, the results of the interviews show that the main outcome expectancies towards a diabetes self-management app were met.

The categories we identified were almost identical to those found in our previous study. Feedback allowed initial users to report whether their expectations towards the application have been met; such feedback is not only recommended by the ISO Norm for the user-centred design of

interactive systems but is also a common standard in user-centred design frameworks for digital health solutions.^{13,24,43}

Limitations

As described in the previous manuscript²⁵ semi-structured interviews have several limitations, mainly because they do not allow for standardization and quantification of results, and rely on the recollection of participants.⁴⁴ The low number of participants and the fact that their recruitment resulted from convenience sampling further limits external validity of findings.

Some additional limitations arise from qualitative content analysis as a method. For example, the individual backgrounds and subconscious expectations of the authors may have impacted the deductive coding process. Although it is a strength of user-centred design processes that they iteratively allow for user involvement, the validated and slightly enhanced (sub)categories may be seen as self-fulfilling prophecy, as they were used to mirror the initially identified expectations.

Despite the overall positive findings, the authors admit that the pioneer character of this work does not allow for a comparison with similar apps or devices in Rwanda. As such, one participant argues, 'It would be difficult to find something negative in Kir'App as there is no other similar App we were using before to compare with it.' [P10] This can be seen as an indicator that participants may have difficulties to imagine functionalities going beyond the presented Kir'App content and features.

Future research and next steps

According to the results presented here, changes will have to be made in the content of Kir'App and its presentation. More visual elements (either pictures or videos) will have to be used to deliver basic concepts of diabetes self care. Along with that, some sections within the app will have to be presented in rather plain language. As participants wished for some modality to interact with other diabetes patients, a social media platform or chat room within the app is intended. For example, the 'bant' app for adolescents with type 1 diabetes contains a chat room called 'banter', which can serve as a role model.⁴⁵

In a next step, results of the quantitative usability testing conducted parallel to the semi-structured interviews will be analysed statistically. The main focus will be on the time it takes to perform certain tasks within the app, and in how far participants are satisfied with the effort they have to put into the completion of these tasks.^{44,46}

Conclusion

The results of the 14 semi-structured and guideline-based interviews show that major expectancies towards a self-management app mentioned by Rwandan diabetics were met by the first prototype. In addition, responses of the participants serve as a first indicator that the use of Kir'app can instigate behaviour change, which should be investigated in future effectiveness studies. Statements about actual use behaviour show that it took time to get used to the app and that visual presentation of content would be welcomed.

All in all, the results will allow for improvements of the first prototype, as intended by the user-centred design process, and form the basis of further, quantitative usability testing.

Acknowledgements

Authors Claudine B. Kabeza and Lorenz Harst contributed equally. The authors would like to acknowledge the Rwandan Diabetes Association for providing permission and for allowing use of the association's facilities. They also wish to thank the Rwandan diabetics whose participation made this study possible. The authors also would like to thank Kristin Kemple for proofreading this manuscript.

Authors' note

C.K and P.S. conceived the study. C.K. collected the data. L.H., P.T and C.K. contributed to the analysis and interpretation of data. L.H., C.K and P.T. wrote the manuscript. P.T. reviewed and edited the manuscript. L.H., C.K., P.T. and P.S. approved the version for submission.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: For the research work; by the Ministry of Education of Rwanda, the University of Rwanda and the German Academic exchange service (DAAD). For

authorship; partly by the European Social Fund and the Free State of Saxony (Grant no. 100310385). For article publication; by the Open Access Funding by the Publication Fund of the TU Dresden. The funding organizations above mentioned are employers and funding agencies of the authors. None funded Kir'App development directly. The App was developed at an educational public organization in Rwanda and will stay a free product for the population of Rwanda.

Conflict of interest statement

The authors declare that there is no conflict of interest.

ORCID iD

Claudine B. Kabeza  <https://orcid.org/0000-0002-1218-5941>

Supplemental material

Supplemental material for this article is available online.

References

- Holmen H, Wahl AK, Cvancarova Smastuen M, *et al.* Tailored communication within mobile apps for diabetes self-management: a systematic review. *J Med Internet Res* 2017; 19: e227.
- Greenwood DA, Blozis SA, Young HM, *et al.* Overcoming clinical inertia: a randomized clinical trial of a telehealth remote monitoring intervention using paired glucose testing in adults with type 2 diabetes. *J Med Internet Res* 2015; 17: e178.
- Kongstad MB, Valentiner LS, Ried-Larsen M, *et al.* Effectiveness of remote feedback on physical activity in persons with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. *J Telemed Telecare* 2019; 25(1): 26–34.
- Haas L, Maryniuk M, Beck J, *et al.* National standards for diabetes self-management education and support. *Diabetes Care* 2014; 37: S144–S153.
- Riley WT, Rivera DE, Atienza AA, *et al.* Health behavior models in the age of mobile interventions: are our theories up to the task? *Transl Behav Med* 2011; 1: 53–71.
- Rogers EM. Diffusion of innovations. New York, NY: Free Press, <http://swbplus.bsz-bw.de/bsz107999064inh.htm> (2003).
- Dou K, Yu P, Deng N, *et al.* Patients' acceptance of smartphone health technology for chronic disease management: a theoretical model and empirical test. *JMIR mHealth and uHealth* 2017; 5: e177.
- Scheibe M, Reichelt J, Bellmann M, *et al.* Acceptance factors of mobile apps for diabetes by patients aged 50 or older: a qualitative study. *Med 20* 2015; 4: e1.
- Harst L, Lantzsch H and Scheibe M. Theories predicting end-user acceptance of telemedicine use: systematic review. *J Med Internet Res* 2019; 21: e13117.
- Georgsson M and Staggers N. Patients' perceptions and experiences of a mHealth diabetes self-management system. *Comput Inform Nurs* 2017; 35: 122–130.
- Hennemann S, Beutel ME and Zwerenz R. Ready for eHealth? Health professionals' acceptance and adoption of eHealth interventions in inpatient routine care. *J Health Commun* 2017; 22: 274–284.
- Hastall M, Dockweiler C and Mühlhaus J. Achieving end user acceptance: Building blocks for an evidence-based user-centered framework for health technology development and assessment. In: Antona M and Stephanidis C (eds) *Universal access in human-computer interaction human and technological environments*. New York: Springer International Publishing, <https://pub.uni-bielefeld.de/publication/2911802> (2017, accessed 3 January 2018).
- Esser PE and Goossens RH. A framework for the design of user-centred teleconsulting systems. *J Telemed Telecare* 2009; 15: 32–39.
- Harte R, Glynn L, Rodríguez-Molinero A, *et al.* A human-centered design methodology to enhance the usability, human factors, and user experience of connected health systems: a three-phase methodology. *JMIR Hum Factors* 2017; 4: e8.
- Dhillon RS and Phillips J. State capability and Rwanda's health gains. *Lancet Glob Health* 2015; 3: e308–e310.
- National Institute of Statistics of Rwanda. *Publication tables*. Kigali: National Institute of Statistics of Rwanda, 2012.
- World Health Organization (WHO). Rwanda. Geneva, https://www.who.int/diabetes/country-profiles/rwa_en.pdf (2016).
- Marshall SL, Edidin D, Sharma V, *et al.* Current clinical status, glucose control, and complication rates of children and youth with type 1 diabetes in Rwanda. *Pediatr Diabetes* 2013; 14: 217–226.

19. Mukeshimana MM and Nkosi ZZ. Communities' knowledge and perceptions of type two diabetes mellitus in Rwanda: a questionnaire survey. *J Clin Nurs* 2014; 23: 541–549.
20. Schierenbeck I, Johansson P, Andersson LM, *et al.* Collaboration or renunciation? The role of traditional medicine in mental health care in Rwanda and Eastern Cape Province, South Africa. *Glob Public Health* 2018; 13: 159–172.
21. National Institute of Statistics of Rwanda. *Statistical YearBook* 2017. Kigali: National Institute of Statistics of Rwanda, 2017.
22. Lygidakis C, Uwizihwe JP, Kallestrup P, *et al.* Community- and mHealth-based integrated management of diabetes in primary healthcare in Rwanda (D2Rwanda): the protocol of a mixed-methods study including a cluster randomised controlled trial. *BMJ Open*. Epub ahead of print 24 July 2019. DOI: 10.1136/bmjopen-2018-028427.
23. Combi C, Pozzani G and Pozzi G. Telemedicine for developing countries. *Appl Clin Inform* 2016; 7: 1025–1050.
24. Årsand E and Demiris G. User-centered methods for designing patient-centric self-help tools. *Inform Health Soc Care* 2008; 33: 158–169.
25. Kabeza CB, Harst L, Schwarz PEH, *et al.* Assessment of Rwandan diabetic patients' needs and expectations to develop their first diabetes self-management smartphone application (Kir'App). *Ther Adv Endocrinol* 2019; 10: 2042018819845318.
26. Schwarzer R. Modeling health behavior change: how to predict and modify the adoption and maintenance of health behaviors. *Appl Psychol* 2008; 57: 1–29.
27. Mayring P. Qualitative content analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*; 1, <http://www.qualitative-research.net/index.php/fqs/article/view/1089> (2000, accessed 9 November 2017).
28. Peng W, Kanthawala S, Yuan S, *et al.* A qualitative study of user perceptions of mobile health apps. *BMC Public Health* 2016; 16: 1158.
29. Petersen M and Hempler NF. Development and testing of a mobile application to support diabetes self-management for people with newly diagnosed type 2 diabetes: a design thinking case study. *BMC Med Inform Decis Mak* 2017; 17: 91.
30. Vaala SE, Hood KK, Laffel L, *et al.* Use of commonly available technologies for diabetes information and self-management among adolescents with type 1 diabetes and their parents: a web-based survey study. *Interact J Med Res* 2015; 4: e24.
31. Rush KL, Hatt L, Janke R, *et al.* The efficacy of telehealth delivered educational approaches for patients with chronic diseases: a systematic review. *Patient Educ Couns* 2018; 101: 1310–1321.
32. Dobson R, Carter K, Cutfield R, *et al.* Diabetes text-message self-management support program (SMS4BG): a pilot study. *JMIR mHealth and uHealth* 2015; 3: e32.
33. Cui M, Wu X, Mao J, *et al.* T2DM self-management via smartphone applications: a systematic review and meta-analysis. *PLoS One* 2016; 11: e0166718.
34. Williams JP and Schroeder D. Popular glucose tracking apps and use of mHealth by Latinos with diabetes: review. *JMIR Mhealth Uhealth* 2015; 3: e84.
35. Goyal S, Nunn CA, Rotondi M, *et al.* A mobile app for the self-management of type 1 diabetes among adolescents: a randomized controlled trial. *JMIR Mhealth Uhealth* 2017; 5: e82.
36. Albanese AM, Huffman JC, Celano CM, *et al.* The role of spousal support for dietary adherence among type 2 diabetes patients: a narrative review. *Soc Work Health Care* 2019; 58: 304–323.
37. Timpel P, Harst L, Reifegerste D, *et al.* What should governments be doing to prevent diabetes throughout the life course? *Diabetologia* 2019; 62: 1842–1853.
38. Toma T, Athanasiou T, Harling L, *et al.* Online social networking services in the management of patients with diabetes mellitus: systematic review and meta-analysis of randomised controlled trials. *Diabetes Res Clin Pract* 2014; 106: 200–211.
39. Edwards L, Rooshenas L and Isaacs T. Inclusion of ethnic minorities in telehealth trials for type 2 diabetes: protocol for a systematic review examining prevalence and language issues. *JMIR Res Protoc* 2016; 5: e43.
40. Cartmill B, Wall LR, Ward EC, *et al.* Computer literacy and health locus of control as determinants for readiness and acceptability of telepractice in a head and neck cancer population. *Int J Telerehabil* 2016; 8: 49–60.
41. Lühnen J, Albrecht M, Hanßen K, *et al.* Leitlinie evidenzbasierte Gesundheitsinformation: Einblick in die Methodik der Entwicklung und Implementierung. *Zeitschrift für Evidenz,*



Fortbildung und Qualität im Gesundheitswesen
2015; 109: 159–165.

42. Schwarzer R. Health action process approach (HAPA) as a theoretical framework to understand behavior change. *Actualidades en Psicología* 2016; 30: 119–130.
43. European Committee for Standardization. ISO 9241-210:2019(en), Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems, <https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-2:v1:en> (2011, accessed 15 November 2019).
44. Kushniruk AW and Patel VL. Cognitive and usability engineering methods for the evaluation of clinical information systems. *J Biomed Inform* 2004; 37: 56–76.
45. Goyal S, Morita PP, Picton P, *et al.* Uptake of a consumer-focused mHealth application for the assessment and prevention of heart disease: the <30 days study. *JMIR mHealth and uHealth* 2016; 4: e32.
46. Lewis JR. IBM computer usability satisfaction questionnaires: psychometric evaluation and instructions for use. *Int J Hum Comput Interact* 1995; 7: 57–78.

Visit SAGE journals online
[journals.sagepub.com/
home/tae](http://journals.sagepub.com/home/tae)

 SAGE journals

5. Discussion

This chapter discusses the main findings of the two qualitative studies conducted before and after the development of Kir'App, the first Rwandan diabetes self-management smartphone application. It also analyses Kir'App content in the context of international research state on mobile medical applications and compares it to the standards of diabetes self-management education and care, and to the content of other diabetes apps.

Discussion of the study findings

The user-centered design that was used in the two studies proved the importance of involving end-users in the development of health interventions that are made for them as emphasized by de Beurs et al. (2017). According to O'Cathain et al. (2019), the development of health intervention that are centered to a special target population can address different contexts such as healthcare delivery system, technology, behavior change or self-management.

