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Design of an m-health application for low-literacy diabetes patients in India

Master Thesis Report
Human Media Interaction

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Design of an m-health application for low-literacy diabetes patients in India

Master Thesis

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Master Thesis Report – Design of an m-health application for low-literacy diabetes patients in India

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Roche Diabetes Care GmbH
i.V. i.V.

_____
Date, signature Prof. Dr.

_____
Date, signature

List of Abbreviations

M-health	Mobile health
UI	User Interface
T1D	Type 1 Diabetes
T2D	Type 2 Diabetes
BS	Blood Sugar
BG	Blood Glucose
SMBG	Self-Monitoring Blood Glucose

Abstract

Despite the significant progress in the design of mobile health (m-health) applications, few of them target low-literacy users. This is a matter of concern because for example 31.1% of Rural India population and 15% of Urban India population are functionally illiterate. Low-literacy users put special requirements on the user interface(UI) of m-health applications. User interfaces that do not meet the needs of this group of users form an unacceptable barrier to finding and using the connection with the health caregivers. To empower low-literacy people to fully profit from the health system and enjoy good-quality life, we studied how to design a mobile application for low-literacy people, especially in the UI design.

In this thesis project, we collaborated with Roche Diabetes Care GmbH to design an m-health application (Tapir) for low-literacy type 2 diabetics. Focusing on India as a primary study case, the research question was proposed, how should the user interface of an m-health application be designed for low (semi)-literacy Indian users, with type 2 diabetics in particular?

In order to answer this research question, we did a series of research to design the Tapir app for low-literacy diabetics in India from which certain conclusions were drawn. The process of Tapir app design was summarized as following.

Initially, we did a concrete context research which includes the summary of mobile UI design guideline for low-literacy users from previous studies, diabetes apps design both in developed markets and emerging markets, global diabetes state, and India environment study. It aimed at having an overview of diabetes and figuring out the specific problem in India to be addressed by Tapir app. Then a user study was conducted through interviews and desk research, which helped to explore the concept of Tapir app, such as functions, information architecture etc. When it came to the app design phase, an expanded model which synthesized the design guideline from the previous research was built and was applied to the Tapir app UI design. With a basic version of Tapir app prototype, a pre-user testing was conducted in Europe to improve the UI design. After improvement, we conducted a user testing in Bangalore, India to validate and improve the Tapir app again.

In doing so, this study verified and improved the expanded model and concluded a few recommendations for designing accessible mobile UI for low-literacy people. The Tapir app validated in terms of usability and value was delivered in this thesis project as well.

Keywords: Low-literacy, diabetes, m-health application, expanded model, mobile UI design, India

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1 Introduction

1.1 Background

Research has shown that low-literacy people are at risk of poor health state. This is because they often misinterpret or do not understand the written medical information and instructions [1]. A research on India published in the journal Social Science and Medicine also showed that illiteracy has a greater impact on public health than low income [2]. This is a matter of great concern because the concluded census activity in 2011 has placed the illiteracy rate at 31.1% in Rural India and 15% in Urban India [3], while the global illiteracy rate for all people aged 15 and above is 13.7% in 2015 [4]. Furthermore, there are other harmful consequences of illiteracy, such as low-socioeconomic status and unemployment [5]. Low-literacy people's quality of health care is also affected by these factors. It is thus essential to focus on better health care delivery for low-literacy people.

With the proliferation of mobile phone users in developing countries, there is a growing interest to make use of the technology to address different social services, including healthcare services [6]. The awareness is strengthened on developing health applications for low-literacy people in developing countries [7]. However, a review of the five most popular mobile nutrition-monitoring applications available through the Play Store shows they rely on high-literacy and numeracy skills, which cuts out the low-literacy segment of the population [8]. On the other hand, specific challenges for low-literacy mobile user interface design are not yet comprehensively solved. Most low-literacy users from developing regions encountered difficulties in using the most basic features of mobile interfaces. Many of the design conventions for interfaces that may be familiar to us might not be understood by people with lower literacy level and different cultures in the developing worlds. For example, making a phone call, clicks are not intuitive to them [9] [10], or trying explaining to someone who has never seen a trashcan symbol for "deleting" something, it requires a different way of thinking in terms of the design, development, maintenance and use of devices. Furthermore, guidelines informing how to design interfaces for low-literacy users remain incomplete. Therefore, we need to find ways to adapt the mobile UI design to make it usable and easily understood for low-literacy people with different culture backgrounds.

1.2 Research question

The thesis project is targeted to design an m-health application for low (semi)-literacy type 2 diabetics in India. Regarding the special target group, we seek to find ways to improve the usability of m-health application for low-literacy users. The low ability to read is only one parameter to consider when designing this application. We also need to take into consideration that different level of smartphone usage experience and knowledge about diabetes. There are also cultural differences which need to be taken into account. Additionally, there are other unique challenges: power, device capability, and uncertain network communication. These challenges are also affecting mobile UI design [11]. For instance, power and device capability are related to the size and type of interface. The interface should resonate with the target users, even if a user has never seen such an interface before, and only know few forms of text. With these considerations in mind, the research question is formed as followed:

How should the user interface of an m-health application be designed for low (semi)-literacy Indian users, with type 2 diabetics in particular?

This brings up the following sub-questions:

1. Language barrier [12]: various local languages in India; No standard for local font and alphabet; Diverse presentation of the alphabet in the keypad.
   How to define graphical components in the user interface which can be easily interpreted and used by low (semi)-literacy people?
2. Novice users: have no or few experience with applications on the smartphone, only use a smartphone to make or receive a phone call.
   How to design the navigation structure which is understandable for novice users and what types of navigation tree is appropriate for low (semi)-literacy people?
3. People who lack of knowledge of diabetes: do not understand diabetes well, such as blood sugar testing, have no idea about the normal range of blood sugar, and do not know how to manage their diabetes in daily life properly.
   How to present the mobile interface which can explain the disease well to low (semi)-literacy people?
4. Culture differences: people in India have a different cultural background compared to people from modern western societies, they also have different religions.
   Is there a considerable cultural difference concerning how people from modern developed countries versus people from India would use a mobile interface?
5. Technique and economic aspects: Which are the dimensions of the user interface specifically targeted for low (semi)-literacy users in India, and what kind of constraints should be taken into account, such as bandwidth limitation or device capability?

In an effort to address these challenges, this thesis work seeks to verify the previous design guideline for low-literacy people in India context and also provide concrete design recommendations to support mobile UI design for low (semi)-literacy people. Good design guidance can facilitate communications among designers and can bring great impact on low-literacy people. In the thesis project, focusing on low (semi)-literacy people with type 2 diabetes (T2D) in India primarily, an m-health application will be designed considering the context of India and users. Thus, the output of the thesis project is an m-health application for low (semi)-literacy users with T2D in India, validation of previous design guideline and new design recommendations for designing accessible mobile UI for low-literacy users.

1.3 Low-literacy definition

Low-literacy is defined only by the ability of reading or writing (educational level) in most mobile UI research [8][23][28]. Education is just one aspect which impacts the low-literacy mobile UI design. In this project, low-literacy should be defined by three parameters: educational level, mobile technology exposure, and diabetes literacy. Based on this, the target users can be characterized in two groups: illiteracy, semi-literacy.

Characteristics	Illiteracy	Semi-literacy
Reading/writing ability	More than or equal to Standard IV and less than or equal to Standard VI	More than Standard VI and less than or equal to Standard VIII [13]
Mobile phone exposure	Rare	Calling, WhatsApp
Diabetes literacy	Rare	Less than 1 year diagnosed

Table 1 Definitions of different low-literacy mobile users group

Parts of Indian education system is listed as following,

- **Primary school**: First to fifth standard/class/grade (for six- to ten-year-olds)
- **Middle school**: Fifth to eighth standard/class/grade (for 11- to 14-year-olds)
- **Secondary school**: Ninth and tenth standard/class/grade (for 14- to 16-year-olds)

The education of the low-literacy people defined in this final project is below the secondary school.

1.4 Structure of this report

This report contains five parts. First part is from the chapter 2 to chapter 6, which includes the methodologies used and context research. The methodologies provide an overview of this research process. The context research first introduces the basic knowledge about diabetes, then it explores the related work including the mobile UI design for low-literacy users and diabetes app design. Furthermore, the India context is introduced, which aims at gaining a big view of the environment and finding the problem to be addressed by Tapir app. Second part is statement of the problem to be addressed by Tapir and solution exploration which is from chapter 6 to chapter 8. Third part is the concrete Tapir app design including chapter 9 and chapter 10. Considering India context, an expanded model which synthesised the design guideline from previous research is built in the third part. This model is applied in the initial Tapir app UI design. Fourth part is the user testing including pre-user testing in Europe and user testing in Bangalore, India, from the chapter 11 to chapter 14. Design improvements and Tapir app validation are in the fourth part as well. Final part, chapter 15 and 16, draws the conclusions and future work.

2 Methodology

The research process of this thesis project consisted of three main parts: The definition of a specific problem for low-literacy diabetics in India and digital solution exploration; Mobile UI design; Validation of the app concept and usability testing of mobile UI design.

2.1 Problem definition and digital solution exploration

In the problem definition phase, secondary research was applied to gather information about diabetes, health care system and diabetic state in India.

Step 1: Diabetes research (chapter 3)

- Read related papers, reports, articles and books about diabetes.
- Collected and summarized information about diabetes.
- Had ideas about what was diabetes, how to treat it and the global diabetes state.

Step 2: Related work (chapter 4)

- Summarized the mobile UI design guideline for low-literacy people from the previous study.
- Gained the overview of the diabetes app design both on the developed markets and emerging markets through literature research.

Step 3: India context research including health care system, diabetes, smartphone and low-literacy state (chapter 5)

- Read literature, watched the videos in Youtube to gather information about health care system in India.
- Had an overview about the diabetic state in India from literature research and interview with Indian people.

Step 4: Concluded the main problem for low-literacy diabetic in India to be addressed by Tapir app (chapter 6)

Step 5: Target users study (chapter 7)

- Gathered data from existing literature, reports and other media materials about target diabetics.
- Applied contextual design and goal-driven design to understand users within the context of their specific goals.
- Analyzed and synthesized information gathered, and concluded user requirements.

Step 6: Digital solution exploration (chapter 8)

- Gained design clues via exploring good practices of diabetes app design and emerging market design.
- Incorporated user requirements into a digital solution, namely the Tapir app design.

2.2 Mobile UI design

In the mobile UI design phase, we referred to the design guideline which were concluded from previous research [8][12][23][24][26][27][65]. An expanded model which was a result of the aggregation and distillation of findings from the previous research was built to serve as a framework of guidelines (chapter 9). With these guidelines in the initial design phase, we

knew how to design the Tapir app UI. The result of initial Tapir app design can be seen in the chapter 10.

2.3 Validation of the Tapir app concept and usability testing of the UI design

In this phase, lean UX principle was used to validate and improve our design. Through the process of build, measure, and learn, we validated the Tapir app design and made improvements for it. The elaborate process is as following: after the first low-fidelity prototype was made, we conducted a pre-user testing in Europe (chapter 11), then made improvements based on the pre-user testing (chapter 12). With an improved-version of Tapir app, we held interviews and conducted user testing with our target groups in India (chapter 13). Eventually, we made conclusions from the user testing in India (from chapter 14 to chapter 16).

3 Diabetes

3.1 Introduction

Diabetes is a serious, chronic disease in which there are high blood sugar levels over the rest of the patients' life. It occurs either when the pancreas does not produce enough insulin (or no insulin at all) or when the body cannot effectively use the insulin it produces[14]. Over time, diabetes can damage the heart, blood vessels, eyes, kidneys, and nerves. There is no cure for diabetes and it is a life-long disease. People with diabetes need to manage their blood sugar (BS) levels to stay healthy.

Type 1 diabetes (T1D): the body does not produce insulin. Patients with type 1 diabetes require a daily administration of insulin. The cause of type 1 diabetes is not known and it is currently not preventable. It is usually diagnosed in children and young adults.

Type 2 diabetes (T2D): the body uses insulin ineffectively which causes the blood glucose (sugar) to rise higher than normal. It is largely the result of overweight, obesity and physical inactivity. The symptoms are less marked which can lead to an undiagnosed state for several years until complications have already occurred. Approximately 85–95% of all cases of diabetes are type 2 diabetes[15].

3.2 Global Diabetes state

The prevalence, morbidity, mortality and economic burden of diabetes have been rising rapidly in most countries for the past 3 decades, especially in low- and middle-income countries [16]. A worldwide estimated 422 million adults were living with diabetes in 2014, which is predicted to reach 642 million by 2040, i.e. one in every ten adults [17] [18]. World Health Organization (WHO) estimates that globally, high blood glucose (BG) is the third leading risk factor for premature mortality after high blood pressure and tobacco use [19]. The impact of this disease on patients and their family has been especially severe.

The addressable target group for diabetes apps is defined as the total number of diagnosed diabetics that have a capable device which can run a diabetes app such as a mobile phone or tablet. Compared to 2014, the total global addressable target group size for diabetes app services has grown by 86.5% to reach 135.5M in 2016 [33]. This large increase of the addressable target group size is driven mainly by the growth of smartphone and tablet ownership amongst diagnosed diabetics. In most regions, almost all diagnosed diabetics carry a smartphone and/or tablet. As the Figure 1, it shows the global addressable target group size for diabetes apps in 2016.

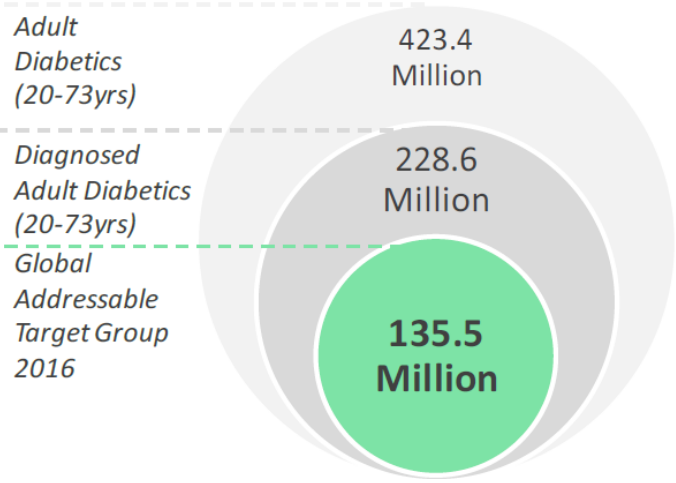


Figure 1: Globally addressable target group size for diabetes apps (2016) [33]

3.3 Current diabetes state in India

There is a larger rise in diabetes prevalence in low- and middle-income countries than in high-income countries [18]. In India, coupled with a bad nutritional history and the fact that Indians are genetically more vulnerable to diabetes compared to other population groups, the national prevalence of diabetes among 20-79 years old is 8.56%. The greatest numbers of people with diabetes are between 40 and 59 years of age. In 2013, India (65.1 million) had the second largest diabetes population after China, i.e. one in five Indians has diabetes. The recent trend of rising diabetes among rural Indians and women is also alarming. Diabetes led to over one million adult deaths in India, 2013 [20]. The increased number of diabetics in India is likely to be due to a significant increase in the incidence of T2D, caused by population growth, urbanization, unhealthy food habits, obesity, lack of physical activity and sedentary lifestyle [21]. Awareness about their diabetes status varies from state to state. The proportion of people who is unaware of their diabetes status is very high in rural areas [22].

India (10.6M) has the third largest addressable target groups for diabetes apps after China (40.8M) and USA (13.1M). Table 2 shows the addressable target group and market size in India [33].

Country	Number of Diagnosed Adult Diabetics (20-79) (Millions)	Smart Device Penetration (%)	Addressable Target Group	Addressable Market Size Costs per Year(USD) (Billions)
India	37.02	29%	10.59	2.07

Table 2 The addressable target group and market size in India

3.4 Management of diabetes

Early detection of diabetes is the starting point for living well with diabetes – the longer a person lives without diagnosed and untreated diabetes, the worse the health outcomes are likely to be. Blood glucose control is important in diabetes management. For type 2 diabetics, there are several basic principles of diabetes management [16]:

- Regularly measure blood sugar level and take regular exams from doctors
- Lead healthy lifestyles, including healthy diet, physical activity, avoidance of tobacco used and harmful use of alcohol
- Medication for blood glucose control – oral hypo-glycemic agents or insulin

The effectiveness of diabetes management primarily depends on people's compliance with treatment. Therefore, education of patients is an important component of diabetes management. Low-literacy people have a risk in understanding the principles and importance of a healthy diet, adequate physical activity, and adherence to medication which is a challenge for them to manage the diabetes.