Our intervention focused on the last two contexts and our findings are in line with the evidence given by Nelson et al. (2017) in their study on mHealth intervention elements and user characteristics where prioritization of users' needs was found to be crucial for the optimization of mHealth intervention utility and appeal.

Since the two studies composing this thesis involved the same participants, we used the original themes identified in the first study for the data analysis of the second study. This process helped us to verify whether all the findings presented similarities as we have used the same themes to develop Kir'App functionalities. This method corresponds to the iterative process used by Schnall et al. (2016) in the identification of barriers and facilitators to develop relevant functional content and features for inclusion in the development of their medical app.

Surprisingly seven out of the eight themes identified within the initial study as needs and expectations of the study participants from a potential diabetes self-management app were re-identified as elements of satisfaction or dissatisfaction when we evaluated users' experiences after three months of Kir'App use. Only one additional theme was found.

Centering the design of Kir'App development on the users from the beginning prevented us to face challenges of rejection met by mHealth developers who don't use the same approach, as experienced by Owens et al.(2011) in the middle of users' participatory intervention.

The new theme that was added is the “*use behaviour and usability*”. It covers Kir’App users’ general experiences with the usability of the app as an innovative software artefact and their individual use behaviour.

The single theme that was missing among the eight original themes is the “*Need for information in crisis situations*”. The study participants wanted to have an automatic information provision system to notify them in case of diabetes complications such as hyperglycaemia or hypoglycaemia in order to prevent panicky behaviour.

For Kir’App to have this function, it would need to be synchronized to a sensor with automated response which would have the same functions of systems such as of continuous glucose monitoring system (Bode, 2000) or flash glucose sensing technology (Haak et al., 2017).

The development of this function was impossible to implement within the first prototype of Kir’App therefore the theme “*crisis intervention*” didn’t serve as any of Kir’App functionalities.

Generally, the study participants were satisfied to find their wishes and expectations from a potential self-management app translated into a real app and that was enough to motivate them to use Kir’App in the self-management of their disease.

Kir’App in the context of international research state on mobile medical applications

Kir’App assists users in diabetes prevention and disease self-management therefore fills the requirements to be called a “*mobile medical application*” since its software functionality meets the definition of mobile medical App as defined by the US Food and Drug Administration in their *Policy for Device Software Functions and Mobile Medical Applications* in section 201(h)(Food and Drug Administration, 2019).

Kir’App also matches the third of the three priorities of mobile medical apps as established by the European Medicines Agency (EMA) in their communication on digital transformation of health and care in the digital single market. It states that mobile medical apps should: “*use digital tools to empower people to look after their health, prevent diseases, and enable feedback and interaction between users and their healthcare providers*” (European Commission, 2020).

Comparison of Kir'App's content with the standards of diabetes self-management education and care

In 1997 diabetes education specialists from the American Association of Diabetes Education (AADE) defined a framework for patient-centered diabetes education and care (Peeples et al., 2007). The framework which provides seven self-care behaviors necessary for a successful and effective diabetes self-management was evidence-based for assessment, intervention, and outcome (evaluation) measurement of the diabetes patient, program and population (Boren, 2007; AADE, 2008).

All diabetes education and care initiatives (diabetes apps included) should relate on those seven self-care behaviors (AADE7™) which are; healthy eating, being active, monitoring, taking medication, problem-solving, healthy coping and reducing risks (AADE, 2008).

Kir'App is mainly a diabetes education app but which has three more features; patient diaries, monitoring and reminder features with logbooks for recording checkups results and the medications taken, and a manual location finder for pharmacies.

Although Kir'App doesn't offer automated or personalized features fitting the AADE self-care behaviors framework, the content of Kir'App educational pages covers the entire AADE framework content; **(1)** the content of Kir'App's second page called "*Food, drinks and diabetes*" fits the first AADE self-care behavior that instructs about "*Healthy Eating*", **(2)** the content of its third page called "*Physical activity and diabetes*" corresponds to the second AADE self-care behavior about "*Being Active*", **(3)** the content of its first page called "*Teach me about diabetes*" relates to the fourth AADE self-care behavior about "*Taking Medication*" and to its seventh one about "*Healthy Coping and Reducing Risks*", **(4)** the content of its fourth page called "*Blood sugar and diabetes*" refers to the third AADE self-care behavior about "*Monitoring*" and to its fourth one about "*Taking Medication*", **(5)** the content of Kir'App's 5th page called "*Feet and diabetes*" and its 6th page called "*Diabetes health checkups*" refers to the third AADE self-care behavior about "*Monitoring*" and to its seventh one about "*Healthy Coping and Reducing Risks*", **(6)** and finally its 7th page called "*Advise me*" helps the user fulfilling the 6th AADE self-care behavior about "*Problem Solving*" together with the diaries available in every page that the user can use to write down their problems, questions, doubts, feelings, and the answers to their questions be it from themselves or from healthcare professionals (AADE, 2008 ; Kirapp, 2019).

Kir'App's features compared to the features of other diabetes apps

A brief analysis of the following systematic reviews published between 2011 and 2018 gives a big picture of the main features of diabetes apps that are available for the users.

According to Chomutare et al.(2011), the four most prevalent features that were common in 101 diabetes applications available in 2011 on the online markets of diabetes self-management apps from Apple iPhone store, Google Android, BlackBerry, and Nokia Symbian were (1) insulin and medication recording, 63 (62%), (2) data export and communication, 61 (60%), (3) diet recording, 47 (47%), and (4) weight management, 43 (43%). Compared to these features, though Kir'App's functions need manual entry, but its diaries and logbooks also offer options to record and to reflect on medications taken, food eaten, body weight and the regular variations of its results. The actual study concluded that diabetes education was missing from the top functionalities of the apps reviewed despite its importance in clinical guidelines. This gap doesn't exist in Kir'App since it is mainly a diabetes education app.

Two years later, Breland and colleagues reviewed 227 diabetes self-management apps that were available on Apple App store. Their study aimed to compare their features to the seven diabetes self-care behaviors by the AADE. The reviewed apps were found to follow only some of the seven self-care behaviors. 109 apps among the 227 apps offered features for Self-monitoring, 106 apps for Medication, 102 apps for Healthy Eating, 67 apps for Problem Solving, 56 apps for Being Active, 27 apps for Reducing Risks, and 13 apps for Healthy Coping (Breland et al., 2013).

The results of that study are similar to the results of another systematic review study that was published in 2018. With the same aim, the researchers assessed 173 apps in November 2015 and 137 apps in December 2017 that were available on Apple App store and Google Play. They found an unbalanced trend among the AADE[™] guidelines included in the features of the diabetes self-management apps reviewed. 77% of the apps were designed to support only the self-care behavior of Healthy Eating, 76% were for Monitoring, 58% for Taking Medication, 45% for Being Active, 31% for Problem Solving, 10% for Healthy Coping and 5% for Reducing Risks (Ye et al., 2018).

Compared to the apps reviewed in the previous studies, Kir'App content has the particularity to relate to each of the seven AADE7™ diabetes self-care behaviors, though not in automated and personalized ways.

Another study with few more different findings than the previous ones was conducted in 2017. The researchers analyzed 346 commercial apps but only 16 apps (16%) from Apple App store and 19 apps (7.72%) from Google Play met their inclusion criteria among which were 8 selected areas used to compare these apps. These areas were (1) app doesn't need internet for use, (2) size of app is less than 50 MB, (3) no subscription is required, (4) is a diabetes education tool, (5) app allows communication (exporting reports), (6) has automatic blood sugar data entry option, (7) has reminders to check blood sugar and take medications, and (8) offers advisory or therapeutic support (Izahar et al., 2017).

If we compare Kir'App features to these selected areas, Kir'App meets 5 out of the 8 elements; (1) it requires neither internet nor subscription to use it, (2) it is a diabetes education tool, (3) it has a reminder set to remind the user about all the medical checkups required, to take drug, going for sport and for doctor's appointment, buying new drug and doing foot care, (4) it has also an advisory page and offers options to ask questions to the diabetes educator.

Although the findings of the study above show that the majority of the reviewed apps were also free, didn't require internet connection for use and were less than 50 MB in size, the researchers reproached them to focus more on reporting and setting reminders, rather than providing personalized education or therapeutic support. And one of the researchers' main recommendations for diabetes app developers was to improve the design of diabetes apps by integrating patients' needs (Izahar et al., 2017).

In light of evidences presented, developing all the features of Kir'App based on our study participants' needs and expectations didn't only contribute to improve the self-management of their disease but also allowed to design the first Rwandan diabetes self-management app that meets international guidelines for diabetes education and care, and follows most of recommendations for diabetes app development.

6. Conclusion and recommendations

This chapter summarizes the research project by reviewing the research process that gave birth to Kir'App, the first Rwandan diabetes self-management smartphone application. The chapter also discusses the limitations encountered, the contribution to knowledge, the implications for practice of Kir'App, and the recommendations for future research.

6.1. Research objectives achievement

This research project intended to develop the first diabetes self-management smartphone application (Kir'App) for Rwandan diabetics. The study aim has been achieved through the realization of the three secondary objectives; assessment of needs and expectations of Rwandan diabetics before Kir'App development, Kir'App development according to Rwandan diabetics' wishes and finally the evaluation of Rwandan diabetics' experiences with Kir'App after 3 months of use.

A user-centered design was implemented by first assessing the needs and expectations of 21 Rwandan diabetic patients from a potential app through in-depth qualitative interviews. The participants showed preferences for an app that combines knowledge-oriented components with monitoring functions. They also suggested that the app should provide them with both social support derived from diabetes peers and from regional and national initiatives.

Following the respondents' qualitative insights, further development regarding the content of the first prototype of Kir'App continued, which in turn, became the first diabetes self-management smartphone application in Rwanda. The majority of the functionalities of the app cover diabetes knowledge and information through means of texts and images. Kir'App also offers diabetics a reminder-monitoring function combined with a logbook for all their health checkups.

As the study participants have suggested, a further function for searching for national initiatives such as pharmacies with diabetes products and events related to diabetes was added. At present, the app offers no social media function.

Once Kir'App was ready for use, a further second qualitative study to evaluate users' experiences was designed. The app was installed in the smartphones of 14 of the 21 participants of the previous study. They were directed on how to use it. Then after three months of use, their experiences with the app were assessed through in depth-qualitative interviews.

The findings of this study showed that the participants' major expectancies towards the first Rwandan diabetic self-management app were met by the first prototype of Kir'App. Their reported experiences with the app demonstrated that the use of Kir'App can lead to health behavior changes (this outcome of the app will be evaluated in future studies).

However, participants expressed their need for an in-app social media platform or chat room with fellow diabetes patients. They also asked for more visual elements, either pictures or videos and for much plainer language that is fully accessible for all. On the whole, the results of this research project will allow for further improvement of the first prototype of Kir'App.

6.2. Limitations of the research project

Both the studies comprised in this thesis share the same limitations as they both used the same study design and the same study participants.

In-depth qualitative interviews using semi-structured guides were conducted. It is well known that semi-structured interviews limit the standardization and quantification of results as they depend on the memory of participants. Although pre-test sessions were carried out prior to interviewing, their translation from English to Kinyarwanda, even if they were translated by a professional may have led to some misinterpretation or loss of information. The same thing may have happened when translating participants' interviews from Kinyarwanda to English.

The Ministry of Health of Rwanda does not have any specific database for patients with diabetes, thus convenience sampling in a professional setting was used, through the Rwandan Diabetes Association (RDA). Attempts were made to recruit diverse patients. But again, the RDA does not have any database of diabetic patients using smartphones. Consequently, diabetic patients using smartphones not attending or irregularly attending the RDA were less likely to be included. Moreover, the additional insights of people who voluntarily refused to participate in the study were missed as well as of iPhone users, as Kir'App runs only on Android phones.

The content analysis of both studies was theme-based and interpretative. The researchers' background and subconscious expectations may have influenced the deductive coding process and thus, the final results. However, this risk of confirmation bias was prevented by allocating two researchers for the independent analysis of the data and a third researcher for the supervision of the coding. Moreover, the involvement of the same participants in both studies through the user-centered design process strengthened the validity of obtained themes.

The data was collected from 21 individuals in the first study and from 14 of the 21 participants in the second study. The low number of participants and their recruitment from convenience sampling method limits the external validity of findings. And although the sample derived from a highly heterogeneous study population in terms of age, gender, time since diagnosis and working status, the results cannot be generalized to a larger population at this moment in time.

Finally, the study participants of this research project to develop Kir'App, the first Rwandan diabetes self-management smartphone application had to face two main challenges due to the non-existence of a comparable app. During the first study to assess their needs and expectations from Kir'App, it may have been stressful for them to foresee its possible functions. And later, when the app was developed following their helpful propositions, it was difficult for some of them to find anything negative in the app, as there was no other similar app they were using before to compare with it, as stated by one participant in particular.

Therefore, in spite of the overall positive findings, the researchers admit that the innovator character of this work does not allow for a comparison with similar apps or devices in Rwanda.

6.3. Contribution to research fields and implication for practice of Kir'App

The findings of this research project have made two major contributions: firstly, to the existing literature and secondly, to the future practical implication of Kir'App.

The user-centered design process that was used and which is much acclaimed in the domain of health technologies help to respect individual factors that influence acceptance. In this project, it proved its benefits by first addressing the potential users' specific needs in developing their first diabetes self-management app and then by meeting their major expectations of the app, as they reported after using it over the period of 3 months of use.

Kir'App has currently been downloaded by more than 500 Android users. The diabetes Educator who runs the App receives regular inquiries about diabetes care from Rwandan diabetics, caregivers and Rwandan healthcare providers. This shows that Kir'App has been accepted by Rwandan people and that it is somehow contributing to the improvement of diabetes care in Rwanda.