4 Related work

4.1 Mobile interface design for low-literacy users

Most literature in low-literacy design are based on ethnographic research and presented the usability barrier of low-literacy and provide suggestions of design ideas in the form of general design recommendations [23][24] [25] [26]. In the study of Medhi et al [27], they found most previous work in UI for low-literacy users focuses more on illiteracy with only a few considerations about other problems or the overall context in which a user is situated. Their study suggested the inability to read is only one parameter to consider when designing the mobile application for low-literacy users. Other issues which mediate how a user interacts with mobile UI should also be considered, such as "cognitive difficulties, cultural etiquette, experience and exposure, intimidation, mediation, motivation, pricing, power relations, social standing and others" [27].

There have been a number of design recommendations for the design of mobile UI for low-literacy users, regarding graphical representations, voice interfaces, avoiding textual input, video, and navigation structure. Huenernfauth [28] listed user interface guidelines of application design for low-literacy users. Chaudry et al. [7] evaluated non-text based graphical widgets focused on low-literacy users, and based on the result of the evaluation non-text GUI widgets with large buttons and linear navigation structure are preferred by illiterate users. Medhi et al. [23] provided useful applications to communities of illiterate users via using ethnographic or contextual design techniques, some key design principles of mobile UI design are proposed. Parikh et al. [29] listed several important features that contributed to a successful application design for low-literacy users. Doe et al. [30] found that hierarchies in information architecture should be avoided through evaluation of a digital library used by low-literacy users. Browsing multiple depths of information (navigation metaphors of "up a level") is difficult for low-literacy users. Medhi et al. [24] conducted an ethnographic research in India, the Philippines and South Africa. It concluded the text interface was unusable for illiterate users and recommended that the best way for mobile UI design is a combination of voice UI and graphical cues. In additional, if there is budgetary feasibility, a live operator is preferred. In India, a live operator is a "cost-effective solution for reporting small amounts of data" [24].

In all, the contributions present usability challenges of low-literacy users and provide design guidance, but none of them specifically focuses on m-health applications in India. To validate this design guidance in a different context (m-healthcare in India) and expand the findings, we will summarize the design guidance (in chapter 9) and apply them to the design of m-health application for low-literacy diabetics in India (in chapter 10). Parameters, such as reading/writing ability, diabetes knowledge, culture backgrounds, smartphone usage experience and economic factors will be considered in this thesis project. Through the design process and user testing, the design guideline from previous studies will be validated and new design clues targeting low-literacy people in India will be concluded.

4.2 Diabetes application designs

4.2.1 Overview of diabetes apps

A systematic review of 14 previous studies which was done by Cardiff University found that smartphone apps could offer patients with type 2 diabetes a highly effective method of self-managing their condition [31]. Compared to patients who did not use an app, there was a reduction in average blood glucose levels in patients that used an app.

There are more than 1,700 iOS and Android apps listed on the Apple Store and Google Play Store that are specifically designed for diabetics and healthcare givers to treat diabetes in 2016 [32]. Currently, diabetes apps can be categorized into nine groups. The majority of diabetes apps are educational apps. 31% of core diabetes apps available for iOS and Android belong to this category. The second most common are diary tracker apps which take up 26% followed by calculators (14%) [33].

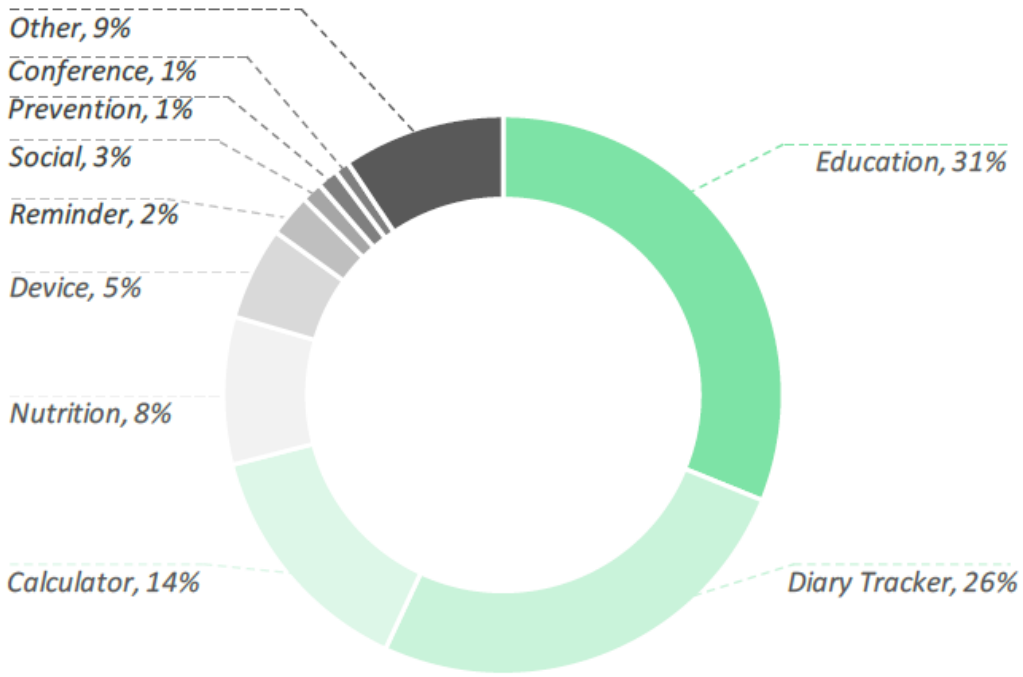


Figure 2 Share of core diabetes app categories [33]

The diabetes app categories are defined by an app's primary use case. It is common in today's market for an app that overlaps in different category types.

Emerging market in developing countries has unique characters, which is different from developed market in developed countries. Considering the different environment, the product design and strategies will differ. So, we divided diabetes apps reviews based on emerging market and developed market. In our case, we seek to design a diabetes app for low-literacy users in India. Also, India is one of the four largest emerging and developing economics countries, so main diabetes apps review in emerging market is based on India market. As for the developed market, we chose UK and US to do the apps research.

4.2.2 Apps in emerging market (India)

Overview of Diabetes Apps in India

Types of diabetes apps: diary tracker, education, and coaching apps are most popular diabetes app in India. The core diabetes apps are selected based on the highest year-to-date (YTD) downloads (Q1-Q3 2016) in Google Play and Apple App Store. For each app, downloads and app store ranking ranges in August 2016 are listed for a monthly perspective [33].

Android vs. iOS play: Top listed apps on Android generate 7.1 times higher year-to-date downloads than iOS.

Country	Platform	Category	Most Downloaded Diabetes App*	Publisher	Downloads		Ranking **
					Q3 2016 YTD	Aug-16	
India	Android	Health & Fitness	BeatO Diabetes Management	BeatO	40,800	330	404-475
	Android	Health & Fitness	Noom Coach: Health & Weight	Noom Inc.	10,400	380	-
	Android	Health & Fitness	Life in Control Diabetes Coach	Life in Control	9,500	4,500	181-295
	iOS	Health & Fitness	Diabetes Diet FREE - Proper Nutrition for the Diabetic	The Jones Kilmartin Group, LLC	3,000	300	-
	iOS	Health & Fitness	Sugar Sense - Diabetes App Blood Sugar Control and Carb Counter	MedHelp	2,200	370	133-997
	iOS	Health & Fitness	Calorie Counter and Food Diary by MyNetDiary - for Diet and Weight Loss	MyNetDiary Inc.	2,100	300	190-893
	Android	Medical	Diabetes Blood Pressure & Wt	Cooey Technologies	17,700	2,600	27-36
	Android	Medical	Beat Diabetes	Let ME Hear Again Apps	8,600	360	186-271
	Android	Medical	Diabetes:M	Sirma Medical Systems	3,000	360	168-277
	iOS	Medical	Sugar Sense - Diabetes App Blood Sugar Control and Carb Counter	MedHelp	2,200	370	-
	iOS	Medical	Diabetes in Check: Coach Blood Glucose & Carb Tracker	Everyday Health, Inc.	1,600	220	24-330
	iOS	Medical	One Drop for Diabetes Management	Informed Data Systems, Inc.	1,500	160	-

Table 3 India's top listed diabetes apps

The Table 3 [33] shows the India's top listed diabetes apps.

In the top popular 12 applications in India, only three of them were developed by local Indian companies and the others were developed by the overseas companies (mainly by companies in US) and the language used in the apps is English. There is no special design for emerging market and low-literacy users in India. Some applications designed and developed by local

Indian start-up indicate special problems and needs in the India market which are listed as examples for reference, even though they are not in the popular list.

Some Examples:

Diabeto – smart blood sugar tracker and personal diabetes caretaker

According to ETHealthworld, India's first diabetes mobile app was launched in November 2015 [34]. This app is called Diabeto which claims to be the only app that facilitates the patients to track their BG data, upload and store the data securely on the cloud in India. It also allows the patients to choose a doctor and schedule a teleconsultation from diabetes doctors available in the app. A glucometer was also developed to remotely update the BG data to the smartphone app. Patients can get personalized diet coaching from expert diabetes diet coaches from the app. The app is available both in the Apple Store and the Google Play store. And people need to pay 799 Rupee monthly or 6999 Rupee per year. Compared to the salary (3000 to 7000 Rupee monthly) of the poor class in India [61], it is easy to imagine that they will not spend around a quarter of their salary on this diabetes product, because they need to spend most of their salary in life necessities, such as food, instead of Diabeto. Figure 3 shows the main functions and interfaces of the Diabeto.

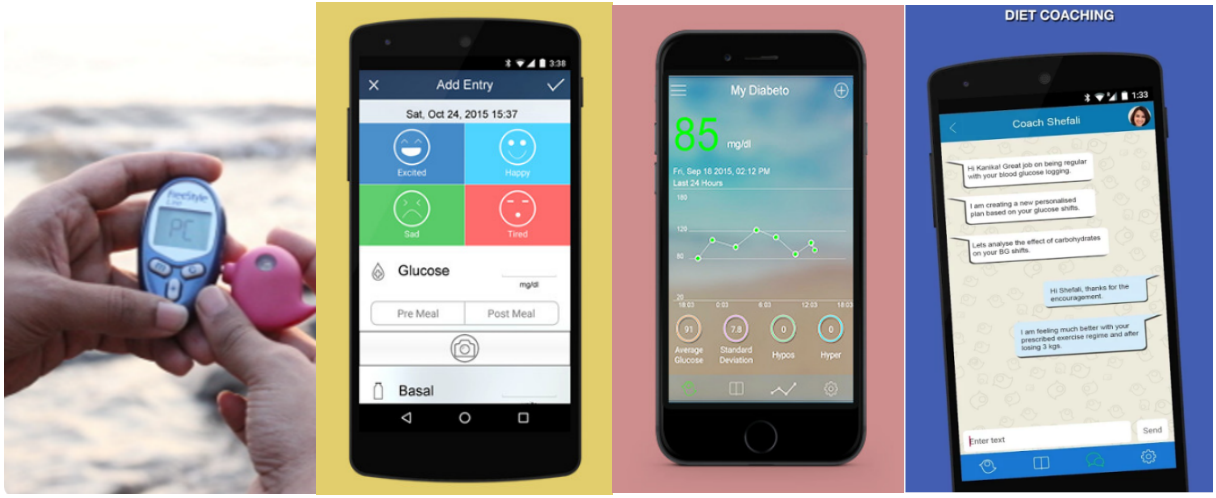


Figure 3 Diabeto (From the left to right: Automated data transfer, Track important parameters, Get a holistic view, Get expert diet coaching)

Diabetic Living India – a lifestyle magazine guiding happy life while managing diabetes

Diabetic Living is a digital magazine aimed at Indian people with diabetes. It is the only lifestyle magazine that demonstrates how to live happily each day while managing diabetes [35]. Delicious diabetic recipes are provided to the reader in this magazine and it also suggests how to implement exercise ideas easily. Users need to pay 4.99 dollars for 6 months subscription or 8.99 dollars for 1-year subscription. It is available both in the Apple Store and the Google Play store. Figure 4 shows the main interfaces of Diabetic Living India.

Figure 4 Diabetic Living India

Intelehealth – Telemedicine for last mile health

Intelehealth is a clinical tool. The main purpose of it is to let health workers in rural communities act as a proxy for doctors who are unable to work in the underserved area themselves [36]. People in rural area cannot get access to doctors most of whom are in cities easily while health workers in remote areas cannot offer tests or consultations about diabetes because of poor training. With Intelehealth, the health worker can create a record of patient's data, any issues a patient is having, and photos. The patient summary is sent to an offsite Indian doctor or a retired physician through Intelehealth, who makes a diagnosis and sends it back to the clinic with a prescription or referral for future care. It can communicate over low bandwidth data connections which can work in rural environment of India. Intelehealth was created by a start-up in India and was just launched recently. Figure 5 shows the platform of Intelehealth and its interfaces.

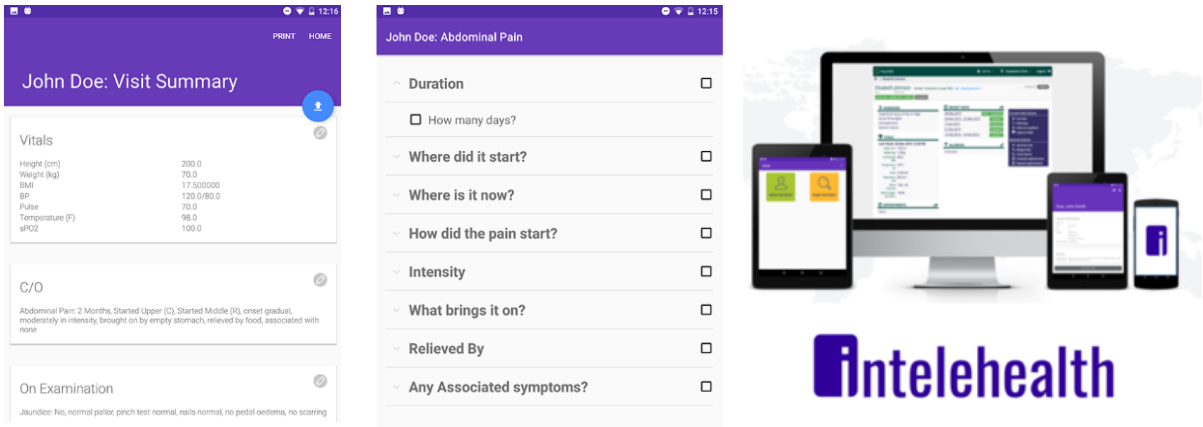


Figure 5 Intelehealth

In all, these diabetes apps in India can only be used by people with higher educational level, because of the text-based interface which is displayed in English. And there is no low-literacy design method applied to the app design. People in Rural India with lower educational level may have troubles when using these apps. The latest technology cannot benefit to low-literacy people.

4.2.3 Apps in developed market

There are tons of diabetes apps in developed markets, such as the UK and US markets, which help to simplify diabetes management. Certain apps are tied to the Glucose meter that the patient uses while many are tracking and management apps for blood glucose, medication, and insulin levels. Others are more general-purpose apps for eating specific diets, proper exercise, which people with diabetes could benefit from. Popular diabetes apps in Google Play and App Store are summarized in the Table 4 [37] [38] [39] [40].

Name	Usability	Availability	Price
 BG Monitor Diabetes	Track everything, calculate how much insulin you need, set reminders, and create spreadsheets and graphs of your data. You can also organize all of your entries with tags.	Android	Free
 Blue Loop	Made for children and the adults with diabetes. It allows everyone to connect and share updates on food intake, insulin, and blood sugar level	iOS Android	Free
 mySugr	A little bit of gamification is added to this app. It helps patients control their blood sugar levels, monitor carbs, track insulin use and avoid hypers/hypos to beat diabetes monster	iOS Android	Free
 Glooko	It is designed to sync and work simply with numerous glucose monitoring devices, insulin pump, AND wearable fitness trackers. Other features like diet, carb intake, insulin and blood sugar tracking could also be added	iOS Android	Free
 Glucagon	It guides people how to inject the medication and store tips and provides drug information. Users can also record notes to discuss with doctor and store location and expiration dates of important medicine.	iOS Android	Free
 Calorie Counter Pro	A weight loss app that helps users track their daily eating, which is useful when people are managing diabetes. It allows users to chart their progress and take daily notes	iOS Android	iOS $3.99 Android Free
 Diabetic Connect	Track users' blood sugar and connect with other people who also have diabetes. Follow blogs, weigh in on discussions and make friends who share similar concerns	iOS Android	Free
 OnTrack Diabetes	It is designed to document blood sugar levels, food, A1c, weight and more. A record of users' history will be maintained which is easy for users to show to doctor how they are doing	iOS	Free

Table 4 Diabetes Apps Summary

To summarize, even though there are an enormous number of apps for diabetes management or treatment, none of them are specially designed for low (semi)-literacy users in developing countries. The interface design of popular diabetes apps in the Google Play store or the Apple Store is simple, intuitive and friendly to people who have higher education level. But for low-literacy users, there is an obstacle for them to understand how to use it.