For every future mHealth technology to be developed in Rwanda, Kir'App as the first Rwandan diabetes self-management app will be a cogent specimen to start from and to make further adjustments for users' satisfaction and better health outcomes.

6.4. Recommendations

Next steps for Kir'App research

- In the near future, the results of the quantitative usability testing conducted parallel to the assessment of users' experiences with Kir'App will be published.
- Kir'App will be made available on both iOS and android platforms.
- A randomized controlled trial to evaluate the effectiveness of Kir'App on diabetics' health outcomes will be conducted.

From the users' suggestions, changes will have to be made in the content of Kir'App and its presentation.

- More visual educational elements (both pictures and videos) will be used to deliver concepts of diabetes self-management.
- A plain language exempt of clinical terms, with full accessibility for all, will be strictly observed.
- Since Kir'App is mainly a self-management diabetes education app and participants expressed a wish to include a social media platform within the app. This will be judiciously considered in the further development of the app.

For further diabetes eHealth researches in Rwanda

In order to be internationally updated in diabetes care, it is the recommendation that further eHealth interventions targeting diabetes care in Rwanda, are to be diverse in their goals and products by availing devices offering special utility functions such as automated text messages, virtual health coaching, wearable blood glucose meters and insulin management applications.

7. Summary

7.1. English version

Background

The last two decades have witnessed Rwanda's rapid industrialization and technology development due to its successful governmental policy. Almost 75% of the population currently has access to the internet due to the increasing availability of smartphones in the country.

Despite these advances, diabetes literacy and coping mechanisms were found to be lacking in some Rwandan communities. And although several studies have demonstrated smartphone applications to improve diabetes patients' self-management capacity, until the introduction of this research project in April 2019, there was no diabetes self-management application available in Rwanda.

Objectives

The main aim of this research project was to develop "Kir'App"; the first Rwandan diabetes self-management smartphone application. Two goals were processed to achieve this. First, the needs and expectations of Rwandan diabetics of the potential app were assessed. Following the results of that assessment, the first prototype of Kir'App was developed. The app was presented to the participants of the previous study for use, and then a second study was conducted to evaluate the users' experiences after a period of 3 months of use.

Methods

Both studies in this research project used the same research methodology. Study participants were recruited using convenience sampling of the Rwanda Diabetes Association. Data was collected using semi-structured, in-depth, face-to-face interviews. Findings were thematically analyzed using Mayring's method of qualitative content analysis. For the second study, both deductive and inductive approaches were used to analyze the transcripts according to the original categories and sub-categories of the previous study.

Results

The first study included 21 participants with both type 1 (female = 5, male = 6) and type 2 (female = 6, male = 4) diabetes. Participants' age ranged from 18 - 69 years, with a mean age of 35.2 years. The second study included 14 people from the previous study. Their age ranged from 19 - 70 years, with a mean age of 34.4 years.

The findings of the first study identified eight main themes: (1) diabetes education and desired information provision; (2) lack of diabetes knowledge and awareness; (3) need for information in crisis situations; (4) required monitoring and reminder functions; (5) information on nutrition and alcohol consumption; (6) information on physical activity; (7) coping with the burden of disease, through social support and network; and (8) app features.

The results of the second study evidenced seven among the eight themes of the previous study and added one new theme: (1) diabetes education and desired information provision, (2) increased diabetes knowledge and awareness, (3) monitoring and reminder functions, (4) nutrition, (5) physical activity, (6) coping with the burden of disease, (7) app features, and (8) user behavior and usability. Generally, participants stated that the app increased their diabetes knowledge and assisted them with their diabetes self-management.

Conclusion

This research project first provided recommendations that were used to design the features of the first Rwandan diabetes self-management smartphone application (Kir'App). Then the first prototype of Kir'App was developed and proved to meet the overall needs and expectations of the diabetics that participated in this research project. The qualitative insights that were discovered from the strict user-centered design process were used in this research project and will be followed for further improvement of the app. The next steps of this research project will focus on the evaluation of the impact of Kir'App on the Rwandan diabetics' self-management capacity and quality of life.

Keywords: diabetes, Kir'App, experiences, Rwanda

7.2. German version

ENTWICKLUNG DER ERSTEN SMARTPHONE-ANWENDUNG FÜR DAS SELBSTMANAGEMENT DES DIABETES FÜR DIABETIKER IN RUANDA

Hintergrund

In den letzten zwei Jahrzehnten erlebte Ruanda aufgrund seiner erfolgreichen Regierungspolitik eine rasche Industrialisierung und technologische Entwicklung. Fast 75% der Bevölkerung hat derzeit, aufgrund der zunehmenden Verfügbarkeit von Smartphones im Land, Zugang zum Internet.

Trotz dieser Fortschritte wurde festgestellt, dass insbesondere die Diabetes-Aufklärung und Versorgung in einigen Teilen Ruandas nicht erfolgreich verliefen. Obwohl mehrere Studien gezeigt haben, dass Smartphone-Anwendungen das Selbstmanagement von Diabetes-Patienten verbessern können, war bis zum Start dieses Forschungsprojekts im April 2019 in Ruanda keine Anwendung zum Selbstmanagement von Diabetes verfügbar.

Ziele

Das Hauptziel dieser Studie war die Entwicklung von Kir'App, die erste Smartphone Selbstmanagement Anwendung von Diabetes in Ruanda. Zwei Schritte waren nötig um dieses Ziel zu erreichen: Im Forschungsteam haben wir zunächst die Bedürfnisse und Erwartungen ruandischer Diabetiker gegenüber einer potenziellen App erfragt. Nach den Ergebnissen dieser Bewertung wurde der erste Prototyp der Kir'App entwickelt. Die App wurde den Teilnehmern der vorherigen Studie für 3 Monate zur Verfügung gestellt, woraufhin eine zweite Studie durchgeführt wurde, um die Erfahrungen der Benutzer nach 3 Monaten zu erfragen.

Methoden

Beide Studien dieses Forschungsprojekts verwendeten die gleiche Forschungsmethode. Die Studienteilnehmer wurden anhand von willkürlichen Stichproben bei der Rwanda Diabetes Association rekrutiert. Die Daten wurden mithilfe von halbstrukturierten persönlichen Interviews gesammelt. Die Ergebnisse wurden unter Verwendung von Mayrings Methode der qualitativen Inhaltsanalyse nach grundlegenden Themen untersucht. Für die zweite Studie wurden sowohl deduktive als auch induktive Ansätze verwendet um die Transkripte gemäß den ursprünglichen Kategorien und Unterkategorien der vorherigen Studie zu analysieren.

Ergebnisse

Die erste Studie umfasste 21 Teilnehmer mit Diabetes Typ 1 (weiblich = 5, männlich = 6) und Typ 2 (weiblich = 6, männlich = 4). Das Alter der Teilnehmer lag zwischen 18 und 69 Jahren, bei einem Durchschnittsalter von 35,2 Jahren. Die zweite Studie umfasste 14 Personen aus der vorherigen Studie. Ihr Alter lag zwischen 19 und 70 Jahren mit einem Durchschnittsalter von 34,4 Jahren.

Die Ergebnisse der ersten Studie identifizierten acht Hauptthemen: (1) Aufklärung zum Krankheitsbild des Diabetes und gewünschte Informationsbereitstellung, (2) Mangel an Wissen und Verständnis für Diabetes, (3) Informationsbedarf in Krisensituationen, (4) Erforderliche Überwachungs- und Erinnerungsfunktionen, (5) Informationen zur Ernährung und Alkoholkonsum, (6) Informationen zur körperlichen Aktivität, (7) Bewältigung der Krankheitslast durch soziale Unterstützung und Netzwerke; (8) App-Funktionen.

Die Ergebnisse der zweiten Studie zeigten sieben der acht Themen der vorherigen Studie und fügten ein neues Thema hinzu. (1) Aufklärung zum Krankheitsbild des Diabetes und Informationsbereitstellung; (2) Erhöhtes Wissen und Verständnis für Diabetes; (3) Überwachungs- und Erinnerungsfunktionen; (4) Ernährung; (5) körperliche Aktivität; (6) Bewältigung der Krankheitslast; (7) App-Funktionen; (8) Nutzungsverhalten und Benutzerfreundlichkeit. Im Allgemeinen gaben die Teilnehmer an, dass die App ihr Diabeteswissen erweitert hat und sie bei ihrem Diabetes-Selbstmanagement unterstützt hat.

Fazit

Dieses Forschungsprojekt lieferte zunächst Empfehlungen, anhand derer die Funktionen der ersten ruandischen Smartphone Anwendung für das Diabetes-Selbstmanagement (Kir'App) entwickelt wurden (siehe 1. Studie). Dann wurde der erste Prototyp von Kir'App entwickelt, der die allgemeine Bedürfnisse und Erwartungen der Diabetiker, die an diesem Forschungsprojekt teilgenommen haben erfüllte (siehe 2. Studie). Die qualitative Erkenntnisse, die wir aus dem benutzerzentrierten Designprozess erhalten haben, werden zur weiteren Verbesserung der App verwendet. Die nächsten Schritte dieses Forschungsprojekts konzentrieren sich auf die Bewertung der Effekten von Kir'App auf die Fähigkeit zum Diabetes-Selbstmanagement und die Lebensqualität der ruandischen Diabetiker.

Schlüsselwörter: Diabetes, Kir'App, Erfahrungen, Ruanda

Bibliography

- AADE (2008). AADE7 Self-Care Behaviors. *The Diabetes educator*, 34(3), 445–449. <https://doi.org/10.1177/0145721708316625>
- Abras, C., Maloney-Krichmar, D., Preece, J.(2004). User-Centered Design. In Bainbridge, W. st *Encyclopedia of Human-Computer Interaction*. Thousand Oaks: Sage Publications. (in press)
- Adu MD, Malabu UH, Malau-Aduli AEO, Malau-Aduli BS. (2018). Users' preferences and design recommendations to promote engagements with mobile apps for diabetes self-management: Multi-national perspectives. *PLoS ONE*, 13(12),e0208942. <https://doi.org/10.1371/journal.pone.0208942>
- Alcántara-Aragón V. (2019). Improving patient self-care using diabetes technologies. *Therapeutic advances in endocrinology and metabolism*, 10, 2042018818824215. <https://doi.org/10.1177/2042018818824215>
- Alhuwail D. (2016). Diabetes Applications for Arabic Speakers: A Critical Review of Available Apps for Android and iOS Operated Smartphones. *Studies in health technology and informatics*, 225, 587–591. <https://doi.org/10.3233/978-1-61499-658-3-587>
- Asiimwe-Kateera, B., Condo, J., Ndagijimana, A., Kumar, S., Mukeshimana, M., Gaju, E., Muhire, A., Muhimpundu, M.A., Kim, M.J., Kurth, A. (2015). Analysis: Mobile Health Approaches to Non-Communicable Diseases in Rwanda. *Rwanda Journal of medicine and health sciences*, 2, 89-92–92. <https://doi.org/10.4314/rjhs.v2i1.13F>
- Bagweneza,V., Musabirema,P., Mwiseneza,MJ, Collins,A.(2019). Diabetes health education: nurses' knowledge of essential components at a Rwandan hospital. *African journals online*, 2:2, <http://dx.doi.org/10.4314/rjmhs.v2i2.13>
- Bode, B.W. (2000). Clinical Utility of the Continuous Glucose Monitoring System. *Diabetes Technology & Therapeutics* 2, 35–41. <https://doi.org/10.1089/15209150050214104>
- Bonoto, B. C., de Araújo, V. E., Godói, I. P., de Lemos, L. L., Godman, B., Bennie, M., Diniz, L. M., & Junior, A. A. (2017). Efficacy of Mobile Apps to Support the Care of Patients With Diabetes Mellitus: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *JMIR mHealth and uHealth*, 5(3), e4. <https://doi.org/10.2196/mhealth.6309>
- Boren S. (2007). AADE7TM Self-care behaviors: systematic reviews. *Diabetes Educator*, 33(6):866-871.
- Boyle, L., Grainger, R., Hall, R.M., Krebs, J.D. (2017). Use of and Beliefs About Mobile Phone Apps for Diabetes Self-Management: Surveys of People in a Hospital Diabetes Clinic and Diabetes Health Professionals in New Zealand. *JMIR mHealth and uHealth* 5, e85. <https://doi.org/10.2196/mhealth.7263>
- Breland, J. Y., Yeh, V. M., & Yu, J. (2013). Adherence to evidence-based guidelines among diabetes self-management apps. *Translational behavioral medicine*, 3(3), 277–286. <https://doi.org/10.1007/s13142-013-0205-4>

- Cahn, A., Akirov, A., & Raz, I. (2018). Digital health technology and diabetes management. *Journal of diabetes*, 10(1), 10–17. <https://doi.org/10.1111/1753-0407.12606>
- Cassimatis, M., Kavanagh, D. J., Hills, A. P., Smith, A. C., Scuffham, P. A., Edge, S., Gibson, J., & Gericke, C. (2015). Development of the On Track Diabetes Program. *JMIR research protocols*, 4(2), e24. <https://doi.org/10.2196/resprot.2823>
- Center for Disease Control (2018, November). *Self-Management Education Programs | Self-Management Education: Learn More. Feel Better.* <https://www.cdc.gov/learnmorefeelbetter/programs/diabetes.htm>.
- Chavez, S., Fedele, D., Guo, Y., Bernier, A., Smith, M., Warnick, J., & Modave, F. (2017). Mobile Apps for the Management of Diabetes. *Diabetes care*, 40(10), e145–e146. <https://doi.org/10.2337/dc17-0853>
- Chomutare, T., Fernandez-Luque, L., Arsand, E., & Hartvigsen, G. (2011). Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-based guidelines. *Journal of medical Internet research*, 13(3), e65. <https://doi.org/10.2196/jmir.1874>
- Clement J. (2020, October). *Number of mHealth apps available at Google play from 1st quarter 2015 to 3rd quarter 2020.* Statista. <https://www.statista.com/statistics/779910/health-apps-available-ios-worldwide/>.
- Clement J. (2020, October). *Number of mHealth apps available in the Apple App Store from 1st quarter 2015 to 3rd quarter 2020.* Statista. <https://www.statista.com/statistics/779919/health-apps-available-google-play-worldwide/>.
- Combi, C., Pozzani, G., & Pozzi, G. (2016). Telemedicine for Developing Countries. A Survey and Some Design Issues. *Applied clinical informatics*, 7(4), 1025–1050. <https://doi.org/10.4338/ACI-2016-06-R-0089>
- Conway, N., Campbell, I., Forbes, P., Cunningham, S., & Wake, D. (2016). mHealth applications for diabetes: User preference and implications for app development. *Health informatics journal*, 22(4), 1111–1120. <https://doi.org/10.1177/1460458215616265>
- De Beurs, D., van Bruinessen, I., Noordman, J., Friele, R., & van Dulmen, S. (2017). Active Involvement of End Users When Developing Web-Based Mental Health Interventions. *Frontiers in psychiatry*, 8, 72. <https://doi.org/10.3389/fpsy.2017.00072>
- El-Gayar, O., Timsina, P., Nawar, N., & Eid, W. (2013). A systematic review of IT for diabetes self-management: are we there yet?. *International journal of medical informatics*, 82(8), 637–652. <https://doi.org/10.1016/j.ijmedinf.2013.05.006>
- European commission (2020, October). *Transformation of health and care in the digital single market.* <https://ec.europa.eu/digital-single-market/en/policies/ehealth>.
- Georgsson, M., & Stagers, N. (2017). Patients' Perceptions and Experiences of a mHealth Diabetes Self-management System. *Computers, informatics, nursing : CIN*, 35(3), 122–130. <https://doi.org/10.1097/CIN.000000000000296>

Global System for Mobile Communication Association (2019, July). *State-of-Mobile-Internet-Connectivity Report*.

<https://www.gsma.com/mobilefordevelopment/wpcontent/uploads/2019/07/GSMA-State-of-Mobile-Internet-Connectivity-Report-2019.pdf>

Haak, T., Hanaire, H., Ajjan, R., Hermanns, N., Riveline, J. P., & Rayman, G. (2017). Flash Glucose-Sensing Technology as a Replacement for Blood Glucose Monitoring for the Management of Insulin-Treated Type 2 Diabetes: a Multicenter, Open-Label Randomized Controlled Trial. *Diabetes therapy: research, treatment and education of diabetes and related disorders*, 8(1), 55–73. <https://doi.org/10.1007/s13300-016-0223-6>

Habtu, M., Uwingabire, S., Mureithi, C., Gashegu M. (2019). Knowledge and Attitude of Diabetes Mellitus and Adherence to Treatment Regimen among Diabetic Patients Attending Kirehe District Hospital, Rwanda. *Journal of Diabetes and Clinical Practice*, 2:2

Index Mundi (2019, December). Rwanda -Diabetes prevalence (% of population ages 20 to 79) <https://www.indexmundi.com/facts/rwanda/diabetes-prevalence>

International Diabetes Federation. *IDF Diabetes Atlas, 9th edn*. Brussels, Belgium: 2019. <https://www.diabetesatlas.org>

International Telecommunication Union (2019). *Measuring digital development Facts and figures 2019*. <https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf>.

Iribarren, S. J., Cato, K., Falzon, L., & Stone, P. W. (2017). What is the economic evidence for mHealth? A systematic review of economic evaluations of mHealth solutions. *PloS one*, 12(2), e0170581. <https://doi.org/10.1371/journal.pone.0170581>

Izahar, S., Lean, Q. Y., Hameed, M. A., Murugiah, M. K., Patel, R. P., Al-Worafi, Y. M., Wong, T. W., & Ming, L. C. (2017). Content Analysis of Mobile Health Applications on Diabetes Mellitus. *Frontiers in endocrinology*, 8, 318. <https://doi.org/10.3389/fendo.2017.00318>

Kebede, M. M., & Pischke, C. R. (2019). Popular Diabetes Apps and the Impact of Diabetes App Use on Self-Care Behaviour: A Survey Among the Digital Community of Persons With Diabetes on Social Media. *Frontiers in endocrinology*, 10, 135. <https://doi.org/10.3389/fendo.2019.00135>

Kemp, S. (2019, February). *Digital 2019: Global Digital Overview – Global Digital Insights*. Data reportal. <https://datareportal.com/reports/digital-2019-global-digital-overview>.

Kirapp (2019, May). *KirApp: The first diabetes self-management Android app for Rwandans* <https://www.kirapp.org/>.

Krošel, M., Švegl, L., Vidmar, L., Dinevski, D. (2016). Empowering Diabetes Patient with Mobile Health Technologies. Bonney W. (Ed), *Mobile Health Technologies - Theories and Applications*. Intechopen. <https://doi.org/10.5772/64620>

Levin, K., Madsen, J. R., Petersen, I., Wanscher, C. E., & Hangaard, J. (2013). Telemedicine diabetes consultations are cost-effective, and effects on essential diabetes treatment parameters are similar to conventional treatment: 7-year results from the Svendborg

Telemedicine Diabetes Project. *Journal of diabetes science and technology*, 7(3), 587–595. <https://doi.org/10.1177/193229681300700302>

Lygidakis, C., Uwizihwe, J. P., Kallestrup, P., Bia, M., Condo, J., & Vögele, C. (2019). Community- and mHealth-based integrated management of diabetes in primary healthcare in Rwanda (D²Rwanda): the protocol of a mixed-methods study including a cluster randomised controlled trial. *BMJ open*, 9(7), e028427. <https://doi.org/10.1136/bmjopen-2018-028427>

Mallow, J. A., Theeke, L. A., Barnes, E. R., Whetsel, T., & Mallow, B. K. (2014). Using mHealth Tools to Improve Rural Diabetes Care Guided by the Chronic Care Model. *Online journal of rural nursing and health care : the official journal of the Rural Nurse Organization*, 14(1), 43–65. <https://doi.org/10.14574/ojrnhc.v14i1.276>

Massaro, D.W. (1990). Review of The Psychology of Everyday Things. *The American Journal of Psychology* 103, 141–143. <https://doi.org/10.2307/1423268>

Mayring, P. (2000). Qualitative Content Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* 1. <https://doi.org/10.17169/fqs-1.2.1089>

Messner, E. M., Terhorst, Y., Barke, A., Baumeister, H., Stoyanov, S., Hides, L., Kavanagh, D., Pryss, R., Sander, L., & Probst, T. (2020). The German Version of the Mobile App Rating Scale (MARS-G): Development and Validation Study. *JMIR mHealth and uHealth*, 8(3), e14479. <https://doi.org/10.2196/14479>

Mukeshimana, M.M., Nkosi, Z.Z. (2014). Communities' knowledge and perceptions of type two diabetes mellitus in Rwanda: a questionnaire survey. *Journal of Clinical Nursing*, 23, 541–549. <https://doi.org/10.1111/jocn.12199>

National Institute of Statistics Rwanda (2017, December). *Statistical Year Book 2017*. <http://www.statistics.gov.rw/publication/statistical-yearbook-2017>.

Nelson, L. A., Mulvaney, S. A., Johnson, K. B., & Osborn, C. Y. (2017). mHealth Intervention Elements and User Characteristics Determine Utility: A Mixed-Methods Analysis. *Diabetes technology & therapeutics*, 19(1), 9–17. <https://doi.org/10.1089/dia.2016.0294>

O'Cathain, A., Croot, L., Sworn, K., Duncan, E., Rousseau, N., Turner, K., Yardley, L., & Hoddinott, P. (2019). Taxonomy of approaches to developing interventions to improve health: a systematic methods overview. *Pilot and feasibility studies*, 5, 41. <https://doi.org/10.1186/s40814-019-0425-6>

O'Dea, S. (2020, August). *Number of smartphone users 2016-2021*. Statista <https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/>

Owens, C., Farrand, P., Darvill, R., Emmens, T., Hewis, E., & Aitken, P. (2011). Involving service users in intervention design: a participatory approach to developing a text-messaging intervention to reduce repetition of self-harm. *Health expectations : an international journal of public participation in health care and health policy*, 14(3), 285–295. <https://doi.org/10.1111/j.1369-7625.2010.00623.x>

Patel, M. S., Asch, D. A., & Volpp, K. G. (2015). Wearable devices as facilitators, not drivers, of health behavior change. *JAMA*, 313(5), 459–460. <https://doi.org/10.1001/jama.2014.14781>

Peeples, M., Tomky, D., Mulcahy, K., Peyrot, M., Siminerio, L., & AADE Outcomes Project and AADE/UMPC Diabetes Education Outcomes Project (2007). Evolution of the American Association of Diabetes Educators' diabetes education outcomes project. *The Diabetes educator*, 33(5), 794–817. <https://doi.org/10.1177/0145721707307615>

Pokhrel, S., Shrestha, S., Timilsina, A., Sapkota, M., Bhatt, M. P., & Pardhe, B. D. (2019). Self-Care Adherence And Barriers To Good Glycaemic Control In Nepalese Type 2 Diabetes Mellitus Patients: A Hospital-Based Cross-Sectional Study. *Journal of multidisciplinary healthcare*, 12, 817–826. <https://doi.org/10.2147/JMDH.S216842>

Presseau, J., Schwalm, J. D., Grimshaw, J. M., Witteman, H. O., Natarajan, M. K., Linklater, S., Sullivan, K., & Ivers, N. M. (2017). Identifying determinants of medication adherence following myocardial infarction using the Theoretical Domains Framework and the Health Action Process Approach. *Psychology & health*, 32(10), 1176–1194. <https://doi.org/10.1080/08870446.2016.1260724>

Research2Guidance (2017, November). *mHealth App Developer Economics*. <https://research2guidance.com/diabetes-management-solutions-still-considered-the-number-one-therapy-field-preference-for-app-developers/>.

Research2guidance (2017, October). *mHealth Economics 2016 Report: Status and trends in mHealth App market*. <https://research2guidance.com/product/mhealth-app-developer-economics-2016/>

Rossmann, C., Riesmeyer, C., Brew-Sam, N., Karnowski, V., Joeckel, S., Chib, A., & Ling, R. (2019). Appropriation of Mobile Health for Diabetes Self-Management: Lessons From Two Qualitative Studies. *JMIR diabetes*, 4(1), e10271. <https://doi.org/10.2196/10271>

Rwanda Health Ministry (2018). *Key Health Indicators*. <https://www.moh.gov.rw/publications/key-health-indicators>.

Scheibe, M., Reichelt, J., Bellmann, M., & Kirch, W. (2015). Acceptance factors of mobile apps for diabetes by patients aged 50 or older: a qualitative study. *Medicine 2.0*, 4(1), e1. <https://doi.org/10.2196/med20.3912>

Schierenbeck, I., Johansson, P., Andersson, L. M., Krantz, G., & Ntaganira, J. (2018). Collaboration or renunciation? The role of traditional medicine in mental health care in Rwanda and Eastern Cape Province, South Africa. *Global public health*, 13(2), 159–172. <https://doi.org/10.1080/17441692.2016.1239269>

Schnall, R., Rojas, M., Bakken, S., Brown, W., Carballo-Dieiguez, A., Carry, M., Gelaude, D., Mosley, J. P., & Travers, J. (2016). A user-centered model for designing consumer mobile health (mHealth) applications (apps). *Journal of biomedical informatics*, 60, 243–251. <https://doi.org/10.1016/j.jbi.2016.02.002>

Schwarzer R.(1992). *Self-efficacy / thought control of action*, Washington ; London: Hemisphere Pub. Corp.

Stoyanov, S. R., Hides, L., Kavanagh, D. J., Zelenko, O., Tjondronegoro, D., & Mani, M. (2015). Mobile app rating scale: a new tool for assessing the quality of health mobile apps. *JMIR mHealth and uHealth*, 3(1), e27. <https://doi.org/10.2196/mhealth.3422>

Tol, A., Alhani, F., Shojaeazadeh, D., Sharifirad, G., & Moazam, N. (2015). An empowering approach to promote the quality of life and self-management among type 2 diabetic patients. *Journal of education and health promotion*, 4, 13. <https://doi.org/10.4103/2277-9531.154022>

US Food and Drug Administration (2019, November). *Digital Health Center of Excellence*. <http://www.fda.gov/medical-devices/digital-health>.

US Food and Drug Administration (2019, September). *Policy for Device Software Functions and Mobile Medical Applications - Guidance for Industry and Food and Drug Administration Staff*. <https://www.fda.gov/regulatory-information/search-fda-guidance-documents/policy-device-software-functions-and-mobile-medical-applications>.