4.2.4 What we do

We seek to design a special diabetes app for low-literacy people with T2D in India while considering different parameters, such as illiterate, low diabetes knowledge, cultural etiquette, smartphone exposure and economic factors. Design guidelines from prior research were summarized into an expanded model which was applied to the Tapir app design in this final project. Through the user testing in India, the prior design guidelines applied to Tapir app could be validated in the India context meanwhile new design clues for low-literacy users could be concluded after the usability testing.

5 India

5.1 Health-care system response to diabetes

India has a vast health care system, but there is a great discrepancy in the quality and coverage of medical treatment between rural and urban as well as between public and private health care. An estimated 70% of the population still lives in rural areas and has no or limited access to health care services since only about 40% of health workers are working in rural areas [41]. Private hospitals are the predominant source of treatment for chronic conditions because India does not have a National health insurance or universal health care system for all its citizens. Most healthcare expenses are paid out of pocket by patients and their families, rather than through insurance [42]. Private insurance is available in India. But only about 17% of India's population was insured according to a 2014 Indian government study [43]. And it does not cover costs of consultation or medication, only hospitalization and associated expenses are covered.

People tend to choose private healthcare rather than a public healthcare. The main reason is the poor quality of care in the public sector. But better-quality healthcare in private hospitals is not affordable to poor people. Most of the public healthcare caters to the rural areas. And because there aren't enough skilled healthcare professionals in India, especially in rural areas, the majority of the public healthcare relies on inexperienced and unmotivated interns who are mandated to spend time in public healthcare clinics as part of their curricular requirement. Formal health workers in remote areas are trained on very basic care. Most of them cannot offer tests or consultations of diabetes [44].

There are no sufficient studies and documents which describe the quality of care in diabetes. However, the defect of health care system and the lack of continuum of care for diabetic patients indicate that there are treatment gaps and poor glycemic control of patients.

5.2 Diabetes patients survey

Most patients are aged 40 years and above with T2D. Less than 20% of diabetes patients in India are able to maintain an adherence blood sugar profile according to a comprehensive scientific study evaluating diabetes management [45]. There are several reasons, such as the inability to afford the healthcare fee, limited access to health services, illiteracy (do not understand the principles of diabetes management), etc. People do not monitor their blood sugar regularly and claim to be self-testing. To the patient, the full benefits of blood sugar testing have not been realized owing to poor testing practices, lack of education about diabetes, and lack of use of the BG results to guide the diabetes self-management.

Diabetes imposes an enormous economic burden on individuals and families. Healthcare expenditure for people with diabetes is around two to three times higher than for people without diabetes [46]. And there are large regional and socioeconomic differences in the prevalence of type 2 diabetes in India. Several studies found that lower income groups generally spent a larger proportion of their income on diabetes care.

5.3 Problems associated with diabetes care

To conclude, India is already facing many problems associated with diabetes care. According to several studies [47] [48], the main problems are the following:

- Awareness of diabetes is low. CURES reported nearly 25% of the population was unaware of diabetes [49]. This study also found that awareness levels increased with

education, which indicates the proportion of low-literacy diabetes population's unawareness of diabetes and lack of knowledge of diabetes is bigger. This hinders patients' ability to manage their disease.

- Limited diagnosis and access to treatment for diabetes. In India, T2D remains undetected for many years until the associated complications have arisen. Many people do not control their diabetes and go to healthcare center regularly.
- Lack of appropriate infrastructure and health personnel. In rural India, people need to travel a lot and spend a whole day in the hospital just for a several minutes consulting. Even though in urban India, people spend a lot time in waiting in the public hospital as well.
- Poor updating of knowledge about diabetes among general practitioners. Healthcare workers in rural areas cannot provide any testing or prescription for diabetics.
- Poor access to healthcare facilities and diabetes drugs.
- The high socio-economic burden on patients. Several rural areas in India are still facing the problem of under-nutrition and are unable to access better food products, which largely hinders patients to manage diabetes and produces a huge economic burden on them. Even though in urban India, there are still many diabetics with low-economic background who cannot offer the clinical and management fee of diabetes.

5.4 Smartphone usage in India

According to a study in the statistics portal [50], in 2017 the number of smartphone users in India is estimated to reach 340.2 million, with the number of smartphone users worldwide forecast to exceed 2 billion users by that time. Figure 6 shows the number of smartphone users in India from 2015 to 2016 and the forecasted users from 2017 to 2021.

As the second most populous country around the world, India (340.2 million) is projected to pass the United States (220 million people use the smartphone by 2017) in the number of smartphone users in 2017. Figure 6 also shows India's fast growth in number of users from 2015 to 2021.

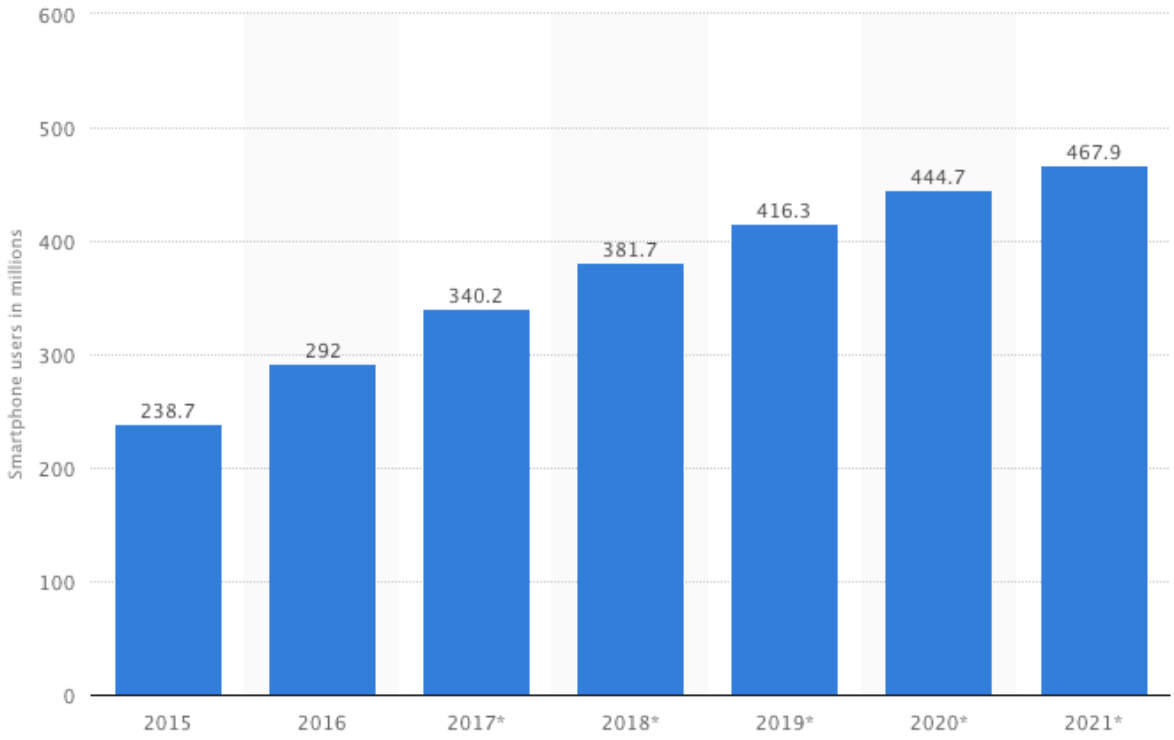


Figure 6 Statistics of smartphone users in India

According to the report on global technology and telecom [51], the smartphone market in India will grow at a compounded annual growth rate (CAGR) of 23% through 2018 and would account for 30% of the global growth during the period, which indicates that India may overtake the US as the second-largest smartphone market with robust annual growth. Samsung is the leading smartphone vendor in India, followed by Indian consumer electronics companies Micromax and Intex, Lenovo-Motorola, Reliance Jio, Lava, Chinese manufactory Xiaomi and Oppo [52]. According to a report released by Strategy Analytics, Google's Android OS captured 97% share of the India's smartphone market in Q2 2016 [53]. Therefore, in terms of mobile diabetes application design, we will choose the Android platform in this final project.

We observed that there were many advertisements about smartphones when we did the context research and user testing in Bangalore, India, which indicated the popularity of smartphone in India as well.

Figure 7 Smartphone advertisements in Bangalore

A report titled “Smartphone User Persona Report (SUPR) 2015” reveals what Indians mainly use their smartphones for [54]: around 20% smartphone users spend over two hours a day using chat and social networking apps. Conversationalists account for 16% and mainly use smartphones for making calls with minimal app usage. Entertainment people spend almost an hour each day playing games, listening to music or watching videos on their smartphones, which accounts for 15%. And around 25% of the total smartphone users are early adopters, consuming the most data and download 18.5 mobile apps and games every month. People whose prime purposes of using smartphone are utility-driven along with apps for voice calls and messaging account for 15%. The rest 15% users are inactive which means they use their smartphone infrequently, seldom accessing apps and sites.

Around 10.6 million diagnosed diabetics have smart devices [33], which mean they can get access to diabetes application and may enjoy the benefit of new technology. It presents a significant opportunity for promoting access to health information and services for patients and also enhances the capacity of health-care providers to provide quality care and counselling for diabetes.

5.5 Low literacy rate in India

A census of India in 2011 [3] concluded that the illiteracy rate in Rural India is 31.1% and in Urban India is 15%. The total number of illiterate population is 431.6 million, 340 million in Urban areas and 91.6 million in Rural areas. In terms of gender, 21.4% males in rural and 10.3% males in urban India are illiterate while the corresponding values for females are 41.2% in rural and 20.1% in urban India. In 2015, the illiterate rate in India is 28.04%. Compared to the illiterate rate which is 30.7% in 2011, it has a bit of decrease. The source defines illiterate rate as the percentage of people aged above 15 who cannot read and write [55].

Even though there is no accurate data which indicates the relationship between low-literacy people and smartphone users, with the fast growth rate of smartphone usage in India, more and more people will use the smartphone in the future including low-literacy people. However, there is a gap between low-literacy people and enjoying the benefits brought by new technology. It is not hard to forecast the increasing design need of applications for low-literacy people so that they can also get access to new technology and lead a better-quality life.

6 Problem to be addressed by the Tapir

As mentioned above, there are many problems concerned with diabetes care in India. The one we focus on in this thesis project is the poor access to healthcare facilities and economic burden on patients with T2D. The detailed scenarios of this problem are described as following.

Successful treatment of patients with T2D depends on regular contact with the health providers and self-management of diabetes. However, there are thousands of villages in India where people have to travel a long distance to the health services. Some treatments, such as medical consultations, laboratory tests, and drugs, have remained unavailable in rural areas [56]. In the urban areas, even though people do not need to travel a long distance to the hospital, due to the terrible traffic in cities, they still need to spend a lot of time on the way to the hospital. Take Bangalore for example, as the Figure 8, in the rush hour, it costed us 1 hour to go to the hospital even though it was just a 10km distance. Additionally, patients need to spend a lot of time waiting in the hospital since the public hospitals are always crowded in India as the Figure 9. And because they do not have a BG monitor at home, they need to go to the hospital for BG measuring. Sometimes, people are unwilling to travel a lot and spend a whole day in the hospital just for 10 minutes consulting, so they do not go to doctors and measure their blood sugar regularly, which leads to the poor treatment and management of diabetes.

Figure 8 Terrible Traffic in Bangalore

Figure 9 Crowded patients in public hospital

Diabetes also imposes a large economic burden on individuals and families. Within the diabetes population, low-income individuals bear the highest burden of diabetes [57]. People do not monitor their blood sugar regularly and 47.2% of patients monitored their condition only four or fewer times in a year [58]. One of the reasons is that they cannot afford the fee of monitoring regularly in hospitals or a private glucose meter and testing strips (a blood sugar measuring tool) to test their BG regularly at home. From our visit in Bangalore we know, that it costs 60 to 70 Rupee for one BG test in the lab or private clinic. People with lower income are not able to spend time and money on regular BG testing.

Additionally, BG testing is an essential and most basic part of diabetes care. Self-monitoring blood glucose (SMBG) provides useful information for diabetes management both to doctors and patients. Basically, it can help doctors and patients [59]:

1) Judge how well the body is reaching overall treatment goals
2) Understand how diet and exercise affect blood sugar levels
3) Understand how other factors, such as illness or stress, affect blood sugar levels
4) Monitor the effect of diabetes medications on blood sugar levels
5) Identify blood sugar levels that are high or low

It provides an important clue in designing the Tapir app for people with T2D in India. The main function of this app is BG testing. Users can scan the test strip with the smartphone camera, then the value of blood sugar will appear on the mobile interface. The technique principle of this app is the comparison between color of the strip and color code on the strip box. It is free for people to download to use so that low-income diabetics can get access to the BG measuring easily and conveniently at home.

7 User study

7.1 Target group profile

Within India's low-literacy population, people with T2D who are diagnosed and have smartphones are our target group. The range of the target group's age is from 20 to 79 years, the majority are aged 40 to 59 years old. And most of the target users are of the low- or middle-income population in India. They do not have blood glucose meter at home mainly due to their inability to afford it.

Generally, low-literacy people do not have the ability to read or write well enough to perform necessary tasks in society or on the job, which leads to high risks of unemployment and lower income [60]. They also have difficulties in understanding oral and written information, for example, in a clinical case, they may find it difficult to describe their diabetes and to understand the information provided by doctors. This is one reason for the poor management of diabetes and low quality of healthcare in low-literacy user groups.

Considering that most of the low-literacy people in India have lower income, the definition of the India low- and middle-income population is listed in the following classes (The estimation is based on sample data of Urban Population of Bihar [61] and interviews in the Bangalore)

- Middle Class: 10,000 to 20,000 Rupee monthly
- Lower Class: 7,000 to 10,000 Rupee monthly
- Poor Class: 3000 to 7000 Rupee monthly
- Wretched: Less than 3000 Rupee monthly

7.2 Persona

In order to understand target users within the context of their specific goals and problems they are encountering, several qualitative personas were made to present the goal and behaviors of different user types. Personas are synthesized from data collected from interviews with users, doctors and desk research. According to Baines et al. [62], the key characteristics of a demographic profile are "age, sex, occupation, level of education, religion, social class and income." These variables will be presented in the personas.

We went to Bangalore, India to do the context research and interviews with users and doctors. All the information is gathered by Roche and only used for exploring solutions. All the data will be kept strictly confidential. No publications or reports will be included to identify information on any participants.

Facts to consider when building the persona are listed following:

Constraints

- Lack of diabetes education and support
- Low ability of reading and writing
- Limited resources for purchasing the glucose meter and strips
- Lack experience in using smartphone
- Low income
- Culture difference

Product expectations

- A cheap solution

- Easy to use, friendly interface
- Data understanding
- Guidance offered consistently during the treatment journey
- Education about diabetes

7.2.1 Persona 1
Alisha, 52 years old

Alisha only has one son, Divit. He is a student at the Technical University. She is working all her life really hard so that Divit can go to university and receive a better education. She only has a standard four education level and does a low-payment job. So, she hopes her son will find a good job with his higher education.

"I want to measure my BG at home, but I am afraid of an overcomplicated system."

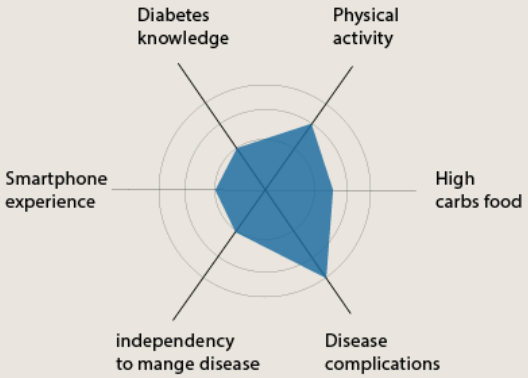
Life with diabetes

Alisha has been diagnosed with T2D recently. Her condition is quite bad. She is managing the disease on oral medicine, insulin and diet.

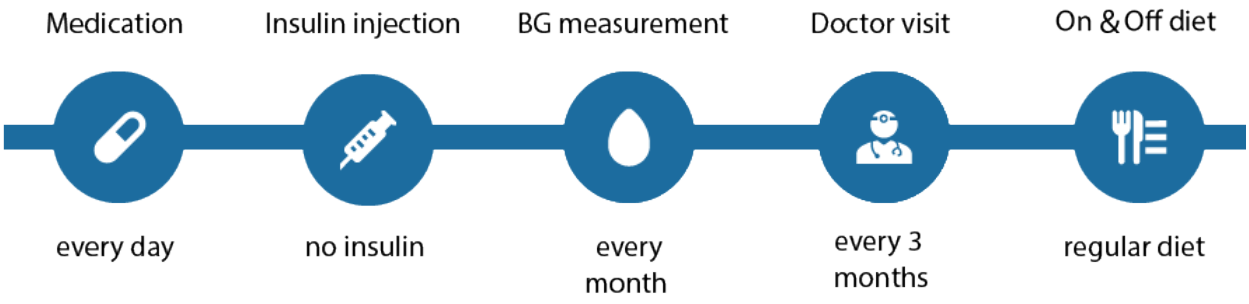
She is very worried about her health and she wants to fight it. She wants to learn how to control diabetes and avoid its complications. But she does not have time and money to attend coaching programs. She still need to work to support her family.

Alisha wants to measure the BG at home. But the BG meters are expensive and she is afraid that she won't know how to use it alone.

Particularitites



Dealing with diabetes



Therapy indications

Measure BG every month

Strict diet

Key needs

Measure BG more often for a peace of mind

Understand diabetes data

Learn to adjust the lifestyle in order to have a better control diabetes

Product expectations

Easy to use and intuitive system

Offer tutorials for features usage

Affordable price

7.2.2 Persona 2

Kamala Devi, 62 years old

Kamala is a housewife. She lives with her husband who is retired. She has three children and all of them are married and well settled in life. She has been diagnosed with Diabetes 4 years ago and has standard eight education. She likes South India food and mango. She only speaks Kannada and only has 4 months smartphone usage experience. Her children teach her how to use the smartphone and help her download apps.

"I want to control diabetes but I do not want to give up my favourite Indian food"

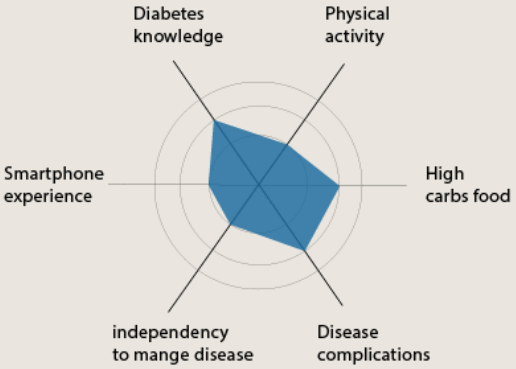
Life with diabetes

Kamala was diagnosed with T2D 10 years ago. Although her mother had diabetes, she was still worried when she first got to know.

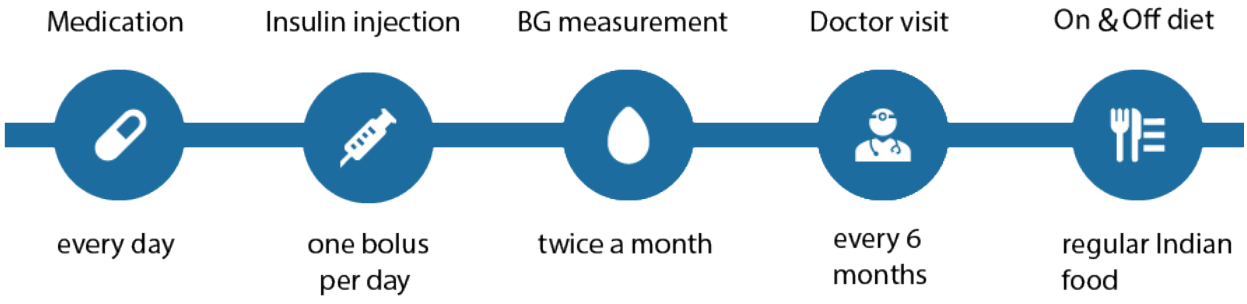
Kamala wants to control diabetes well. But she is unable to walk much as her feet swells. She and her family love south Indian food so much which is not good for diabetes people. She also loves mango. But sometimes her blood sugar is uncontrol after eating mango.

She wants to test BG easily when she felt uncomfortable and adjuest food style.

Particularities



Dealing with diabetes



Therapy indications

Measure BG twice a month

Insulin injection

Key needs

Maintain a healthy lifestyle by keeping sugar in check

BG testing often makes her feel streesed and ill

Learn to adjust food style

Product expectations

Offer food choice based on India context

Recommendations of delicious and healthy food

7.2.3 Persona 3

Sailesh, 43 years old

Sailesh is a long-distance driver. He is married and has two children. He lives in the same house with his parents. He has been diagnosed with diabetes 7 months ago and has a standard 6 education level. He has been using a smartphone for 1 years and mainly uses his smartphone for WhatsApp and calling back home. His recent type 2 diabetes does not affect him too much. He is always busy with earning money because he needs to support the whole family.

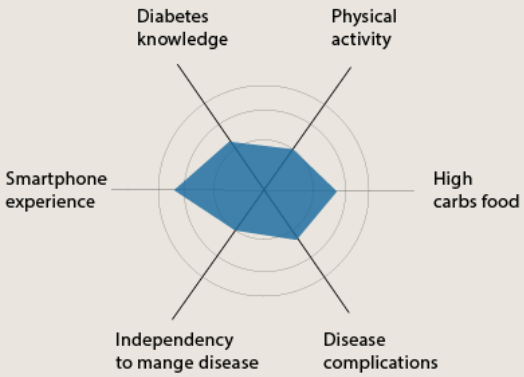
"I have a very hectic schedule and want to check my BG easily and conveniently"

Life with diabetes

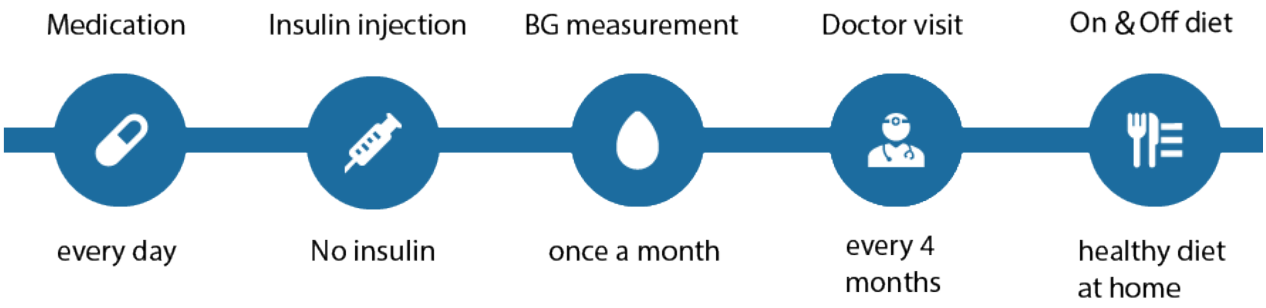
Sailesh leads a very hectic lifestyle. Working as a long distance driver, he often sits in the car and does not have time to exercise. As long as he can drive and provide money for his family he will be fine. But his wife took it very serious and worried about it. Both of them do not have too much experience of dealing with diabetes. His wife changes the food for Sailesh when he is at home since traditional south Indian food contains too much carbs.

Sailesh wants to measure BG easily when he is at work and share to his wife.

Particularitites



Dealing with diabetes



Therapy indications

Measure BG once a month

Reduce smoking, intake of non-vegetarian food and alcohol

Diet at home

Key needs

Maintain a balance of work and health

Want to learn simple exercise which can be done during the work

Easily measure BG during the work

Product expectations

The BG testing should be accurate

Easy to carry and easy to use

7.3 User journey

In order to understand the users' phycology better, a user journey is concluded as the Table 5.

Phase	Pre-Diagnosis	Diagnosis	Treatment	Changed lifestyle
Doing	Feels sick and goes to see a doctor	Gives blood samples in a lab and receives the test results from the doctor	Follows the recommendations provided by the doctor; Modifies lifestyle, diet and takes medicines on a regular basis; Visits the doctor once in every 3 months	Struggles to find the right balance; Gets tempted to eat sweets; Carries something to eat all the time; Eats something once every two hours; Self-monitoring of symptoms
Thinking	Why am I feeling sick? I know I have diabetes in my genes	I was prepared for this; I worry if I will have to go through the same pain as my parents	How will I manage to maintain this kind of lifestyle for the rest of my life? Why do I need to give up on so many things? I know diabetes is not a taboo anymore but I don't want to discuss it	I don't want to test my BG very frequently; My BG will be in control if I maintain a healthy lifestyle and control my diet; I just need to go to my doctor once every 3 months; I don't want to worry much about my BG
Feeling	Worried Concerned	Denial Acceptance	Unsure Unconfident Hesitant	In control Hopeful

Table 5 User journey

7.4 User Requirements

From user interviews, doctor interviews, and desk research, the users' requirements for the solution are summarized as following:

- A cheap and easy way to measure their blood sugar.
- The BG result should be accurate.
- Understand how to manage their daily life to control diabetes better, for example how to choose suitable food and have the least interference with their daily activities and lifestyle.
- Gain more reliable suggestions and guidance of controlling diabetes so that they can lower the frequency to the hospital.
- Understand their diabetes state, it is good or not?
- Gain more education about diabetes.

Considering the specialty of the low-literacy people, an additional set of user requirements for app UI design were derived from a survey of the literature [30] and expert (senior designer in emerging markets) interviews.

- Target users have a high need for ease of learning, easy to use, and ease of remembrance, due to their low levels of education, low smartphone experience, low frequency of use, and potential uncertainty or anxiety towards technology.
- Limited reading/typing skills suggested an interface with simple or less textual requirements. Icons and visual displays (possibly with the use of speech synthesis) are suggested.
- The potentially broad cultural and ethnic backgrounds of users require an interface that supports internationalization [63].
- The design content should be useful, and the design should be robust in order to promote learning and exploration.

8 Digital solutions exploration

Based on the Indian context and user research, our initial idea is to apply a new technique to design a mobile health application named Tapir which can act as a BG meter to measure patients' blood sugar. Tapir can be downloaded for free. So that patients can get access to this application easily and measure their BG conveniently at home and do not need to pay for a BG meter. Thus, this comes to our basic concept.

8.1 Basic concept

The goal of Tapir is to deliver an acceptably accurate and understandable blood glucose (BG) result via a smartphone application to a person living with diabetes, where due to reasons such as (but not limited to) lack of medical infrastructure, access, affordability or meter investment restrictions, self-monitoring of blood glucose (SMBG) would otherwise be limited or non-existent[64]. The user can scan the testing strip via Tapir app, the value of BG will appear on the mobile interface.

8.2 Function table

Besides the main function, measuring BG value via scanning a strip, additional functions are provided as well according to the users' requirements. Food, exercise, and medication therapy are important for managing T2D. However, low-literacy type 2 diabetics lack diabetes knowledge in general and they do not know how to choose food and manage diabetes better. Newly diagnosed patients sometimes will forget to take pills. They want an easy way to learn how to manage diabetes and could receive reliable feedbacks and suggestions. Therefore, food monitoring, pills taken remind, and education channel are proposed. The functions of Tapir are shown in Table 6.

Function	BG Measuring	Food Monitoring	Diabetes Education	Pills taken remind
Details	Use camera of smartphone in Tapir to scan a test strip to gain the BG value; BG value is recorded in the Tapir; Corresponding suggestions would be provided by Tapir if the result of BG value is out of the normal range	Track daily meals; Learn how different meals affect patients' blood sugar; use Tapir to test BG before meal, then take a meal photo, another BG test 2 hours after meal; to judge whether the food taken is a good choice or not	Use graphic and voice output or video to explain the general knowledge of diabetes, how to manage diabetes; Recommend India healthy food; Proper exercise	According to the data input, Tapir will remind patients to take pills per day

Table 6 Tapir's functions table

9 Design Methods

9.1 Model development

In order to have a logical and structural view of the existing design guidelines which can help us to design the information architecture and mobile UI for this app in the initial phase, the model, a result of the aggregation and distillation of design recommendations from previous research, will be built up. The development of the model consisted of two parts: summarized best practices in mobile interface design from literature and obtained information from the field via using domain expert interviews.

The purpose of the model is to facilitate UI design work for low-literacy people with the help of a set of guidelines and choices, which define what an interface should contain and what kind of considerations should be made in order to comply as suitable for low-literacy users. There is an existing similar model for this purpose, but it was designed for West Africa [65]. We will refer to the model in existence, also integrate additional recommendations from the scientific literature, feedback from expert interviews, and combine the context in India to expand and rebuild a new model.

9.2 Model Results

Considering our target users, low-literacy people with T2D in India, the recommendations and considerations from the conclusions of the earlier research can be divided into four main sections: design constraints, navigation, visual language, and support.

9.2.1 Design Constraints

When it comes to India, there are many potential constraints which are specific to local circumstances. These constraints should be examined and determined early on in the design process, because these constraints may influence the whole design, such as functions and information architecture. Appropriate attention should be given to these constraints during the design.

A total of three constraints are considered in our cases.

- The first constraint is the poor internet connection in Rural India. Even though the availability of internet through mobile network is growing fast in India, it is mostly concentrated in the urban areas [66]. So, the model suggests if a poor internet connection happens, we should make sure that information will load even on 2G connections. And if the loading time is too long due to the poor connections, corresponding interface feedbacks should be displayed so that users would know the current states. While video content might require a system with greater bandwidth, in the condition of poor internet connection, audio and static images should be available to replace video content.

- Another common constraint is the familiarity degrees of smartphone usage experience. As stated earlier, even though the market penetration rate for the smartphone in India is high and growing fast, there are still many novice users for the smartphones. When it comes to this case, the model advises that some simple training showing the basic operation of smartphone should be provided. And the interface design should be intuitive, simple and easy for understanding.

- Lastly, the constraint is related to diabetes literacy. Most people just have a basic idea about diabetes, for example, their blood sugar is high which is not good. But they do not know what a low or normal level is and they do not have idea about number itself (the normal range of BS (tested while fasting) is from 70 to 100 mg/dL.) Thus, the model suggests using analogies and visual clues to talk about the illness so that people could understand better and easier [67].

After applying a solution, the model would check if the chosen solutions are effective enough to overcome the constraints. If this is the case, one may continue. If it is not, other approaches are suggested to be tried again. If there is no other way to solve the constraint, the model suggests the project should be terminated.

9.2.2 Navigation

Navigation is an essential part of an application which helps users to navigate through different layers and pages. It contributes to communicating information in a clear way within an app. There are separate guidelines for low-literacy users.

As mentioned in the related work, Chaudry et al. [8] analyzed the ideal navigation structure of mobile interfaces for low-literacy populations. The recommendation was to "use a hybrid navigation structure that combines linear navigation with a navigation bar". From their research results, purely linear navigation paths worked best, which guides the user from task to task through a sequence of consistent screens. Kodogoda et al. [68] found that hierarchies in information architecture should be avoided. Beenish M. et al. [69] found that each screen should incorporate a Back button for shorter recovery lengths, and a Home button for longer recoveries. The study also proposed designer should help low-literacy users establish a sense of location within the application. Users should know they are completing tasks and are successfully using the application. Medhi et al. [23] suggested keeping a help button in the same location on every screen in order to provide help.

Chaudry et al. also studied interface components. In their study, the size and type of the widget which low-literacy users prefer were concluded. The result is bigger or medium size widgets were preferred by the populations [8].

9.2.3 Visual language

Regarding the design targeted for the low-literacy group, it is best to use less text in the interface. Medhi et al. [23, 24] suggested avoiding text all together while numbers can be used as interactive interface elements to deliver a certain amount of information. Numbers can be acceptable as many low-literate people can read and understand numerical digits. In our case, we would use some simple text with graphic clues because, in terms of education, the definition of the low-literacy users is from standard four to standard eight. They can read simple but not so much text. The model, therefore, provides a choice based on the level of literacy of the users. If the user is illiterate (almost do not know any text), the guideline will be using text as little as possible.

Medhi et al. [23] also suggested semiabstract cartoons and photorealistic graphics could be recognized much better than abstract graphics by low-literacy people. Work in "Text-Free UIs" established that static, hand-drawn representations are better understood than photographs or abstract iconography. But with deeper interaction, more photorealism can be helpful [70]. Gatsou et al. [71] advised designing interface elements which are familiar to the user based on their prior knowledge and cultural background.

Another important point of the UI design is how to explain the actions to the user. The research of Medhi et al. [23] suggested a way of communicating activities by showing cartoons. They also emphasized the need for realistic graphics with voice feedback. Many types of research also looked at voice as an interaction modality, Cuendet et al. [72] concluded the speech input did not provide much assistance compared to a graphical touch system with audio output for low-literacy people. Considering the infrastructure and technique constraints in India, speech input may be difficult to implement. The combination of voice feedbacks with graphic clues (explain a spoken dialog system) is recommended by Medhi et al. [24].