Whittemore, R., Vilar-Compte, M., De La Cerda, S., Marron, D., Conover, R., Delvy, R., Lozano-Marrufo, A., & Pérez-Escamilla, R. (2019). Challenges to diabetes self-management for adults with type 2 diabetes in low-resource settings in Mexico City: a qualitative descriptive study. *International journal for equity in health*, 18(1), 133. <https://doi.org/10.1186/s12939-019-1035-x>

Witt Udsen, F., Lilholt, P. H., Hejlesen, O., & Ehlers, L. (2017). Cost-effectiveness of telehealthcare to patients with chronic obstructive pulmonary disease: results from the Danish 'TeleCare North' cluster-randomised trial. *BMJ open*, 7(5), e014616. <https://doi.org/10.1136/bmjopen-2016-014616>

Wong-Rieger, D., & Rieger, F. P. (2013). Health coaching in diabetes: empowering patients to self-manage. *Canadian journal of diabetes*, 37(1), 41–44. <https://doi.org/10.1016/j.jcjd.2013.01.001>

World Bank (2020). *Country Rwanda*. <https://data.worldbank.org/country/rwanda?view=chart>

World Health Organization (2016). *Diabetes country profile*. https://www.who.int/diabetes/country-profiles/rwa_en.pdf

Ye, Q., Khan, U., Boren, S. A., Simoes, E. J., & Kim, M. S. (2018). An Analysis of Diabetes Mobile Applications Features Compared to AADE7™: Addressing Self-Management Behaviors in People With Diabetes. *Journal of diabetes science and technology*, 12(4), 808–816. <https://doi.org/10.1177/1932296818754907>

APPENDIXES

A. Appendix of study 1: Assessment of the Rwandan diabetics' needs and expectations to develop the first diabetes self-management smartphone application (Kir'App)

A.1. Interview guide

Section A: Biographical data		
1. GENDER	MALE	
	FEMALE	
2. AGE		
3. MARITAL STATUS	SINGLE	
	MARRIED	
	OTHER	
4. TYPE OF DIABETES	TYPE 1	
	TYPE 2	
5. DURATION FROM DIABETES DIAGNOSIS	LESS THAN 1 YEAR	
	1-5 YEARS	
	6-10 YEARS	
	11-15 YEARS	
	16 – 20 YEARS	
6. EDUCATION LEVEL	MORE THAN 20 YEARS	
	NONE	
	PRIMARY SCHOOL	
	SECONDARY SCHOOL	
	UNIVERSITY	
	VOCATIONAL TRAINING	
6. WORK STATUS	OTHER	
	JOBLESS	
	STUDENT	
	FULL-TIME WORK	
7. HOW DO YOU RATE YOUR KNOWLEDGE AND SKILLS OF USING SMARTPHONE APPLICATIONS?	TEMPORARY WORK	
	EXCELLENT	
	VERY GOOD	
	GOOD	
	POOR	
8. HOW OFTEN DO YOU USE YOUR SMARTPHONE APPLICATIONS A DAY?	VERY POOR	
	NEVER	
	AT LEAST ONCE A DAY	
	MORE THAN ONCE A DAY	

Section B: Questions about needs and Expectations from a Diabetes self-management Smartphone Application

1. Would you like to have a Mobile Phone Application which could help you in the management of your diabetes?
2. Can you imagine and tell me possible functions you wish that Mobile Phone Application could have in order to help you in the management of your diabetes?
3. Think about all your daily activities related to the management of your Diabetes and tell me, in which circumstances do you think you would need to use it?

Questions 4-5-6 were directing questions in case the participant didn't mention any of the following elements in his/her answer of the previous questions.

4. Let's suppose that the Mobile phone Application could help you dealing with the self-management of your : (was asked one by one) 1) Blood Sugar 2) Blood Pressure 3) HbA1C 4) Body Weight 5) Feet. Can you tell me how you wish it should help you?
5. During the self-management of your Diabetes, you need to do some self-regulation activities for example: (was asked one by one) 1) Physical activities 2) Management of your diet 3) Management of your drinks 4) Management of hypoglycemia 5) Management of hyperglycemia 6) preparation of your trips. Is there any assistance you wish the mobile phone Application could offer to facilitate you doing it?
6. Can you think about activities of the management of your disease in which you would like the mobile phone Application to play as your reminder?
7. Is there any topic about diabetes education would you wish the mobile phone Application to teach you and in which way (how)?
8. If the mobile phone Application could connect you to your treating physician, how would you wish it to do it?
9. Would you like to receive some recommendations and advices concerning your disease from the mobile phone Application? If yes, how?

A.2. Summary of recurrent themes and sub-categories with examples

Theme	Sub-category	Examples
<p>1 Education and desired information provision</p> <p><i>Theme refers to the provision of information, specialised education on diabetes in general and the coping with the disease.</i></p>	<p>1.1 General information on diabetes, management and complications</p> <p><i>Sub-category refers to information that should be provided by the app in order to close general knowledge gaps on disease characteristics, management (through medication and behaviour change) and complications.</i></p>	<p>P5: <i>“I wish the application to help me to master in the care of my disease by giving me more information about diabetes and helping me to change behaviour in order to care after my disease.”</i></p> <p>P5: <i>“I need to know much about insulin. I think that even all those tablets we take are also insulin in different forms, but I would like to know if insulin injections taken on a long-term may cause damages in the human body. I know it’s the only medication we must take, but are there precautions we should follow or respect while taking injections or other tablets? What are the short or long term complications which may occur? Right now I have neuropathy; can’t it be due to those insulin injections I am taking? There is also another problem we often discuss with other diabetics without finding answers; why are our bodies not producing insulin? I heard that it is because of malfunction of the pancreas (though I am not sure if that information is correct) but if it is, why can’t our pancreas be treated and healed?”</i></p> <p>P 11: <i>“First of all, the application should teach us the difference between type 1 and type 2 diabetes because most of people of my age don’t know which type of diabetes they are living with. The application should also teach us more about the medications we take and why some people use tablets when others are using insulin although we all have type 2 diabetes? It should also teach us about side effects of medications, you know taking the same medicine for 10-20 years, I guess it causes some harm to the body. Because I know someone who was diagnosed with diabetes after me</i></p>

		<p><i>and the Dr prescribed her immediately insulin. He told her that tablets are not good because they immediately go into the blood, and that insulin was better. I was really confused.”</i></p>
	<p>1.2 Medical parameters (e.g. blood pressure, blood glucose, HbA1c, weight etc.) <i>Sub-category refers to specialised knowledge on parameters of diabetes symptoms and progression.</i></p>	<p>P18: <i>“The application should have a special page about all the tests and health exams we need to do as diabetics and mention when and why we should do them. Imagine that I used to think that through the HbA1c test; both my eyes and kidneys were also screened.</i></p> <p>P4: <i>“My blood glucose levels sometimes reach 400 mg/dl, I wish the Application to tell me what caused it to raise that high and very importantly to teach me how I should lower it. Can it also have the capacity to show me my blood glucose levels?”</i></p> <p>P3: <i>“The Application should teach me what are the normal values of HbA1C, the poor values to avoid and how to keep it in normal ranges.”</i></p>
	<p>1.3 devices <i>Sub-category refers to information provision on new medical devices to monitor diabetes parameters</i></p>	<p>P5: <i>“I wish the application to inform me about newly discovered devices being available on the market that may help in diabetes care. You see, we use different glucose meters. I would like the application to tell us for example whenever there are some other available new glucose meters that can be more efficient, and maybe less expensive. Or maybe some other devices we don’t know so far that can be used in diabetes care.”</i></p> <p>P16: <i>“In case I want to check my blood glucose levels, I wish an application that can show me my blood glucose levels by using my finger print only without being obliged to prick my finger to get a blood drop.”</i></p>

		<p>P21: <i>“You know many diabetics like me don’t have glucose meters or we buy them and don’t repair them once they have defects. We take our medication without knowing our levels of blood sugar and we only come here to the clinic once in month to check it or whenever we don’t feel okay. Is that good? The application should teach us more about that.”</i></p>
	<p>1.4 Frequently asked questions by newly diagnosed patients <i>Sub-category refers to a repository of information for those newly diagnosed with diabetes</i></p>	<p>P13: <i>“There are some people who are newly diagnosed with diabetes and who have a million questions about it, even we ourselves still have many unanswered questions about it; so the application should have a function of ‘ frequently asked questions ‘ with their answers for a rapid consultation in case of need.”</i></p> <p>P14: <i>“It’s been only 1 year since I was diagnosed with diabetes and I have to confess that I have many unanswered questions about it. Maybe the application can make a kind of summary about everything a new diabetic has to know so by reading it we can have an overview of our disease.”</i></p>
	<p>1.5 National/ regional update and initiatives as well as services <i>Sub-category refers to information on national and/or regional initiatives on diabetes care as well as local services</i></p>	<p>P5: <i>“I wish the application to inform me about activities concerning diabetes that are taking place in Rwanda and that we can attend. And those ones taking place outside Rwanda even if I may not be able to attend them. Activities like meetings, workshops, conferences and sensitization activities about diabetes that are being organised for patients because now we don’t attend many due to lack of information.”</i></p>

		<p>P1: “Another idea that would be great would be an application that can indicate us possible pharmacies (in Kigali for example) where someone can buy insulin and syringes. Because someone can come from another province (for example western) to Kigali and not knowing where to buy products he really needs for his diabetes care.”</p>
<p>2 Lack of knowledge / awareness Theme comprised characteristics of the individual end user, mainly knowledge gaps</p>	<p>2.1 Lack of knowledge on living with diabetes Sub-category refers to knowledge gaps concerning the everyday life with diabetes, especially concerning disease related behaviour</p>	<p>P16: “Sometimes there are some topics the Dr teaches me when I come to my regular appointments but I don’t understand them well and I ask for more explanations to my mother and then we google them (for example about the control of blood glucose levels , food and so on) and try to get answers. So, I think that if we had the application; it would help me to learn more.”</p> <p>P7: “What is the problem with feet in diabetes? I didn’t know that someone could develop foot problems because of diabetes. Right now I have athlete’s foot and I’ve never thought that it could be linked to my diabetes but now that you mention it, I will go back to the Doctor and ask for a treatment. Now, I wish the application to teach us about foot problems in diabetes, I can learn how to take care of them and I can use it to teach other diabetics like me who may be unaware of that information.”</p> <p>P10: “The application should teach us about type 1 diabetes and pregnancy. We are not sure if as type 1 diabetics we can have children, and if we get pregnant, can we keep taking insulin?”</p> <p>P4: “The application should teach us about diabetes care in our everyday life, for example I smoke, I would like to know if it is good or bad for a diabetic.”</p>

	<p>2.2 prejudice & myths (social media knowledge) <i>Sub-category refers to false information being considered true</i></p>	<p>P4: <i>“The Application should also tell us about all possible diabetes myths (for example some people say that when you grow up, your diabetes shift from type 1 diabetes to type 2), in order to protect us against them since there are many outside here and sometimes the person telling it looks smart and you are tempted to believe him.”</i></p> <p>P6: <i>“The application can teach type 1 diabetics about how to live their love life with their diabetes. Most of them are ashamed to tell it to their partners. Because there are many known cases where the partner broke with the person after knowing that s/he had diabetes. Some people didn’t go to school or don’t know much about diabetes, they think that the person can contaminate them, others think that once they get married they can die or develop complications and that their lives would be worse or the healthcare would cost them much.”</i></p> <p>P3: <i>“The application should teach us about diabetes myths and how to behave as young diabetics. How to behave once a type 1 diabetic gets married, how to behave at your work or in your family and how to deal with alcoholism, drug abuse, adultery, fighting, etc.”</i></p>
	<p>2.3 lack of knowledge on web 2.0 <i>Sub-category refers to gaps in digital knowledge and trust in technology</i></p>	<p>P15: <i>“I’ve seen some [application] on google play but it requires a subscription; they are being connected to your bank account and they draw money from it. I was not sure of them, scared of hackers, I abandoned the idea of subscription.”</i></p>
<p>3. Crisis Intervention Theme</p>		<p>P3: <i>“When I am in class and start feeling bad; I wish to be able to check the Application and get to know if it is</i></p>

<p><i>refers to information provision in case of disease complications in order to prevent panicky behaviour</i></p>		<p><i>a hypo or a high episode I am going through.”</i></p> <p>P12: <i>“The application should teach us how to behave once you have hypos or highs because sometimes you become stressed which can raise your blood sugar levels more. It [the application] can also be my logbook where I can write my blood sugar levels and my doses of insulin of everyday.”</i></p> <p>P9: <i>“I wish the application to teach me tips about food and drinks or anything else that can help me to keep myself from hypos and highs. I hate to have hypos because after the hypo episode everyone knows that I have diabetes and I hate people to know that I have diabetes.”</i></p> <p>P14: <i>“Right now I have a flu and whenever I have it, I lose appetite and can’t eat anything which causes me to have high blood sugar levels that I treat with insulin and then I have low blood sugar levels. So the application should teach us about the management of diabetes in case we have other diseases like flu, malaria that can interfere with our appetite and cause changes in our blood glucose levels. Those diseases have even some symptoms similar to hypo/highs and you can’t guess if you have a hypo or high.”</i></p>
<p>4. Monitoring and reminder functions <i>Theme refers to monitoring and reminder functions the app should incorporate for disease-relevant parameters, including</i></p>	<p>4.1 BG/ BS recording and trend visualization <i>Sub-category refers to monitoring and display of changes in diabetes parameters to be done via the app</i></p>	<p>P2: <i>“Another thing I wish the Application to offer would be a kind of dairy to record the results of our blood glucose, A1c, blood pressure and body weight checking. A diary on which we can write possible mistakes, which may have caused the results of these health checkups to be high or low compared to the normal values. That diary would help us to do a kind of self-evaluation. Based on knowing the mistakes we did, next time we may take measures for correcting them</i></p>