The amount of experience a user has with the smartphone interface influents a lot in how the user sees an interface and recognizes certain functions. So the model will consider the amount of smartphone experience the target users have.

9.2.4 Support

When considering the support system provided by the applications, mostly we will refer to the existing model designed for West Africa [65]. The supports mainly come from two parts: direct human support for installing the app and teaching users how to use it; supports from the application itself (such as help button). Other supports are the language used in the application and the usage of the words. Medhi et al. [24] suggested the local spoken language of the users should be supported by the application and specialized or technical terms should be avoided since it might be difficult for users to understand.

9.2.5 Summary

The expanded model which is tailed for low-literacy people in India is visualized as Figure 10. We will refer to this model in the initial phase of the application and UI design for diabetics in India. Then the user testing will be conducted in India to evaluate the application design and validate the expanded model. During this process, combined with user feedbacks and local context, some design recommendations will be concluded.

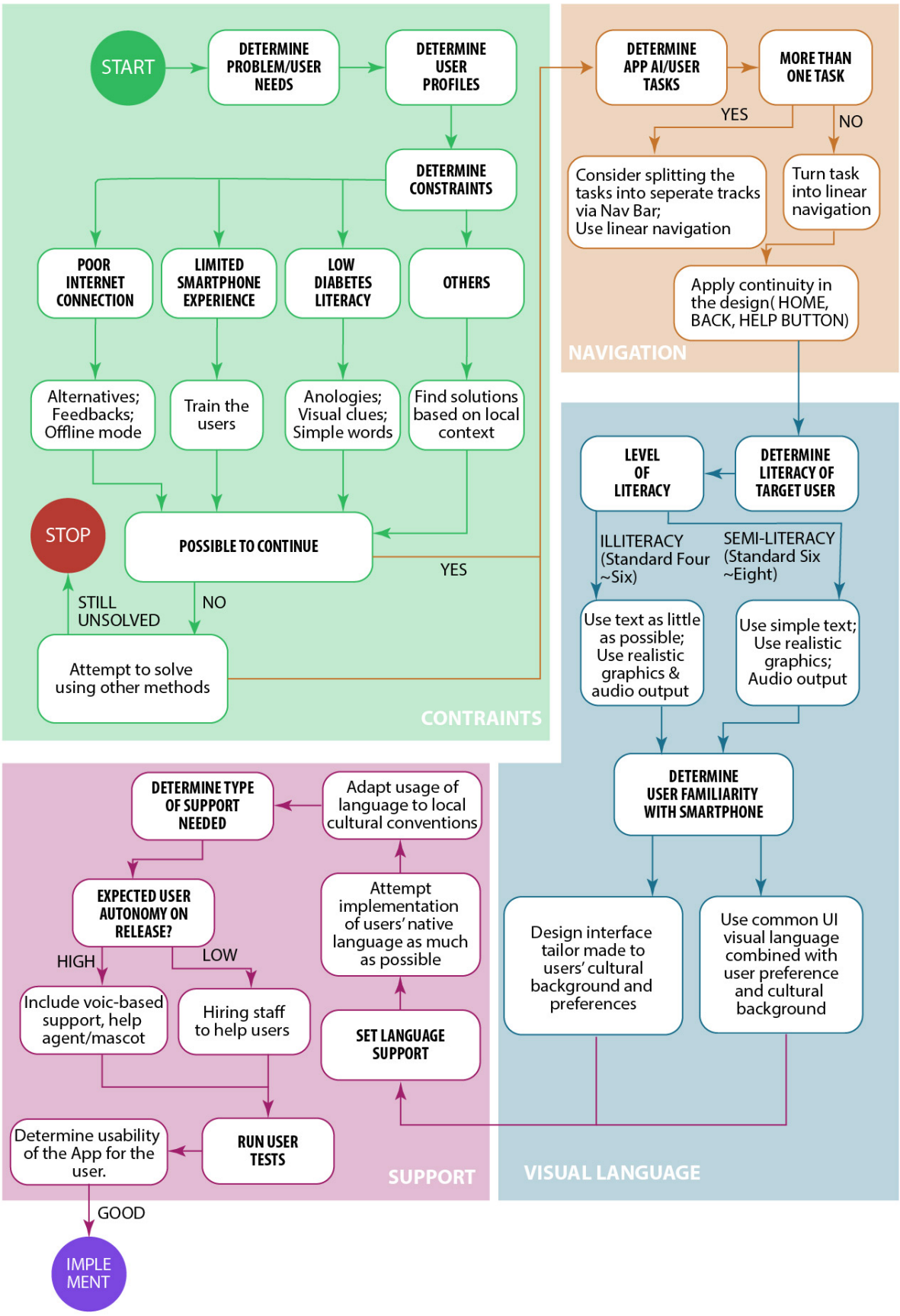


Figure10 Schematic version of the expanded model

10 Design

10.1 Tapir Information architecture design

According to the expanded design model, linear navigation is recommended for low-literacy users. Basically, users have 4 tasks according to the function table. The most important task is measuring BG value by using Tapir. The other three tasks are to track daily food, learn the management of diabetes and set up the remind of taking medicine. In case the first-time users are overwhelmed by multiple functions, the priority function, BG measuring is displayed in the main interface and other functions are stored in a navigation drawer bar. Each task has linear navigation structure. The first version of the information architecture design is as Figure 11.

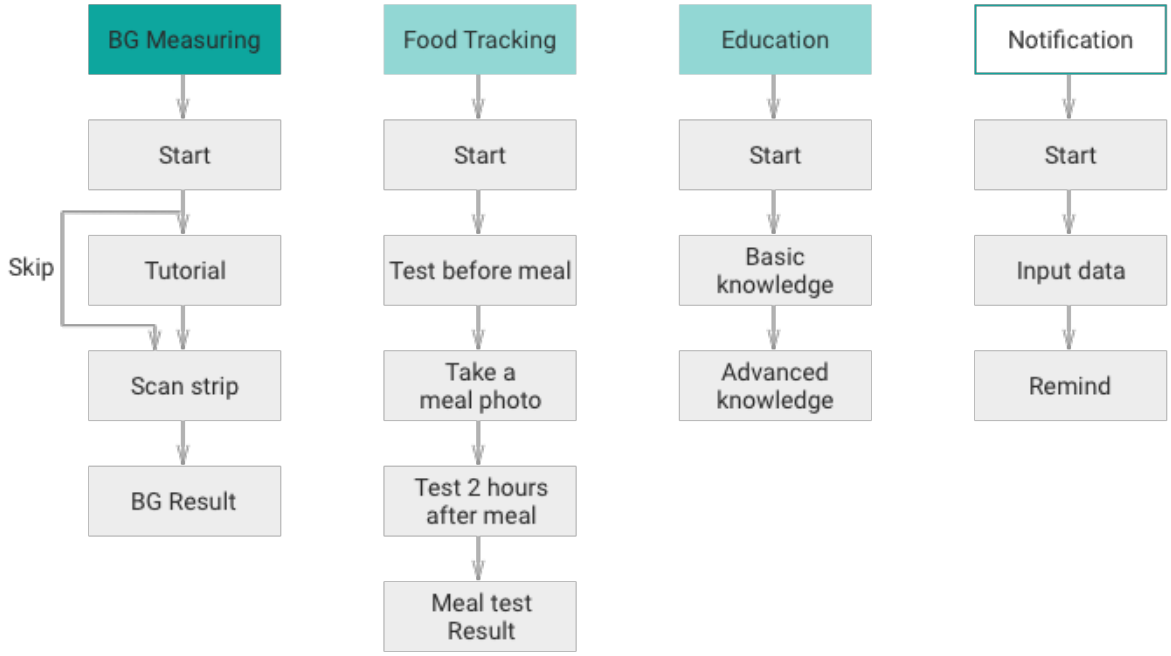


Figure 11 The information architecture of Tapir

10.2 Tapir Wireframe design

The wireframe design of the primary function – measuring BG value is as Figure 12. Considering first-time users may not know how to use the lancing device to prick their finger and apply blood to the test strip, a tutorial of measuring BG is provided in Tapir. According to the expanded design model, a help button in the same position of screens and linear navigation structure is applied to the design of Tapir. The button with first priority is always located at the bottom of screens with a bigger size.

Figure 12 Wireframe design of BG testing

The wireframe of food tracking is displayed as Figure 13. The purpose of this function is to help the user understand how different meals affect their blood sugar. If after a meal, their blood sugar value is out of the target range. The food they took will not be recommended and Tapir will suggest to eating less such food. Oppositely, if the BG after a meal is still in the target range, Tapir will show this is a good choice. The layout design is similar to the function of BG testing to keep the design consistent, including buttons position and types.

Figure 13 Wireframe design of food tracking

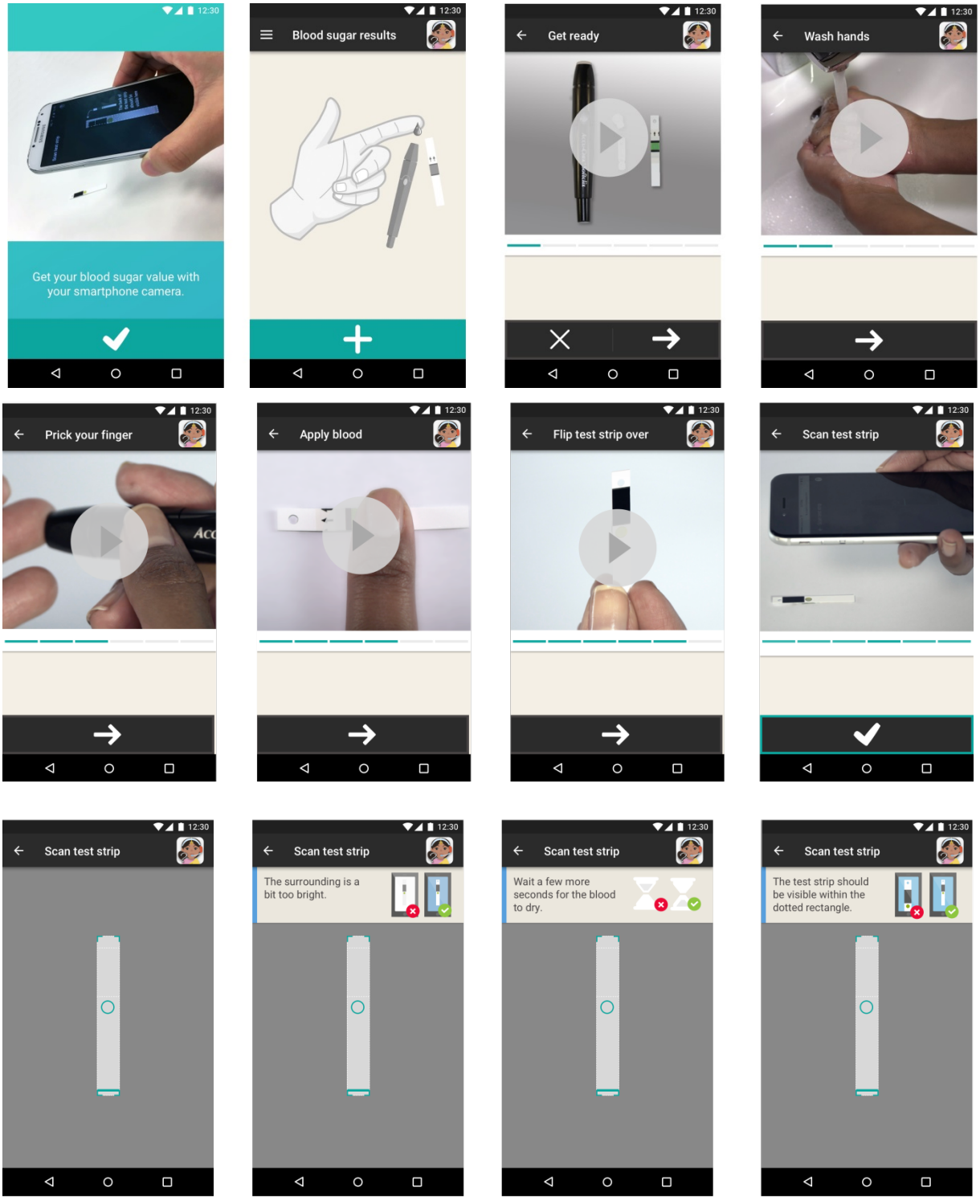
10.3 Mobile UI design

In the initial design phase, we mainly focus on the primary function design because this is the most significant function for users. When they understand how to use the primary function, other additional functions will be introduced which are hiding in the navigation drawer.

Visualization of the primary function of Tapir is as Figure 14. According to the expanded design model, visualization should be more realistic instead of abstract images so that low literacy people could understand it better. Thus, the real Tapir usage picture is shown on the

first screen. All the buttons are displayed on the bottom of the screen with the same size. A “tick” symbol means done and a “right arrow” means continue.

A video tutorial with audio is made to explain how to use Tapir step by step. On the top right corner of each screen, an Indian girl is presented as a help button with an audio output. In order to explain BG value better to low literacy diabetics, two different visualizations were proposed. The trumpet icon on “My blood sugar screen” presents a voice output for explaining the results and corresponding suggestions to users. Different graphics are used to present the range of blood sugar and the meaning of the blood sugar results.



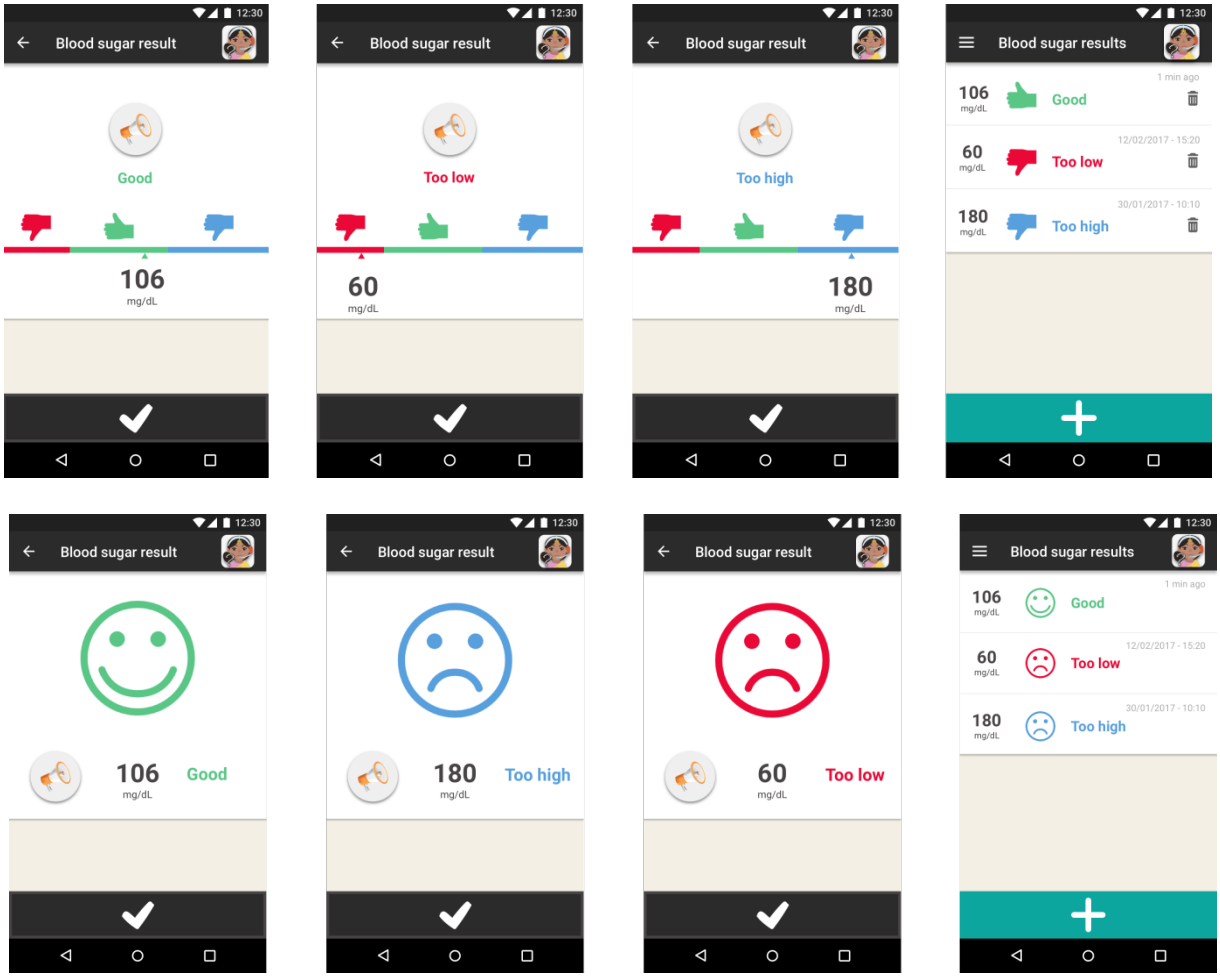


Figure 14 Visualization of the primary function

10.4 Implementation & Prototype

Justinmind is a prototype tool which can support offline video play. Considering the unstable wireless connections in India, the prototype should be offline available. At first, we used Justinmind to do the prototype and conducted a pre-user testing in Europe which aimed at improving the design quickly.