<p><i>medication, physical activity and nutrition</i></p>		<p><i>referring ourselves to our dairy.”</i></p> <p>P3: <i>“The Application should [...] help me to keep all my previous health records in order to show them to the Dr so he can do a follow up of my progress.”</i></p> <p>P4: <i>“I usually use a diary to record my blood glucose results but when I have a fieldwork or when I go unexpectedly for a job mission I forget the diary but I never forget my Smartphone, so it would be good to have a kind of electronic diary.”</i></p> <p>P13: <i>“Sometimes when you are not at home, it’s challenging to measure your blood sugar in order to take your insulin. I know that there are applications that show people what is their heart beat and pulse. I wish we could also have an application that shows us our regular blood glucose levels without being obliged to use glucose meter and needles.”</i></p> <p>P15: <i>“I usually work much and use much energy since I am an IT technician, so at 11- 12 AM when I take a break, I would like the application to show me the variation of my blood glucose levels. Then other times when I am not using much energy like when I am repairing a computer, the application can also help me to track the variation of my blood glucose levels. This way I can get to know how my blood sugar levels change depending on my daily activities and know how to adjust to it.”</i></p> <p>P16: <i>“I wish the application to track my physical activity, show me my heart beat and tell me when I have done enough exercise.”</i></p>
	<p>4.2 Reminder functions Sub-category refers</p>	<p>P2: <i>“It could also remind me when to do exercise during the week days because I forget it most of the time and</i></p>

	<p><i>to automated reminders for physical activity, insulin use and food intake to be provided by the app</i></p>	<p><i>my mother has to remind me to do it with her only on Fridays after work though I know I have to do it at least three times a day. So if I had an Application in which I could set days of doing sport for example on Mondays, Wednesdays and Fridays; I think it would be great and help me more in controlling my blood sugar.”</i></p> <p>P3: <i>“The Application should first remind me of the Dr’s Appointment.”</i></p> <p>P13: <i>“The application can remind me to check my blood sugar and to take my insulin injection at the same hour of every day. It should ring also at the same hour of every day to remind me to do exercise because I can be busy and forget to do it so the application should remind us that even when busy, we should find 30 minutes for exercise. It should also remind me of doctor’s appointments.”</i></p> <p>P14: <i>“The application should remind me when it’s time to check my blood sugar and the estimated time my insulin medication will run out so I can buy another one on time because sometimes I just forget to buy it and I experience shortage when I am not ready to buy another one (not having money for example) and I can spend a day or two without taking it which is bad.”</i></p>
<p>5. Nutrition and alcohol consumption <i>The theme refers to information provision on food and drink choices as well as alcohol intake to be delivered by the app</i></p>	<p>5.1 Composition of a diabetic plate <i>Sub-category refers to information provision on what kind of food is complementary with the disease</i></p>	<p>P3: <i>“The application should teach us about types of food that don’t contain much glucose. Sometimes I may take much quantity of rice and little quantity of beans whereas I should do the opposite. I wish the Application to teach me what quantity of which food to put on my plate and the content of each possible food in terms of glucose and other nutrients.”</i></p> <p>P6: <i>“For the food, the application should show us which one is allowed. They usually teach us about how a</i></p>

		<p><i>diabetic plate must be prepared (how to divide it in 4 parts: with one side for banana, another one for beans, another one for vegetables and fruits) but we most of the time forget it, so the application should give us a list of different categories of food we can eat depending on the availability of food we have here in Rwanda.”</i></p> <p>P5: <i>“We need to have an application that can teach us more about diabetics’ diet. Having a list of common food with their glucose content. You hear some people saying; potatoes contain much glucose, another one; rice is worse, another one; forget sweet potatoes for the good. That’s the main problem I experienced when I was diagnosed with diabetes; suddenly I was not allowed to eat anything, I lost much weight and I was most of the times nearly fainting because of hunger. [...] And when I talk with other diabetics; that is the very first main challenge they say that they meet.”</i></p>
	<p>5.2 information on non-alcoholic beverage choices <i>Sub-category refers to information about diabetes-appropriate choice of beverages the app should provide</i></p>	<p>P2: <i>“Sometimes it is really hard for example in case of a party taking place at home when others are drinking Soda or juice and you wonder what to do; drinking them or mix them with water and do like you are enjoying the drinks like others? So most of the time I check my blood sugar and drink a Soda. I also heard that drinking water reduces blood sugar, so sometimes when I have high blood sugar (in case of sorrow, stress,etc.) although I have taken my insulin shot, I wonder if I could drink water and reduce my blood glucose instead of taking another injection.”</i></p> <p>P7: <i>“[...] for example I personally like soda very much and after I was diagnosed with diabetes I had to stop taking it and whenever I used to pass by shops with sodas in fridges I felt my heart aching remembering that I couldn’t drink it anymore. But is it true? Can’t we take some food or drink we like maybe once in a while and keep enjoying our life?”</i></p>

		<p>P8: <i>“The application can teach us about milk, because I love milk; I can take 1 litre of curdled milk a day. But the application should also tell us something about pasteurised milk. There are some people like me who can even take 3 litres of milk a day but we don’t know if it can cause problems or if it can interfere with the pills or insulin we take.”</i></p>
	<p>5.3 information on alcohol intake <i>Sub-category refers to information about the acceptable kind and amount of alcohol the app should provide</i></p>	<p>P13: <i>“[...] some people like drinking alcohol, the application should maybe direct us how much quantity they should drink, maybe a half bottle. For example, type 1 diabetics feel young and strong. Some drink alcohol and when you get drunk, you can easily fall down and get injured and some people aren’t even aware of their injury when they are high, coming home, they sleep and the next day they deal with their hangover and the person may have to go to a hospital when the wound is infected and maybe get amputated in the future.”</i></p> <p>P18: <i>“I wish to have a special page about beers diabetics can drink and have fun with friends and still enjoy life. Or a page on how to still enjoy life besides having diabetes, because some people choose not to take insulin injection or pills when they are going to take beers, thinking that beers and medications should never be mixed. Other people cannot stop taking beers, should they die? Like me, I can take 5 bottles of skol [malt] when I am with my friends, I know it’s bad but what should I do, I like it.”</i></p> <p>P5: <i>“You hear also some men [diabetics] saying that the doctor said they can take skol and you wonder which kind doctor advices his patients to take alcohol. They forget that even if alcoholic beverages are bitter</i></p>

		<p><i>but still have amount of carbohydrates which increase blood sugar levels.”</i></p>
	<p>5.4 pleasure of eating <i>Sub-category refers to the perceived cognitive effort of dietary food intake and the consequences for enjoyment when eating</i></p>	<p>P21: <i>“Isn’t there any way our everyday life could be improved? Why do we have to eat only bitter? Aren’t there new researches about that? The application should inform us about that.”</i></p> <p>P11: <i>“Maybe the application can also give us tips on how to enjoy our food, because diabetics are known to always eat bitter. And when you are diagnosed at an old age, it is really hard to stop with your life time habits in terms of food.”</i></p> <p>P4: <i>“Sometimes I refuse to go to parties because I don’t drink alcohol and when I think I can’t take soda either I refuse to go as I hate to always drink water. Can the Application teach me what else I might do to enjoy parties like others?”</i></p> <p>P19: <i>“I stopped to eat whatever contains sugar even fruits; I can’t eat banana or pineapple, I only use the diabetic sweeteners. If the application could teach me which fruits are good and at which quantity I can eat them, it would be great.”</i></p> <p>P20: <i>“I stopped to eat quite everything because people and doctors were telling me to do so. I used to like rice, I can’t eat it anymore. That is to cite one example; they tell us to eat pumpkins only. But can someone survive with that one kind of food? The application should tell us about all categories of food we are allowed to take.”</i></p>
<p>6. Physical activity <i>Theme refers to information provision on right kind and amount of exercise as</i></p>	<p>6.1 kind of sport to do <i>Sub-category refers to the kind of physical activity one should pursue when</i></p>	<p>P11: <i>“Which physical activity fits old people like me?”</i></p> <p>P17: <i>“The application can teach us about acrobatic games that are safe for diabetics. I used to be a player of acrobatic games but when I was diagnosed with diabetes, I stopped it and this frustrates me because I</i></p>

<p><i>well as motivational input for physical activity to be delivered by the app</i></p>	<p><i>having diabetes</i></p>	<p><i>used to like it much.”</i></p> <p>P16: <i>“The application should show us which equipment diabetics are allowed to use in fitness studio and the time they should spend using them. Which one is better to use in order to make us healthier? And of course the ones that might be dangerous for us and what we don’t really need”</i></p>
	<p>6.2 motivation for physical activity <i>Sub-category refers to motivational input the app should deliver to the end user</i></p>	<p>P11: <i>“I am retired and have time for exercise but I lack motivation and become discouraged whenever I imagine what people would think if they see an old woman running on the street. I don’t have people who motivate me. Sometimes I exercise at home and walk many rounds during 30 minutes but it’s not every day. I wish the application to give us motivation.”</i></p> <p>P14: <i>“The doctor told me to exercise at least 40 minutes a day, he said I have to walk quickly but I am not able to do so, that’s why I don’t exercise at all. Maybe the application could teach us more flexible ways of exercising so we can be motivated to do it instead of abandoning it completely”</i></p> <p>P20: <i>“It is really hard to exercise every day. You know it is really difficult to wake up every morning for exercise when you are 50 years old and you’ve never done it before. I tried and failed.”</i></p>
	<p>6.3 frequency & duration of physical activity <i>Sub-category refers to information on the right amount of physical activity one should pursue to be</i></p>	<p>P16: <i>“I wish the application to track my physical activity, show me my heart beat and tell me when I have done enough exercise.”</i></p> <p>P20: <i>“Then I decide to exercise twice a week after my job. I do it for like 1h. But I don’t know if it is enough. The application should teach us about what is better to do.”</i></p>

	<p><i>delivered by the app</i></p>	<p>P3: “Sometimes we see other people exercising for example for 2 hours and we follow them. I wish the Application to teach me what, as a diabetic I am supposed to do before I am working out. The Application should [...] teach [...] the right duration of physical exercise because for example I can go for a football game which lasts for 90 minutes and may encounter some problems.”</p>
<p>7. Coping with burden of disease <i>Theme refers to functionalities of the app which allow for a better coping with diabetes through emotional supportive content and the ability to connect with others suffering from diabetes</i></p>	<p>7.1 emotional support <i>Sub-category refers to supportive content for emotional distressing situations due to the disease, which should be provided by the app</i></p>	<p>P1: “Receiving some recommendations and advice from the Application would be very helpful. For example some advice about behaviours to adapt in different situations like now I am about to start University. The application can give me some advice for example about how to cope with the stress caused by the new environment; how to keep on respecting my schedule of taking my insulin injections on time and so on.”</p> <p>P2: “I wish the Application could give me advice about how to control my emotions (anger, bitterness, stress, sorrow, etc). Since I heard that most of them cause the blood sugar to raise. It should give me some advice for example to listen to music and sleep whenever I feel unhappy and so on.”</p> <p>P3: “The application should teach us how to behave as a diabetic; for example as a young girl how to avoid alcoholism, drug, and adultery which hinder my health and my blood sugar and worsen my diabetes. How to behave with my friends who don’t have diabetes or other people or my family in general. Because there are some diabetics who live isolated, always angry or depressed and don’t live well with others. How to behave at home; some don’t live relaxed at home with their siblings (or are never happy for/with them) or are</p>

		<p><i>jealous of them because they are sick and not them. Some refuse to do any chore at home pretending that they are sick and spend time in bed while their siblings are doing everything. They may not play with them as a kid, not eat the same food like them and use their disease to be capricious or disturb the family atmosphere because of their diabetes.”</i></p> <p>P6: <i>“You can teach young people with type 1 diabetes about having hope in life. As we know that diabetes can be hereditary, some of us just stack on that idea and live hopeless thinking that they can never get married because they don’t want their children to live the same hell they are living. Whenever I meet some, I try to convince them of the opposite; showing them how a young type 1 like me became a happy married woman with one kid without diabetes and pregnant with a second one and that I live a happy life but it is hard to convince them. So if the application could teach us about that aspect, it would be very great.”</i></p>
	<p>7.2 social support <i>Sub-category refers to social support when dealing with diabetes, which should be incorporated into the functionalities of the app</i></p>	<p>P11: <i>“I told you that I sometimes become discouraged to go for exercise alone because in my neighboring there are only young people busy with their jobs. There is no other people with diabetes or hypertension to motivate me; if the application could help us knowing each other; we can even organise meetings and share our experiences; our hope to live. Like I was diagnosed at an old age but there are young mothers and fathers who need to be encouraged to fight and keep living and see their children growing up.”</i></p> <p>P12: <i>“The application can give us a function to teach us to accept our disease, to strengthen our self-confidence and help us to keep strong. To remind us</i></p>

		<p><i>that despite of our disease we will become adults like others. Because sometimes when we meet with discouraging people, we feel down. I don't know if we can have a forum on the application where we can meet as diabetics but also invite other people so we can explain them about diabetes. Telling them that despite of our diabetes, we are also human beings. To tell them, that they should not despise us because we didn't choose to suffer from it."</i></p> <p>P8: <i>"Can the application put me in contact with other people for example when I am feeling down so they can help me feel better(a kind of disease partner not necessary sick but who knows diabetes well and who can help me)?"</i></p> <p>P17: <i>"There should also be a function like a forum where we can share our contacts, address, picture and our goal or dream in life so we can get to know each other as diabetics. See, today I met a guy here at the clinic I use to meet in my neighbouring without knowing he was also a type 1diabetic If we knew we had the same condition, I am sure we could have helped each other much."</i></p> <p>P18: <i>"I think the app can connect us because like me I don't know many other diabetics and I think its causes me to be less informed."</i></p>
<p>8. App Features <i>Although participants had difficulties to imagine possible App functions, many this theme refers to interactive information</i></p>	<p>8.1 information delivery <i>The sub-category refers to content to be delivered via text, images, audios and videos.</i></p>	<p>P5: <i>"Videos are better, because you can see and understand what the doctor is explaining. At my age, reading may be tricky. I think that having both may be better."</i></p> <p>P3: <i>"Sometimes we cannot even raise our hand when we are in a hypo, so the idea of having an audio would be to instruct us on what to do in case of a hypo crisis."</i></p>