When the design was improved and confirmed from the pre-user testing, Android Studio was used to develop an app demo which could support multiple interactions, such as offline video play, audio output, and camera scan function. The language used in Android Studio was Java.

11 Pre-user testing

A limitation of this final project is that in the initial design phase we could not get access to real low literacy users in India and improve our design through usability testing. So, we conducted a pre-user testing in Europe and a remote testing from China. The purpose is to validate the current design and improve it before we go to India. The participants hired in the pre-user testing had some similar characters of the low-literacy people defined in this study. For example, one participant did not have any smartphone usage experience, one participant had standard 3 education level and did not know any English and one participant had few knowledge about diabetes. 4 participants in total attended this pre-testing, two were from Germany and the others attended remotely from China. Before doing the pre-user testing, the researcher explained the purpose of this study and tasks to subjects clearly. If subjects agree to attend this pre-user testing, they would sign the pre-user testing consent form as the Appendix A. All the data gathered is only used to improve Tapir UI design and all the information will be kept strictly confidential by Roche.

11.1 Subject 1

Subject information

Man; German; aged 45; does not have any smartphone usage experience; has a university education. But he knows diabetes well and works as a first-aid staff in Red Cross during his spare time. Even though he has higher education, he does not use smartphone at all. We also can learn how he reacts to the Tapir UI design as the first-time user.

The task for this subject was to go through the app and use Tapir to measure BG. Lancing device, lancets, control solution, and strips were provided.

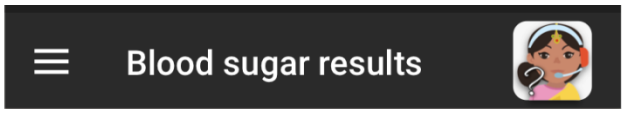
In general, the testing outcomes were as following,

1. He could understand the videos and know how to use Tapir to measure BG.
2. He understood the visualization of continue and done button and watched the tutorial video step by step.
3. He recognized the top right button “Indian girl” as a help button with audio output. He said “the Indian girl looks like having a voice and can speak something to me”
4. All the buttons in the same position of the screen were easier for him to find out. He thought bigger size buttons were easy for him to find out.

Some problems of design were found as well,

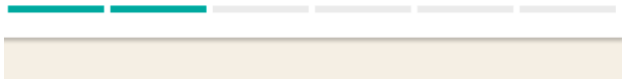
1. Flat button was not easy for him to find out. He preferred a 3D dimension button which imitated the physical mechanical button. The design of the buttons should be consistent to let users know all of these are clickable.

2. He did not notice the buttons on the top bar, he just thought they were symbols and did not know what it meant. He thought the right top button (the girl with earphone) was a symbol and with the function of “tone, can say something to me” automatically, and did not think this “girl” could be touched. Also, the navigation drawer button was recognized as a symbol and he did not think it was a button.

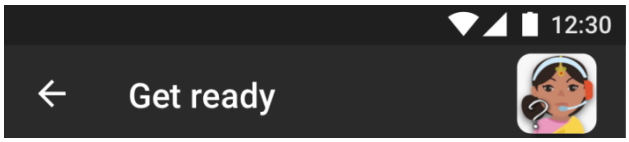


3. He wants to go back to the previous tutorial but did not know how to do it. After simple encouragement, he found the back button in the bottom of the screen, the standard one in Android smartphone. Because his eyesight was mainly focusing on the bottom of the screen and searched for the back button around the big continue button.

And he thought he can press the green rectangle to go back to the previous step while it did not be considered in the design.



The left arrow button on the left top of screen for going back to the previous step was not recognized as a button.



Conclusion

1. Maybe Skeuomorphism design is easier for people who do not have smartphone usage experience to understand. Skeuomorphism presents perceived affordances, which mimics the objects in our daily life to present in the UI design, such as door handles and push buttons so that people could understand the components of UI easily.

2. In the video tutorial, when it said to press the “continue button” if we can show the screen and a hand to press the continue button may be better for users to know what to do in the next step.

11.2 Subject 2

Subject information

Female; aged 23; German; Master student; has no idea about diabetes; has high-level smartphone usage experience; know English well. Since she has no diabetes knowledge at all, it is interesting to see if she can understand the diabetes content display in the Tapir well.

The task for this subject was to use Tapir to measure BG. Lancing device, lancets, and strips are provided as well. The purpose was to see if this subject can understand how to use Tapir and lancing device etc. to measure BG since she did not know the terminology of diabetes before.

Outcome

The video tutorial was easy for her to understand. There was no any difficulty in using Tapir. Even though she did not have the concept about an accurate number of BG value, she could understand each BG result screen. And she thought the functions of Tapir were too simple. Besides BG value, other information does not provide enough value to her. For example, the suggestions were too simple and she wanted to know more.

Conclusion
Tapir could be easily understood by people who have higher education and rich smartphone experience. The subject got to know how to use Tapir quickly.

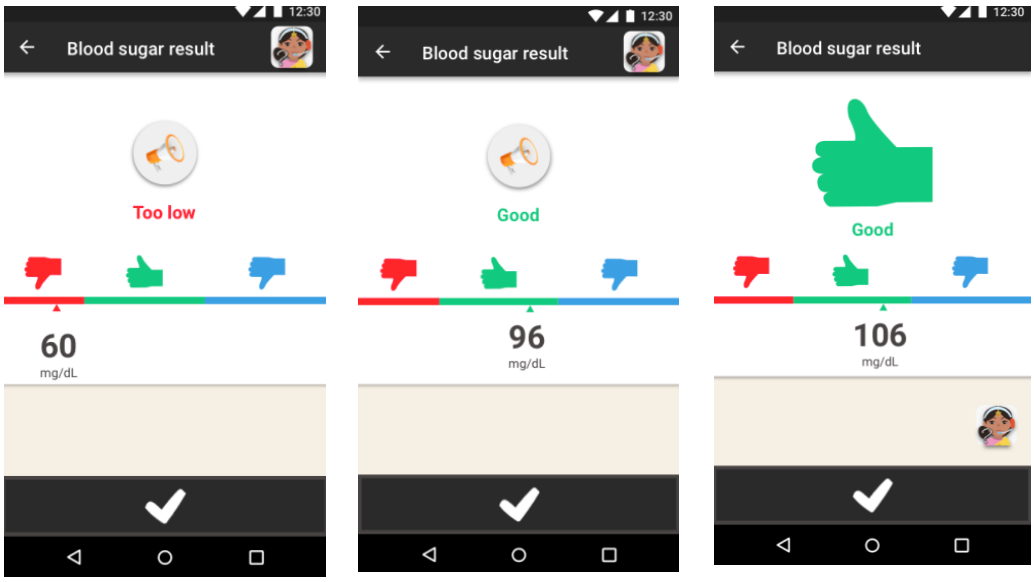
11.3 Subject 3

Subject information
Female; age 57; Chinese; only has the 3rd grade education in the primary school; has type 2 diabetes; has basic knowledge about diabetes but has no idea about the BG value with mg/dL unit; does not know English at all, has middle level smartphone usage experience and use WeChat to communicate with others.

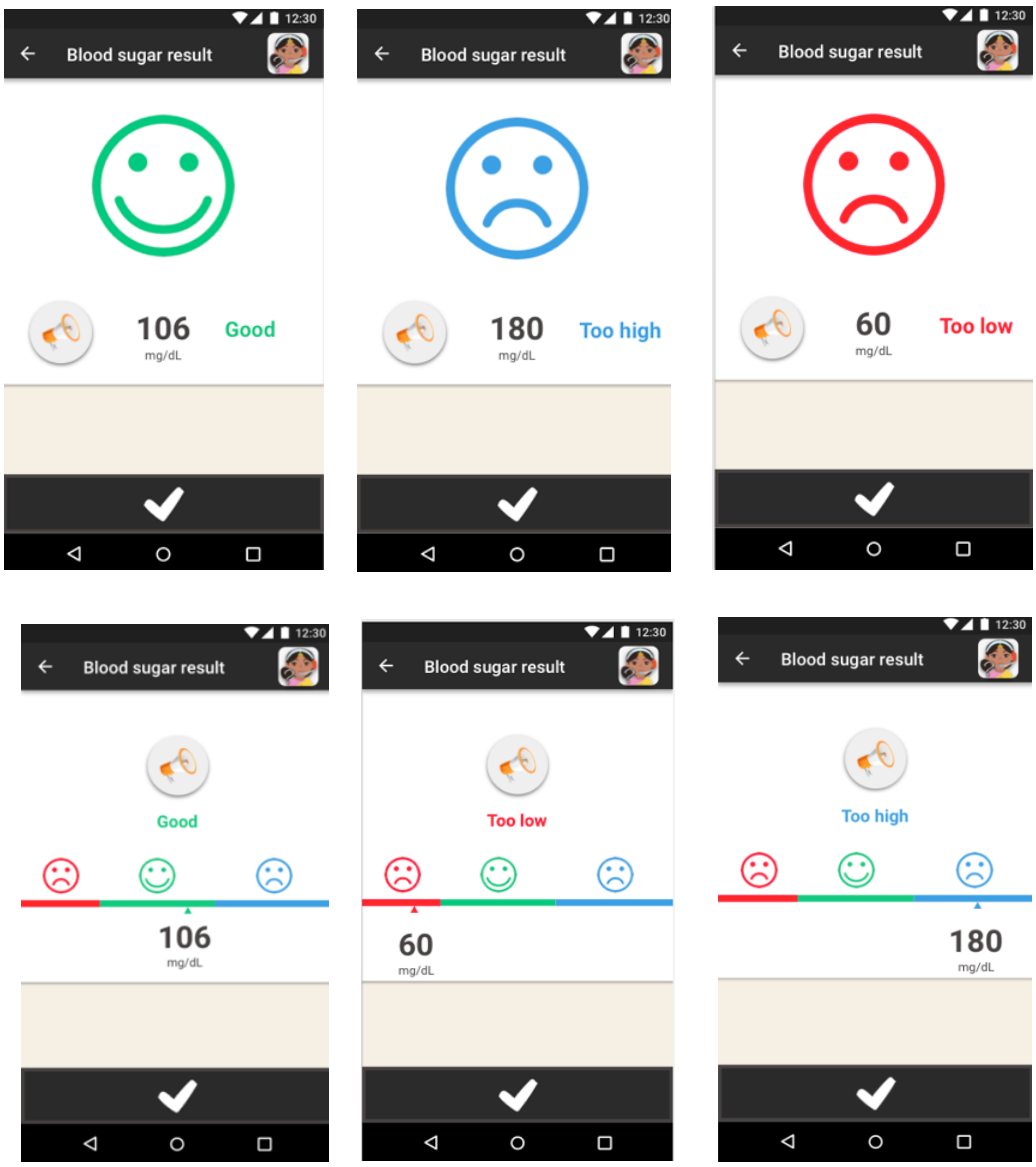
The task for this subject was to recognize different visualizations of BG value and told us what these results meant.

Outcome

1. Subject was confused by the screens bellow because there were too many icons and she thought all of the results were bad because she saw there were thumbs which were turning down. And she did not get the idea of the line of explaining the target range, the left was too low, the middle was normal and the right was too high.



2. The subject had correct answers in the following screens. She combined the icons and number to judge the BG result.



Conclusion

The graphic design is too complicated for the subject to understand. This subject did not get the line of explaining target range. Icons should be clear, less and simple. In the later testing, she more focused on the number because she already had some awareness about the number during the testing.

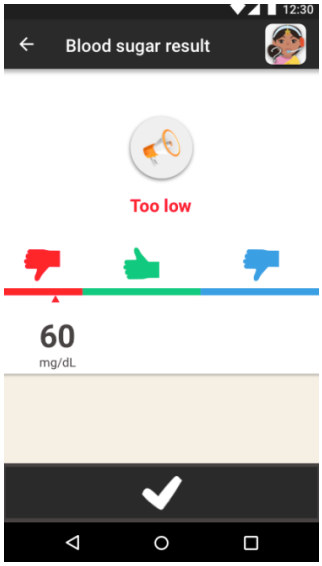
11.4 Subject 4

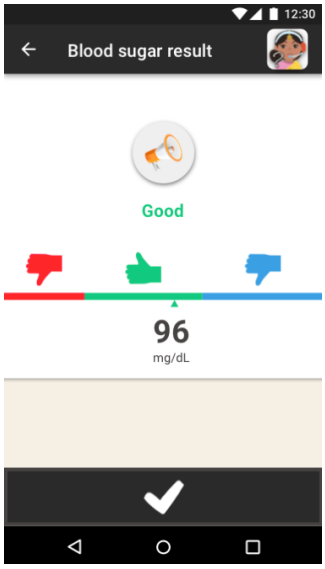
Subject information

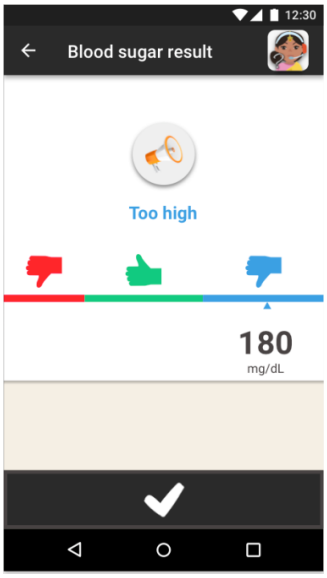
Chinese; Pre-type 2 diabetics; Secondary school education; has basic knowledge about diabetes, knows too low or too high BG value is not good but does not know the accurate range. He does not know which number means too high or which number means normal. He knows simple English words, like “good” “high” etc.

1. Subject noticed the number below the red turning down thumb in the left screen, so he judged the result as too low. And he judged the middle screen as a normal one and he said, “the number is in the middle and is below the up thumb, it should be good result”. He

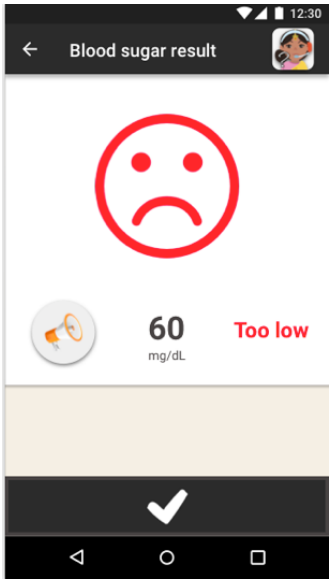
judged the right screen as too high and he said: “with a turning down thumb and a higher number”. He got the idea of the straight line of explaining BG value range. This subject had more sense of the color of the thumbs. And he also said: “Red means dangerous”.







2. He thought the result of the following screen is normal because the color of the number is black. He was more familiar with Thumb icons.



Conclusion

This subject has the basic idea about the math, so he could understand the line which explains the target range. Education does have influences in subjects’ cognitive level.

12 Design Improvements

After pre-user testing, several improvements are made to visualize the mobile UI. The help button is moved to the bottom right corner which is just above the big bottom button. Because together with the big bottom button is easier for users to notice there is a help button on the screen. The size of help button is increased to 62px * 62px and an introduction page of virtual helper will be shown to the first-time user at the beginning. In additional, a clearer visualization of the BG value is designed as the Figure 15.

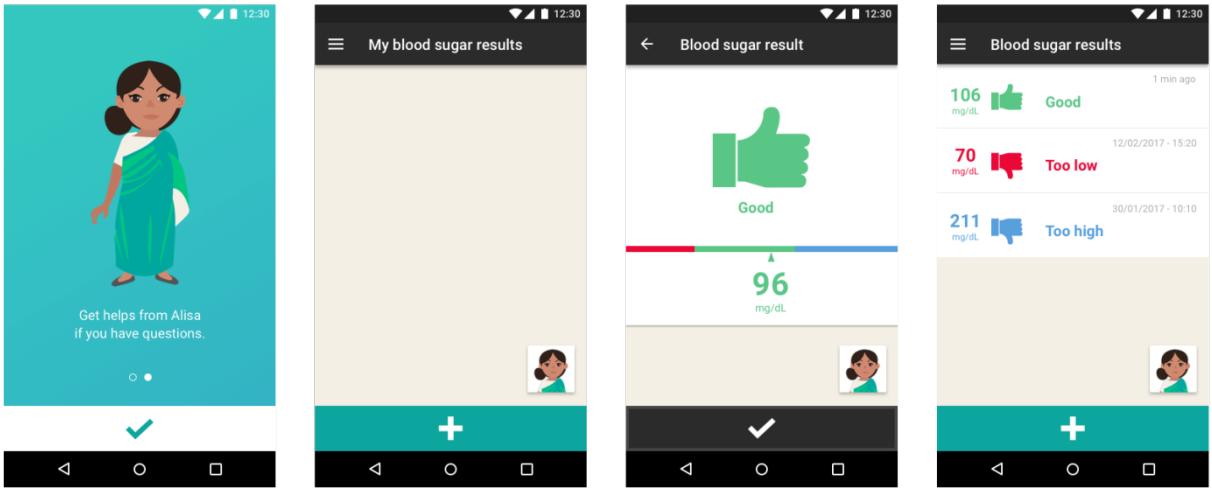


Figure 15 Samples of new design

Furthermore, in order to explore a better and clear visualization of BG results for low literacy people, certain UI designs displaying BG value are proposed as the Figure 16.

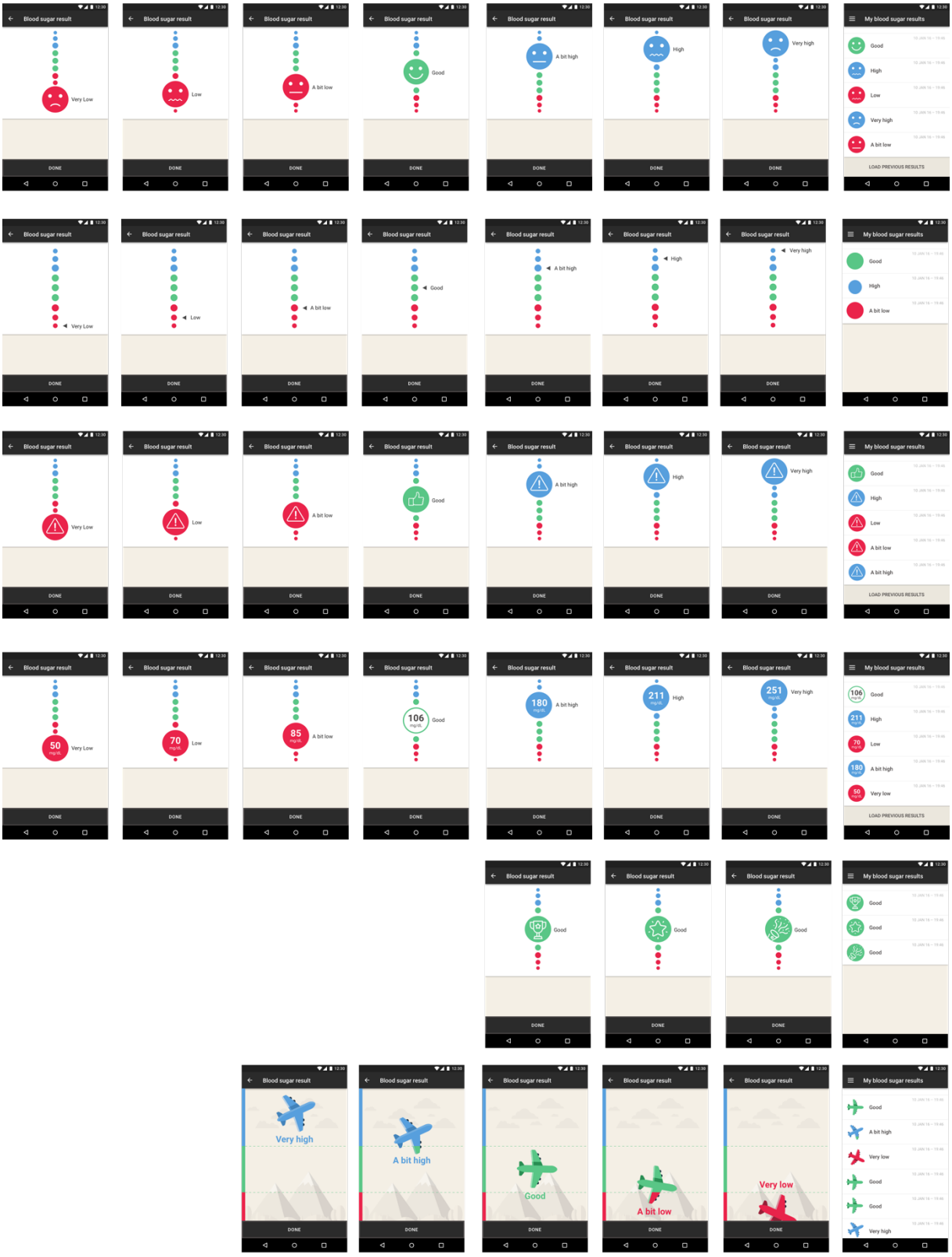


Figure 16 Different visualizations of BG value

Different characters of help button are proposed as Figure 17.

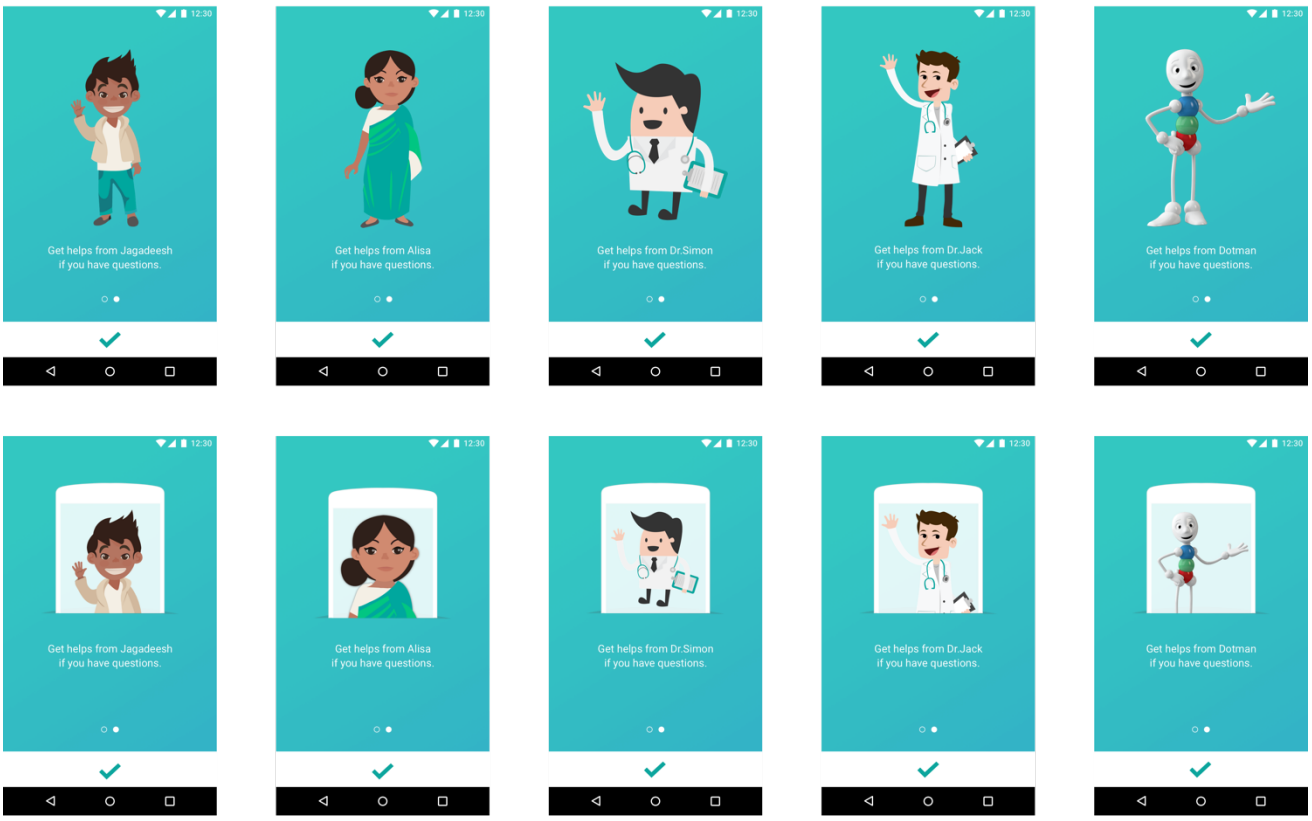


Figure 17 Characters of help buttons

13 Usability Testing in India

The user testing was conducted in Bangalore, south of India. Total 14 subjects attended this user testing.

Tapir Design
The Tapir design was made to be visual while trying to avoid text as much as possible as the Figure 18. Dotty is the virtual help character.

Kannada is the most common language in Bangalore. A significant number of people in Bangalore also speak English while the proportion of the population speaking Hindi is quite small. Considering the multiple languages in India, some Indian living in Bangalore may not speak Kannada if they come from other states, the video tutorial was shot separately in Kannada and English. If subjects are more comfortable with English, Tapir with English video would be used in the testing. On the other side, Tapir with Kannada video would be shown to subjects. The simple texts on the interface are English.

The audio output of the help button was recorded both in English and Kannada as well. The script of the audio output and the video caption is in the Appendix B.

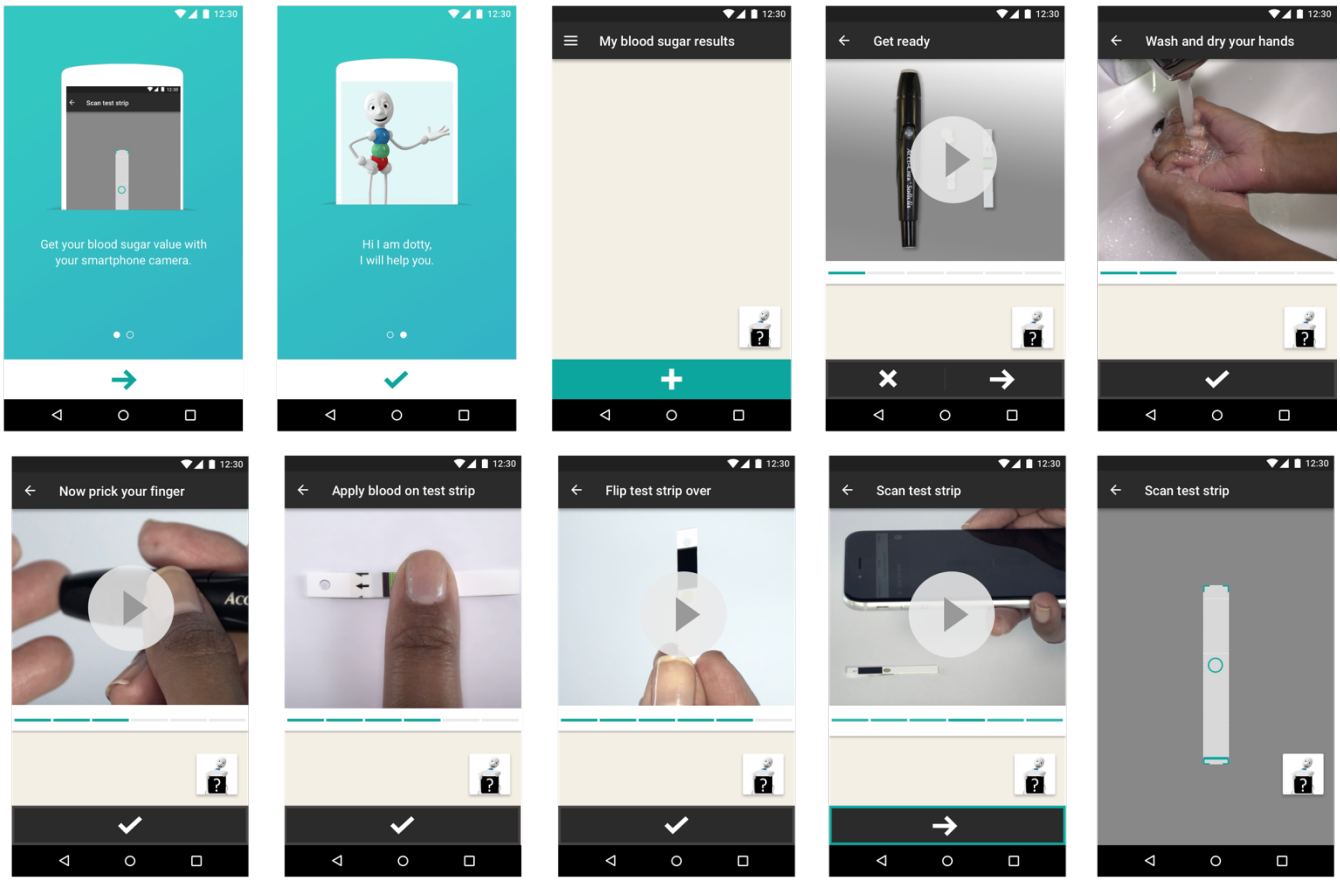


Figure 18 Tapir Design

13.1 Goal of evaluation

13.1.1 General goals

1) Evaluation of different design suggestions.
2) Evaluate whether the first-time users are able to use the app to measure their blood sugar.

13.1.2 Specific goals

1) Do subjects know they can start the video to see the tutorial?
2) Can subjects understand the video tutorial and learn how to measure their BG?
3) Which language do they prefer in the video instructions?
4) Do subjects see the simple text on the navigation bar? Do these texts help subjects to understand what the current state of the interface is and what they could do?
5) Do subjects understand the icon on the button?
6) Do subjects easily find the help button in its present location and visualization?
7) Which visualization of the help button is better understood and liked by the users?
8) Does the help button work if users have troubles in the current interface?
9) Do subjects understand the BG value as a number?
10) Will the graphical visualization of the BG value instead of a number easily be understood by subjects?
11) Which visualization of the BG value is easier for users to understand?
12) Do subjects see the suggestions provided by the app when their blood sugar is out of range?
13) Which presentation of suggestions is easier to be understood for subjects? Voice output or text output.

13.2 Subjects hire requirements

Number of subjects

Total 14 subjects were needed.

1) **10 subjects** in the user testing lab.
2) **4 subjects** at their home.

Timetable for the user testing

In the home visit, the researchers were divided into two groups. Each group visited two families and conducted the user testing at their home.

Time	05/06/2017 Monday			06/06/2017 Tuesday	07/06/2017 Wednesday		08/06/2017 Thursday
	Morning	12:00	14:00	Same as Monday	9:00	14:00	Same as Monday
Subjects	Preparation	1	1	4	1+1	1+1	4
Location	lab			lab	Subjects' home		lab

Time	09/06/2017 Friday		
	8:00	10:00	Afternoon
Subjects	1	1	Summary
Location	lab		

Table 7 Timetable of subjects attending

The main characters of subjects

1) **Indian people** diagnosed with T2D who are mixed between **newly diagnosed** and **long-time diagnosed**

The range of T2D diagnosed years is divided as,
<1 year; 2-3 years; 3-5 years; 5-10 years; >10 years

2) Therapy: Take tablets, or use insulin

3) No own blood glucose meter at home or limited/non-existed access to self-manage blood glucose

4) No university degree, rather only **primary school**.

5) Owns a smartphone with a camera or shares a smartphone within a family, mix between novice and experienced users.
   Novice users:
   a) No smartphone usage experience, for example, a family owns a smartphone while the Type 2 diabetics seldom use this smartphone.
   b) Experience with using smartphones but only for basic functions such as receiving and making calls.

Experienced users:
   c) Experience with using smartphones for complex functions such as sending text messages or using smartphone applications (Facebook, WhatsApp, etc.).

6) Mix between **ages of 30 and 65**

7) Mix between **female and male**

8) Can read simple English on app

Subjects hire summary

The information of the subjects should be gathered and recorded during the recruitment. The key characteristics of the subject's demographic profile are age, gender, occupation, level of education, income, diagnosis year of type 2 diabetes, diabetes knowledge, smartphone usage level. The data could be recorded in the subjects' information table attached in Appendix C. All these data are stored and gathered by Roche and will be kept strictly confidential. None identifying information on any participants will be included in any reports or publications.

13.3 Evaluation Methods

1) Observation of participants doing the tasks
2) Data collection and analysis from the experiment
3) Feedbacks gathering via interview

13.4 Experiment design

The two general goals of the user testing will be achieved from the experiment, observation, and interview. And specific goals will be achieved from different tasks in the experiment. Good design components for low literature people will be concluded from this user testing.

13.4.1 Tasks

Four tasks were given to each subject. The estimated time to complete the 4 tasks was 50 minutes.