<p><i>delivery options and the integration of different languages.</i></p>		<p><i>Otherwise you can neither read nor watch a video.”</i></p> <p>P1: <i>“Having an audio to tell you what to do in case of hypos and high sugars would be great since you cannot read or watch a video properly when you are experiencing one of those crises but you can listen to an audio and follow instructions.(...) The idea of using images to show you how to take care of my foot would also good.”</i></p> <p>P7: <i>“Videos are also better because when reading, you can get confused, but when you see the person speaking, you understand well.”</i></p> <p>P11: <i>“Videos are better because sometimes you can read and don’t understand meaning and the context.”</i></p>
	<p>8.2 available languages <i>Sub-category refers to desired languages to be supported by the App. Participants either wish to include local language, Kinyarwanda, or to also include English.</i></p>	<p>P7: <i>“Kinyarwanda is better because even if you think you speak English, you may start reading and be confused with medical or scientific terminology, though you needed to understand everything well.”</i></p> <p>P3: <i>“It would be great to have an option to change the language like for Facebook (the Application should be both Kinyarwanda or in English for the choice of the use).”</i></p> <p>P1: <i>“Having an option of either using it in Kinyarwanda, French or in English would be better.”</i></p> <p>P5: <i>“It’s better to have the application in Kinyarwanda because many people - even if they went to school - they may not understand medical terms if they are in English.”</i></p> <p>P13: <i>“Some Rwandans don’t know Kinyarwanda well, it will be better to put the Application in both Kinyarwanda and English.”</i></p>

B. Appendix of study 2: A qualitative study of users' experiences after 3 months: the first Rwandan diabetes self-management Smartphone application "Kir'App"

B.1. Comparison of themes

Theme	Subcategory	Follow-up (positives)	Follow-up (negatives)
<p>1. Diabetes education and desired information provision</p> <p><i>This theme refers to the availability of materials for diabetes education in the App.</i></p>	<p>1.1. General information on diabetes, its management and complications</p> <p><i>Users stated that the app supported them to fill gaps in their knowledge about diabetes.</i></p>	<p>P3: I think Kir'App is not only needed by people living with diabetes. Like the first page called "Teach me about diabetes", it contains a summary of all information about diabetes, for example how to differentiate types of diabetes or again people who are at risk of developing type 2 diabetes. I think that non diabetic people would also need to know this kind of information.</p> <p>P5: I don't know if you remember but the first time when you asked me which type of diabetes I had, I said type 2 then went to ask my doctor and came back to tell you I was type 1. I didn't really know how to differentiate both but now I know. The detailed explanations I found in Kir'App helped me to understand all types of</p>	

		<p>diabetes and I now explain it to other people confidently.</p> <p>P9: (...) I also learnt about warning signs in case of foot problems, now I know that some signs that we consider to be normal like having very hot or very cold feet can alert some danger and that I have to go to see my doctor whenever I feel it.</p> <p>P10: With Kir'App I learnt that I could enjoy ceremonies like other people. It had been a while that I haven't attended any, but with the tips given in Kir'App I found back the pleasure of enjoying my life with friends and family again.</p> <p>P12: I found the 13 steps in images and texts that show how to take care of our feet very interesting. The other day my husband came home earlier in the evening, and I asked him to help me in my foot care by inspecting the skin under my feet.</p> <p>P14: (...) I learnt much when reading recommendations about physical activities in</p>	
--	--	---	--

		<p>diabetes; I used to do sport without knowing much about why it is recommended in diabetes.</p> <p>P14: I also discovered something I didn't know called glycemic index in Kir'App. I was aware that foods we eat contain glucose but I didn't know about their classification on how their glucose enters in our blood after we take them. Since then I started to check the color each food I take is classified in.</p>	
	<p>1.2. Medical parameters (e.g. blood pressure, blood glucose, HbA1c, body weight etc.)</p> <p><i>Users expressed satisfaction with the individualized feedback on different medical parameters they received from the App.</i></p>	<p>P2: (...) Kir'App also interprets my blood sugar results and shows me which action to take immediately.</p> <p>P2: I can even calculate my BMI using the calculator in Kir'App but also can check my ideal body weight range so I keep in mind what my limit must be.</p>	

	<p>1.3. Medical devices</p>	<p><i>No quotes attributable</i></p>	
	<p>1.4. Frequently asked questions by newly diagnosed patients.</p> <p><i>Users were pleased that the app provided a forum for posting inquiries about their individual experiences with diabetes, in addition to the section for frequently asked questions.</i></p>	<p>P6: Another thing I like in Kir'App is the part of frequently asked questions found on every page. Sometimes you ask yourself many questions without finding answers but it so helpful to click there and find your question and its answer there. And another good thing is that, even if you don't find it there you can even use the different forums and ask immediately your questions.</p>	
	<p>1.5. National/regional update and initiatives as well as services.</p> <p><i>Users found it helpful to have information in the app about local services (e.g. pharmacies) needed in their daily diabetes management.</i></p>	<p>P3: (...) another thing that I liked in Kir'App is the list of pharmacies with available medicines and materials needed by diabetes people in every district of Rwanda. Like me when I am at my parents' place in the North province, I check which Pharmacy has the item I need, I can even call them using their telephone number in Kir'App and I can go there without doubting about the availability of what I need.</p>	

<p>2. Increased knowledge and awareness.</p> <p><i>The theme reveals users' experiences with the app in compensating for their knowledge gaps.</i></p>	<p>2.1. Increased knowledge on living with diabetes.</p> <p><i>Users reported the app helped them to increase their level of knowledge about diabetes self-care behaviours.</i></p>	<p>P9: I also learnt about warning signs in case of foot problems, now I know that some signs that we consider to normal like having very hot or very cold feet can alert some danger and that I have to go to see my doctor whenever I feel it.</p>	
	<p>2.2. Prejudice & myths (social media knowledge).</p> <p><i>Users reported that Kir'App helped them to uncover and discard false information (rumours and myths) on diabetes.</i></p>	<p>P13: I've always wanted to ask my doctor about a rumour I heard about the effect of diabetes on sexual performance but our doctors are all the time in hurry that you cannot ask them all questions you have. When reading the first page of Kir'App called "Teach me about diabetes", I saw a picture of a man with diabetes complications on different parts of his body even on sexual organs. This disease is terrible.</p>	
	<p>2.3 Lack of knowledge on web 2.0</p>	<p><i>No quotes attributable</i></p>	
<p>3. Crisis Intervention</p>	<p>-</p>	<p><i>No quotes attributable</i></p>	

<p>4. Monitoring and reminder functions</p> <p><i>This theme refers to monitoring and reminder functions of diabetes care parameters available in the app.</i></p>	<p>4.1. Blood glucose or sugar recording and trend visualisation.</p> <p><i>In this sub-category, participants express their experiences with recording and monitoring of diabetes-related clinical parameters, and how this impacted their disease management.</i></p>	<p>P4: Usually when I am stressed, I don't even remember to record my daily blood sugar numbers but as I always carry my phone with me, I am able to record it in Kir'App logbook at any moment whenever I remember it even when sitting in bus or in class.</p> <p>P7: I like also the logbooks available for every health checkup. Like now I have a record of quite all my BS numbers of the last three months and with the option to check their variation, I can see where it went up or down and I can read the comments I wrote on every record and get to manage well my blood sugar levels. This will also help my Doctor to make a follow up whenever my A1C will be high; he will know how to adjust my insulin treatment accordingly.</p> <p>P9: Kir'App taught me the frequency of checking my blood sugar levels. Since I am a type 2, I used to check it only in the morning and in</p>	
---	---	---	--

		<p>the evening but now I know it is also be necessary to check it before and after physical activity or when I change my usual eating habits.</p> <p>P11: Kir'App taught me different complications you can get from diabetes. I am now trying to control my BS numbers better than ever to avoid them.</p> <p>P11: (...) logbooks available to note down my reflections on every information about my health.</p>	
	<p>4.2. Reminder functions</p> <p><i>Users were pleased to have several automated reminders for a variety of tasks relevant to diabetes care.</i></p>	<p>P1: (...) another thing I like in Kir'App is the reminder. You can easily set different reminders for testing blood sugar, taking insulin and even going for sport and it helps you to do on time what you need to do.</p> <p>P2: I think Kir'App came as a solution for us Rwandan diabetics to help us taking good care of us. For example when I am planning to do other activities, the reminder reminds me that it is time to do sport and I</p>	

		<p>postpone my other activities. I am sure this discipline will help me to keep my A1c at a good level.</p> <p>P3: I mostly liked its last page called “Remind me”. I now just set different reminders then when it rings I come to check and see one time it is for blood sugar testing and take of insulin, other time is for other regular checkups or just about my coming appointment with the doctor.</p> <p>P4: Some days are very hectic and I become much stressed which makes me forget my regular health checkups but with Kir’App reminder, I don’t forget them anymore. The good thing with this reminder is that I can set alarms for different activities like blood sugar testing, taking drug, A1c checking , eye check, doctor appointment, buying a new drug and many others and each will ring at its own time.</p> <p>P5: Something amazing I think was due to Kir’App; is the change in my A1C this month. These last three months I started using Kir’App reminder for sport,</p>	
--	--	---	--

		<p>blood sugar and insulin taking. Whenever it rings I immediately do the action I am supposed to do which is different from before where I could remember taking my insulin 2 hours after the required time. This reminder helped me to avoid these irregularities and this month I found my A1c level at 7.4% when it was at 8.9% three months ago. I will do my best to always have my phone with me so Kir'App can keep me on good track.</p> <p>P9: I like much how Kir'App reminder became like a friend or someone who lives with me by the way it keeps reminding me what I should do and when I should do it; it's time for going for sport, it's time to check your BS, now it's time to take your tablets, tomorrow it's your doctor's appointment or tomorrow you have to buy new medication when I have only 1 or 2 tablets left. I like it very much.</p> <p>P11: I liked much its option of reminding me every</p>	
--	--	---	--

		activity I need to do for managing my disease and the diaries (...).	
<p>5. Nutrition and alcohol consumption</p> <p><i>This theme refers to the availability of information about the appropriate diet for patients with diabetes.</i></p>	<p>5.1. Composition of a diabetic plate. <i>The content in Kir'App on how to prepare a diabetic plate helped the users to control their eating habits.</i></p>	<p>P1: Kir'App taught me how to balance my food now it has been some weeks that I no longer get high blood sugar episodes because of food.</p> <p>P5: Through Kir'App I've learnt how to prepare a diabetic plate (...).</p> <p>P7: Again with Kir'App, I am sure I will manage my BS well because now I know how to balance my food; what to eat in which quantity and the content in glucose of the food I eat. So I don't think my eating habits will raise my BS anymore.</p>	
	5.2 Information on non-alcoholic beverage choices	<i>No quotes attributable</i>	
	5.3 Information on alcohol intake	<i>No quotes attributable</i>	
	5.4 Pleasure of eating	<i>No quotes attributable</i>	

<p>Physical activity</p> <p><i>The theme refers to the provision of information on the kind and amount of exercise required when coping with diabetes. It also covers the motivational advice given within the app.</i></p>	<p>6.1. Kind of exercise to do.</p> <p><i>Participants describe how the information about the adequate type of exercises provided in the app changed their physical activity.</i></p>	<p>P1: (...)I also learnt the importance of doing sport in regulating my blood sugar, I have started to alternate the two categories of sport a diabetic person has to do as described in Kir'App.</p> <p>P8: Kir'app taught me physical activities doable by old people like me.</p>	
	<p>6.2. Motivation for physical activity.</p> <p><i>Some users reported change in their exercise behaviour due to the motivational messages within the app.</i></p>	<p>P8: I used to neglect to do sport mainly because of my age but when I got to know its benefits on my health, I got encouraged to do it.</p>	
	<p>6.3. Frequency & duration of physical activity.</p> <p><i>Users found recommendations in the App about the right amount of physical activity required.</i></p>	<p>P1: Two times a week I play volleyball or do jogging as aerobic exercises and at least once a week I lift weights in gym-tonic (fitness studio) as strength training.</p> <p>P5: (...) I've also discovered many other benefits of doing physical activities additionally to the regulation of my blood sugar levels and since then I started doing it regularly without interruption.</p>	

<p>6. Coping with burden of disease</p> <p><i>Theme 6 refers to the emotional support the app content provides and the current inability of the app to connect diabetics with each other. It also covers the empowerment users felt when being able to participate in shared decision making with their doctor concerning their individual diabetes care.</i></p>	<p>7.1. Emotional support</p> <p><i>The participants felt that the app assisted them in coping with situations of emotional distress.</i></p>	<p>P10: I am widow since now 8 years, my husband left me with three kids and I am always worried about their future, when I think about dying and leaving them alone. I was glad to find in Kir'App some advice given to parents who live with diabetes. I am trying to follow them and I hope they will help me given that my eldest daughter has also read the advices given to children with a diabetic parent. I sometimes hear her reminding things to her siblings. Maybe it will make them feel more responsible for their future</p>	
	<p>7.2. Social support</p> <p><i>Users wished the app could put them in contact with other people living with diabetes.</i></p>		<p>P11: It would be good to have in Kir'App a social media forum for example where type 1 could meet, exchange ideas and share experiences of our everyday life.</p>
	<p>7.3 Shared-Decision-Making / Empowerment</p> <p><i>The information</i></p>	<p>P8: I usually have good numbers of blood sugar levels. But for example I didn't know anything about A1c and other health checkups we need to do regularly. When I read about</p>	

	<p><i>and knowledge found in the app empowered users to make shared decisions in their healthcare together with their physician.</i></p>	<p>them in Kir'App, I couldn't understand why the doctor I have been seeing all these years have not prescribed me all of them. I changed the doctor and I told the new one that I needed to do all necessary health checkups and she prescribed me all of them. Now I have set a regular schedule for every health check-up and can follow my progress.</p>	
<p>7. App features</p> <p><i>The theme refers to experiences of the participants with the app features provided for information delivery and to the availability of content in different languages.</i></p>	<p>8.1. Information delivery</p> <p><i>Users appreciated the content organization of the app and its information delivery through texts and images but regretted the absence of audios and videos.</i></p>	<p>P7: I like much how appealing Kir'App is. It has beautiful colors that attract attention. I like also how well organized it is; information about every topic (food, sport, feet, etc) has its own page and again when you enter in each page, they start by defining the specific topic then treat other different aspects of it separately and specifically. The information is not mixed at all; this makes it easy to find what you need.</p> <p>P12: Something I liked about Kir'App is the variety in colors that start every page. It attracts your attention to read the introductory word of every page since you see it must be different from the previous one. I also liked the way every page has an introductory word that explains what the content of the</p>	<p>P1: Some pages of Kir'App contain much texts, it would be good if there were as many images as possible and just few words under the images.</p> <p>P2: Kir'App is a very good diabetes educative tool for us but unfortunately people who live both with diabetes and blindness can't use it. It would be good if you</p>

		<p>page is about.</p> <p>P14: “I liked the way every page start by general recommendations on every topic for example food, sport, foot care, etc.....”</p>	<p>could add another version of audio so these people can listen to the helpful texts in Kir’App.</p> <p>P4: Everything in KirApp is clear and well organized. You just need to read and know what is where. I think that this App can’t be used by someone who is not intelligent thou.</p> <p>P6: What is obvious is that Kir’app is a smart App. I don’t think people with poor education background will be able to use it. Even if it is in Kinyarwanda but I don’t think people who don’t know how to read can use it.</p>
--	--	--	--

			<p>Again people who have diabetes complications with their eyes will not be able to use it. As suggestion, please think about how you can also reach these categories of people since they also need the information in Kir'App.</p> <p>P9: It is good Kir'App has images that go with the texts but it would be better if it could also have some videos. For example in physical activity; having some videos that show how to do all these exercises shown on images would be</p>
--	--	--	---

			<p>great.</p> <p>P12: I don't know if I can call it a challenge but I think Kir' App contains much information. You can't finish reading everything in few minutes. You really did well to call it a friend in diabetes. It is like a lifetime friend who will always be there whenever we need it for advising or teaching us stuff for our self-care.</p> <p>P13: Using Kir'App seems like being back to school. You can't use it if you are not smart or at least if you don't have patience to read calmly.</p>
--	--	--	---

	<p>8.2. Available languages</p> <p><i>Users were pleased to have the app content in their local language, Kinyarwanda.</i></p>	<p>P7: Some people are not used to some medical terms used in diabetes management for example ketones; at the beginning I couldn't even understand the explanation given about it in English till I turned into Kinyarwanda then I realized it was something new for me. I hope other people will also remember to read explanations given in our language to get to understand better those terms.</p> <p>P13: I liked that I can read in Kinyarwanda more about the medications used in diabetes, the explanation of how they work and the possible side effects they can cause. I now understand many things about why the Doctor has been changing my medications these last years. Last time he said that he will probably prescribe me insulin injections.</p> <p>P14: I appreciated having all this helpful information about my disease in Kinyarwanda. Nowadays we use much English, but being able to understand things that concern your life in a language you understand well is a very good thing.</p>	
--	--	---	--

<p>7. Use behaviour & Usability</p> <p><i>This theme refers to the users' general experiences with the usability of the app and to their individual use behavior.</i></p>		<p>P6: In general, using Kir'App is like seeking pieces of advice from a friend, you cannot come just like that, get what you want and go back. You need to give it time because, the more you spend time using it, the more you get more interesting information and the more you understand more about diabetes and get ideas about your self-care.</p> <p>P8: I haven't found yet anything I can call negative in Kir'App. It has been of only good utility for me till now.</p> <p>P3: I can't really call anything in Kir'App negative because everything it has is very needed by people living with diabetes.</p> <p>P5: It is impossible to find negative aspects of a first product in the whole country like Kir'App. I am more interested in all new things it is offering us and can't really find something negative about it.</p> <p>P10: It would be difficult to find something negative in Kir'App as there is no other similar App we were using before to compare with it.</p>	<p>P 2: At the beginning I had hard time to set the alarm of the reminder; I didn't know I had to touch and move the pointer of the clock to set the time I wanted.</p> <p>P7: For the reminder; it is good I set it for once and it keeps ringing at the same hour every day but it would also be good to be able to set it for some days only; like early in the morning from Monday to Friday but at a different hour on weekend days because I wake up a bit late.</p> <p>P14: The other day I was reading all the myths about</p>
---	--	--	---

			diabetes and on other different topics like food, sport, blood sugar, foot care but when I reached on health checkups there was "coming soon". I felt a little bit disappointed; it would be good to have content on every component.
--	--	--	---

C. Autobiographic reflection

“Shoot for the moon. Even if you miss it, you will land among the stars.”

-Norman Vincent Peale

I have had a special interest in diabetes since the year of my 15 years. That is the year my mother was diagnosed with diabetes. After the tragedy of the 1994 Tutsi Genocide, which my family survived, diabetes was the next trouble we had to face. I powerlessly witnessed how it gradually devastated my mother’s health until it ended her life.

Later on I became a healthcare provider and got to work with people with different ailments; diabetes included. Although I could provide health care to my diabetic patients, I always found pitiful that they were struggling with the same issue as my mother; self-management of their disease with little information at hand. We were using posts, small books to educate them but still these tools could not convey enough information about their disease for their self-management. And moreover they could not carry them on hand for prompt use.

The illumination to develop Kir’App crossed my mind when I got the chance to volunteer in an educational camp for type 1 diabetes youth organized by the Rwanda Diabetes Association in 2016. It was my first time to meet with a big number of young people with diabetes. They were so helpless when dealing with their disease but at the same time they seemed to be very skilled at using their smartphones. That is how the idea came to mind: to put a tool in their smartphones that assists them with the knowledge and information they need for self-care of their disease.

I am always delighted to think about Kir’App being changing Rwandan diabetics’ lives with more than 500 downloads of the App since its publication on Google Playstore. It is just the first prototype; hopefully the best of it is still to come.

Claudine B. Kabeza

D. Acknowledgement

Firstly I would like to express my gratitude to Herr Prof. Dr. med habil Peter Schwarz for being my PhD thesis advisor. I thank him for his immense knowledge, guidance, motivation and patience.

Besides my advisor, I would like to thank my research team: Patrick Timple, Lorenz Harst and Kristin Kemple for their availability and their valuable assistance in my research project.

My sincere thanks also go to my proofreaders; Pacis and Max who made this work decipherable.

Finally yet importantly I thank God; my creator, my protector, my refuge, my strength, my joy, my peace, my inspiration and my ever-present helper in each and every moment of my life.

E. Dedication

I dedicate my thesis work to my family and friends.

A special feeling of gratitude to my late parents; to my father who left us very early and to my mother whose fight against diabetes inspired me to develop Kir'App.

To my sisters; Barada, Bako, Benie, my nephews and my cousin Carine; you are my best cheerleaders; thank you for never leaving my side.

F. Impact factor of journal with InCites Journal Citation Reports

This research project is made of two research articles that were published in the same journal; “*Therapeutic Advances in Endocrinology and Metabolism*” since the second article was the follow up of the first one.

Article 1 : Kabeza, C.B., Harst, L., Schwarz, P.E.H., Timpel, P. (2019). Assessment of Rwandan diabetic patients’ needs and expectations to develop their first diabetes self-management smartphone application (Kir’App). *Therapeutic Advances in Endocrinology*, 10, 2042018819845318. <https://doi.org/10.1177/2042018819845318>

Article 2: Kabeza, C.B., Harst, L., Schwarz, P.E.H., Timpel, P. (2020). A qualitative study of users’ experiences after 3 months: the first Rwandan diabetes self-management Smartphone application “Kir’App.” *Therapeutic Advances in Endocrinology*, 11, 2042018820914510. <https://doi.org/10.1177/2042018820914510>.

Journal name: *Therapeutic Advances in Endocrinology and Metabolism*

Impact factor at the time of the first publication (April, 2019): 3.978

Ranking in the category of Endocrinology, Diabetes and metabolism: 54 out of 145

Journal Impact factor (JIF) Quartiles: Q2

Impact factor at the time of the second publication (April, 2020): 3.543

Current impact factor (December, 2020): 2.173

Ranking in the category of Endocrinology, Diabetes and metabolism: 109 out of 143

Journal Impact factor (JIF) Quartiles: Q4

Erklärungen zur Eröffnung des Promotionsverfahrens

1. Hiermit versichere ich, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe; die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht.

2. Bei der Auswahl und Auswertung des Materials sowie bei der Herstellung des Manuskripts habe ich Unterstützungsleistungen von folgenden Personen erhalten:

Pr. Dr. med. habil Peter Schwarz
Patrick Timpel
Lorenz Harst

3. Weitere Personen waren an der geistigen Herstellung der vorliegenden Arbeit nicht beteiligt. Insbesondere habe ich nicht die Hilfe eines kommerziellen Promotionsberaters in Anspruch genommen. Dritte haben von mir weder unmittelbar noch mittelbar geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

4. Die Arbeit wurde bisher weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

5. Die Inhalte dieser Dissertation wurden in folgender Form veröffentlicht:

Original Articles

.....
6. Ich bestätige, dass es keine zurückliegenden erfolglosen Promotionsverfahren gab.

7. Ich bestätige, dass ich die Promotionsordnung der Medizinischen Fakultät der Technischen Universität Dresden anerkenne.

8. Ich habe die Zitierrichtlinien für Dissertationen an der Medizinischen Fakultät der Technischen Universität Dresden zur Kenntnis genommen und befolgt.

Ort, Datum
Dresden, 22.01.2021

Unterschrift des Doktoranden

Einhaltung der gesetzlichen Vorgaben im Rahmen meiner Dissertation

Anlage 2

Hiermit bestätige ich die Einhaltung der folgenden aktuellen gesetzlichen Vorgaben im Rahmen meiner Dissertation

- das zustimmende Votum der Ethikkommission bei Klinischen Studien, epidemiologischen Untersuchungen mit Personenbezug oder Sachverhalten, die das Medizinproduktegesetz betreffen

Aktenzeichen der zuständigen Ethikkommission

No 021/CMHS IRB/2018 (From Rwanda)

- die Einhaltung der Bestimmungen des Tierschutzgesetzes
Aktenzeichen der Genehmigungsbehörde zum Vorhaben/zur Mitwirkung

.....

- die Einhaltung des Gentechnikgesetzes

Projektnummer

- die Einhaltung von Datenschutzbestimmungen der Medizinischen Fakultät und des Universitätsklinikums Carl Gustav Carus.

Dresden, den 22/01/2021

Unterschrift des Doktoranden

Anlage 3: Ethical clearance to conduct the research project in Rwanda



CMHS INSTITUTIONAL REVIEW BOARD (IRB)

Kigali, 2nd /02/2018

Claudine Balahali Kabeza
School of Nursing and Midwifery, CMHS, UR

Approval Notice: No 021 /CMHS IRB/2018

Your Project Title *“Development Of The First Diabetes Self-Management Smartphone Application (KIRAPP) For Rwandan Diabetics (A Pilot Study) “* has been evaluated by CMHS Institutional Review Board.

Name of Members	Institute	Involved in the decision		
		Yes	No (Reason)	
			Absent	Withdrawn from the proceeding
Prof Kato J. Njunwa	UR-CMHS		X	
Prof Jean Bosco Gahutu	UR-CMHS	X		
Dr Brenda Asimwe-Kateera	UR-CMHS	X		
Prof Ntaganira Joseph	UR-CMHS	X		
Dr Tumusiime K. David	UR-CMHS	X		
Dr Kayonga N. Egide	UR-CMHS	X		
Mr Kanyoni Maurice	UR-CMHS	X		
Prof Munyanshongore Cyprien	UR-CMHS		X	
Mrs Ruzindana Landrine	Kicukiro district		X	
Dr Gishoma Darius	UR-CMHS	X		
Dr Donatilla Mukamana	UR-CMHS	X		
Prof Kyamanywa Patrick	UR-CMHS		X	
Prof Condo Umutesi Jeannine	UR-CMHS		X	
Dr Nyirazinyoye Laetitia	UR-CMHS	X		
Dr Nkeramihigo Emmanuel	UR-CMHS		X	
Sr Maliboli Marie Josee	CHUK	X		
Dr Mudenge Charles	Centre Psycho-Social	X		

After reviewing your protocol during the IRB meeting of where quorum was met and revisions made on the advice of the CMHS IRB submitted on 31st January 2018, **Approval has been granted to your study.**

Please note that approval of the protocol and consent form is valid for **12 months**.

You are responsible for fulfilling the following requirements:

1. Changes, amendments, and addenda to the protocol or consent form must be submitted to the committee for review and approval, prior to activation of the changes.
2. Only approved consent forms are to be used in the enrolment of participants.
3. All consent forms signed by subjects should be retained on file. The IRB may conduct audits of all study records, and consent documentation may be part of such audits.
4. A continuing review application must be submitted to the IRB in a timely fashion and before expiry of this approval
5. Failure to submit a continuing review application will result in termination of the study
6. Notify the IRB committee once the study is finished

Sincerely,

Date of Approval: The 2nd February 2018

Expiration date: The 2nd February 2019

for Professor Kato J. NJUNWA
Chairperson Institutional Review Board,
College of Medicine and Health Sciences, UR

[Signature]
Prof. JB Gathuku
Vice Chair



Cc:

- Principal College of Medicine and Health Sciences, UR
- University Director of Research and Postgraduate Studies, UR