1) Do a blood glucose measurement with control solution according to picture/video tutorial (20 minutes)
2) Let them make suggestions for how they would expect the result to look like (participatory design) (10 minutes)
3) Explain what they think about the BG value presented in different ways, numbers or graphics and ask for preferences. (10 minutes)
4) Search for the recommendations provided when the BG value is out of range. (10 minutes)

13.4.2 Experiment set-up

Lab

During 4 days, the user testing was conducted in the lab. Wireless data connection was available in the lab. In case the situation of poor internet connection, off-line prototype and real demo were prepared as well.

Before the experiment, subjects needed to sign a Tapir user testing consent form as the Appendix D. The process of experiment was video recorded (data was stored by Roche). Thus, it came to the props preparations.

a) Enough copies of the User Testing Agreement
b) 1 Video recorder + 1 Tripod
c) 1 Audio recorder
d) Tapir offline prototypes, paper mock up materials, real demo
e) 1 Camera
f) 3 SAMSUNG smartphones
g) 2 Lancing devices, a box of lancets and strips for measuring blood sugar, control solution

Subjects' home

It has high possibility that there is no wireless connection in subjects' home. Therefore, offline prototype and real demo which could be run on the smartphone were prepared.

The props preparations at subjects' home are the same as that used in Lab.

13.4.3 Experimental process

Welcome (3 minutes)

Subjects came in one by one according to Table 7 (subjects attending timetable). The interviewer first welcomed the subject and checked the "subject information table" (from subjects hiring) to verify the subject's ID. Then he briefly explained the scope of the project and the need to sign a consent form. The subjects signed the consent form.

Script

Thank you for participating in this study! The objective of this study is to learn about your opinion about a new product.

The study will proceed as follows: we first talk about your current diabetes and smartphone usage state. Then we discuss a new product concept, the prototype will be shown to you, and you need to complete 4 tasks related to this product and talk about your feedback of this product. The study will take about 1 hour 30 minutes in total.

The interview will be recorded. All the information you give to us is anonymized and we do not record your name. We do not want to sell you anything. Before starting, you need to sign a testing agreement document.

General interview (30 minutes)

At the beginning, subjects were invited for a general interview. Since it is a good chance for us to get access to real users face to face, the interviewer is expected to cover a broader range of questions.

- The purposes of general interview
    a) Gain an insight on diabetes of subjects, such as the level of diabetes knowledge, the state of self-management
    b) Get an insight on opinions about smartphone usage from the perspective of diabetics in India

According to the purposes of the interview, the questions are divided into two categories: 1) diabetes states related, 2) smartphone usage related. The questions are documented in Appendix E.

When the interviewer conducted the interview, he was allowed to explore the answers of the participants or ask other questions that might seem relevant in the context of what was being spoken about. The script below is a reference.

When starting the interview, the interviewer briefly explained the purpose of it towards participants. In addition, the interviewer should tell how long it would take (estimated 30 minutes). A voice recorder would be used for recording the answers.

Introduction of Tapir (2 minutes)

In order to help the subjects to grasp the general context, an introductory overview that explained the concept of Tapir was given to subjects. The overview format was a live, verbal explanation.

Script

Now I would like to show you a new concept of testing your sugar. The new product concept is a smartphone application. It works as a tool to measure your blood sugar value like a BGM. You can use this application to measure your blood sugar through scanning the strips with the smartphone camera. (This needs to be discussed with the local designers, maybe use the local language to explain)

Testing (50 minutes)
Once we were satisfied that our subjects understood the general idea of Tapir, we then told them the 4 tasks they needed to do in the scenarios, and asked them to speak loudly. The process of subjects' completing the tasks was video recorded.

1) Your family is worried about your diabetes and they want to know the current state of your diabetes. You want to tell them your blood sugar value and use the app to measure your blood sugar. But we don't use our blood, instead we use an artificial liquid (control solution) to simulate it (estimated 20 minutes)

   Smartphone (the app), lancing device, lancets, strips and control solution were on the table and were explained by the interviewer. The interviewer told the subjects that they could ask for a help if they met some troubles during the task. Subjects were encouraged to speak loudly what they thought about each screen.

   Task 1 is considered completed when the participant applies a drop of the control solution to the right side of the strip and successfully uses the app to scan the testing strip. **Time taken to achieve task 1 and whether task 1 completed or not were recorded.** The subjects' behaviors were observed and noted.

- **Prompts provided**
  As the goal is to explore the experience of first-time users, there is no training provided. The only assistance received is in form of prompts from the interviewer when the subjects appear to be stuck, make a mistake or ask for a help. The prompts provided are classified into **four categories** by the interviewer: simple encourage; remind to search a help button within the interface (if subjects cannot find the help button, experimenter press the help button for subjects); live spoken reminds of how to do the next step; Hand-holding (actually helping them to complete the task). A **general assistance score** will be computed as a weighted sum of the number of prompts in each of the four categories. The weights reflect the amount of help provided by a given type of prompt: 1 for simple encouragement, 2 for searching a help button, 3 for live spoken reminder, and 4 for a hand-holding intervention. With higher scores indicates more difficult in completing a task. **The number, types, and effect of prompts were recorded for each subject.**

  After finishing task 1, the interviewer explained task 2 to the subjects.

2) Before getting the result, how you would expect the result to look like? Could you please draw it on the paper or explain it orally? (10 minutes)

   Paper and pen were provided to subjects and their explanation was recorded.

3) You got the blood sugar value now, and want to explain it to your family. Different presentations of the blood sugar values will be shown to you, just tell us what you

think about them. What would you guess, what concrete value could be behind the image? What are values that are a bit high or high for you? What would you do if you get this result after a measurement? (estimated 10 minutes)

Total 21 screens with different blood sugar values were shown to the subjects one by one as the attachment F, simple number presentation and different visualizations. The interviewer told subject to speak loudly what they thought about the BG value when they first saw them. Was it too high, too low or normal and asked them why they thought so. Finally, series of different BG value visualization were shown to subjects together as the Figure 15. Subjects were asked to choose the one they favor.

The subjects' cognitive level and explanations of these screens with different blood sugar values were observed and recorded. Accuracy rate of the answer for BG value will be calculated.

4) Assured the result of your blood sugar is not good. Don't worry, you can get recommendations provided by the app. Different screens with suggestions will be shown to you, please tell us what you think about them and what your next action would be. (estimated 10 minutes)

   Different screens with various recommendations were shown to the subjects as can be seen in Figure 19. The format of the recommendations was text or audio output (through pressing a help button). The Interviewer told the subject to speak loudly what they thought about the different formats of suggestions when they first saw them.

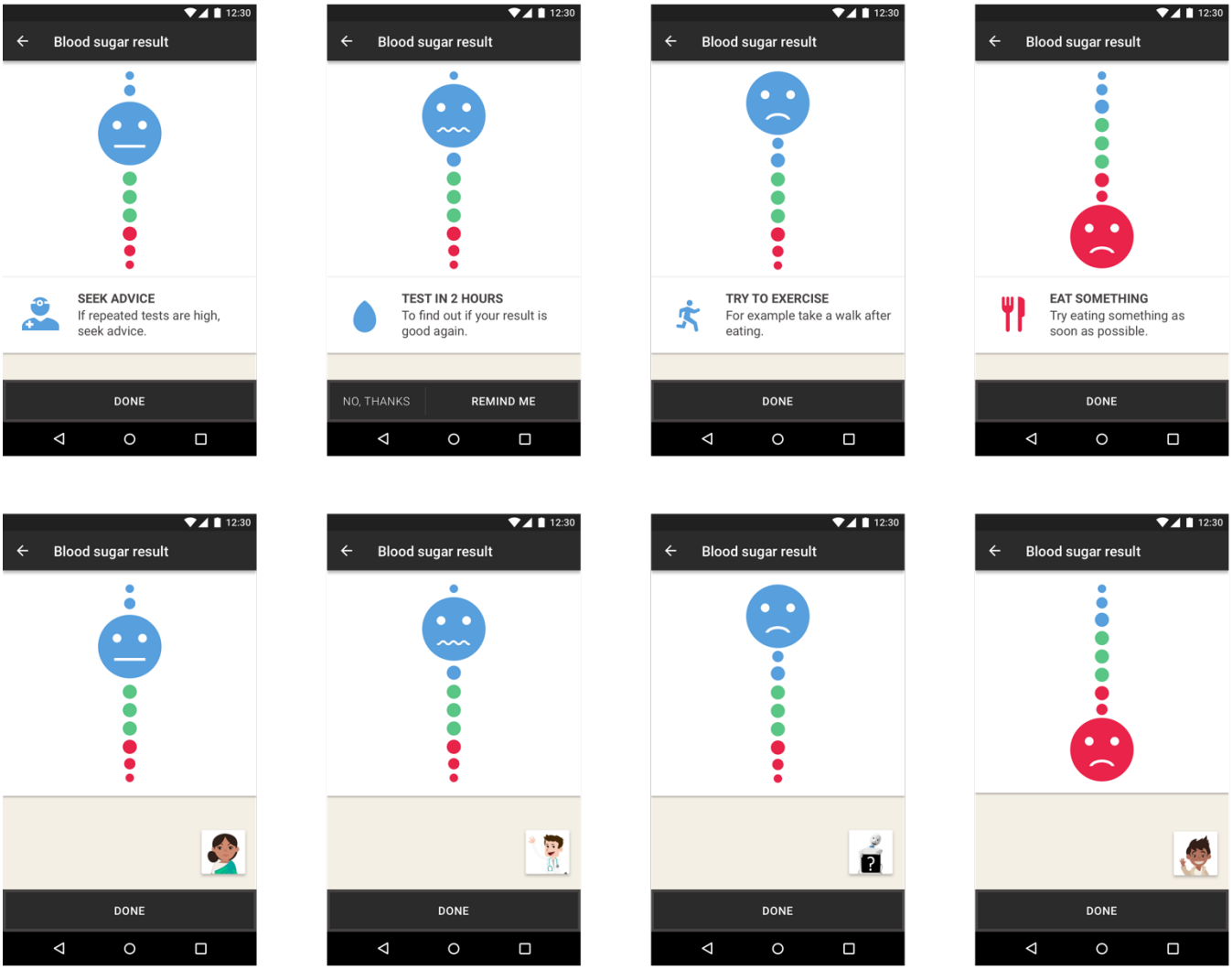


Figure 19 Different formats of comments

The characters of help button as the Figure 17 were also shown to subjects. Subjects were asked to choose their favorite character.

The purposes of tasks

The purpose of task 1 is to achieve the two general evaluation goals. The purpose of task 2, 3 and 4 is to realize specific goals, more focus on detail interaction components which also contribute to answering the general goals.

Data collections

Tables for data recorded, notes taken and UI related questions are displayed as Appendix G.

Thanks & Close (2 minutes)

The interviewer explained to the subjects that the study was finished and thanked them for their participation.

Script
We are at the end of the study now.
Do you have anything else that you want to tell or do you have any questions?

Thank you for your participation.

13.5 Testing Results

13.5.1 Part 1 -- General interview

Table 8 summarized the characters of participants according to their age, gender, education, diabetes diagnosed year, diabetes knowledge and smartphone usage experience. All the participants are type 2 diabetics. When the duration of smartphone usage is less than 1 year, the subjects are considered as novice smartphone users in this user testing.

Code	Age	Gender	Duration of diabetes	Education level	Smartphone usage experience	Diabetes knowledge	English level
1	42	M	6 months	Standard 4	7 months	Basic	None
2	32	F	1 year	Standard 6	1 year	Basic	Basic
3	50	F	3 years	Standard 4	4 months	Middle	None
4	34	M	4 months	Standard 8	1.5 years	Basic	Fluent
5	39	F	5 months	Standard 7	1 year	Basic	None
6	55	M	5 years	Standard 4	8 months	Middle	None
7	46	M	2 years	Standard 5	5 months	Middle	Basic
8	62	F	8 years	Standard 7	4 months	Advanced	None
9	42	M	4 years	Standard 8	2 years	Advanced	Middle
10	34	F	7 months	Standard 6	5 months	Middle	Middle
11	58	F	6 years	Standard 4	5 months	Middle	None
12	65	M	10 years	Standard 7	1 year	Advanced	Basic
13	46	F	1 year	Standard 8	2 years	Middle	Middle
14	38	M	3 months	Standard 7	1 year	Basic	Middle

Table 8 Group composition

The gender representation is 50% (7 Females) – 50% (7 Males) and the age range goes from 32 to 65. None of them owns a blood glucose meter at home and test blood sugar in a lab or public hospital. They go to doctors once every 3 months in average. The doctor suggested they should test their blood sugar once a month. The majority only takes tablets, few of them also take insulin. All of them are quite dependent on doctors for recommendations. They all respect doctors and strictly follow the doctor's suggestions. Most of the diabetes knowledge of subjects is from doctors. All the subjects go to the same doctor every time for treatment and have been going to the same doctor over a long period of time. They would buy medications in a medical shop nearby with doctor's prescription. All of them do not consider diabetes to be a social taboo and would like to tell friends and family. Their friends and family would provide supports to them. Some of them complained that the fee (medication and BG testing) spent on diabetes per month is a burden for them.

All of the participants indicated that they had a smartphone. 8 of them had their private smartphone and 6 of them shared one smartphone with their family. Housewives were not comfortable using smartphones. They mostly depend on other family members to use smartphones. 13 of them indicated that they had mobile data package in the smartphone. Only one subject did not have mobile data on her smartphone. The mobile data package was cheap and popular in Bangalore. The usage of data was not a concern, most of the users owned a JIO SIM card which provided 1GB data per day. Most of the subjects did not have WIFI at home and only used mobile data because mobile data was enough and there was no need to set up a WIFI at home.

Most of the subjects use their smartphone for calling. WhatsApp is the second popular purpose subjects use their smartphone. Some of them also use Facebook. None of them use a health-related App. They do not use any digital solutions (App) to manage their diabetes. Figure 19 presents the percentage of main purpose subjects use their smartphone.

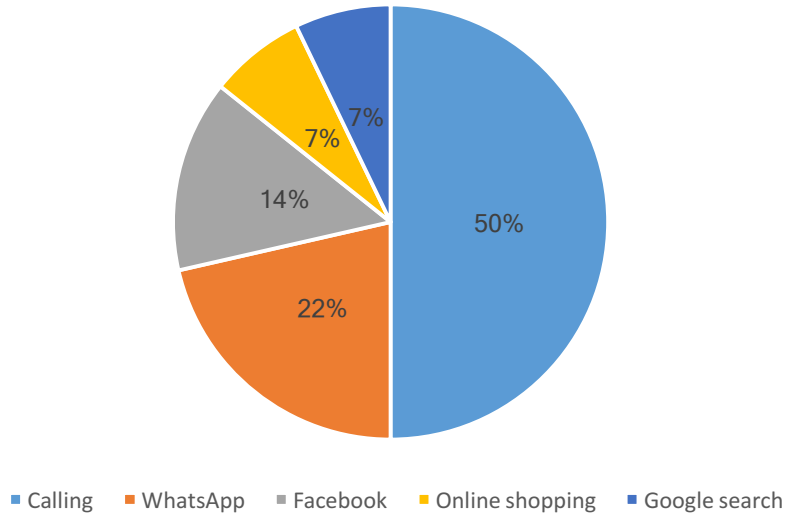


Figure 20 Representation of purpose subjects use their smartphone the most

13.5.2 Part 2 -- Experiments

Task 1 – first 8 subjects

5 of the first 8 subjects could complete the task 1, using Tapir to measure blood sugar with control solution. However, the subjects needed lots of prompts to complete the task 1 and it costs around 16 minutes in average. Table 9 presents the overall results of task 1.

Task Completion	Time Taken*	Mean weighted prompts score*
62.5%	16 minutes	28

**Averaged across subjects who completed the task*

Table 9 Task 1 results of the first 7 subjects

Overall performance

Most of the subjects did not have any problem with navigation. They knew how to go to the next page. The linear navigation was easy for them to understand. They understood the icon of "Continue" (right arrow) and "Done" (tick) and found them easily on the bottom of the screen. But 3 of them did not know how to go back to the previous page. Interviewer simply

encouraged them to find out the button of going back in the interface. 1 of them found the left arrow button on the left top corner of the screen. 2 of them cannot find the way for going back. Then we asked them to find the help button on the screen. Both of subjects found the help buttons (dotty character) on the screen, one pressed the help button and the other did not know he could press the help button (he pressed the help button after spoken remind from interviewer). The audio output from the help button guided the both subjects to find the button of going back successfully.

Only one subject, who was 62 years old and just owned a smartphone since 4 months, had problems with navigation. Even though she used WhatsApp as the main purpose of smartphone usage, she did not know how to start at the beginning. She did not notice the Continue Button on the bottom of the screen and she tried to press the smartphone picture on the first screen. She said, "The picture is the biggest one and catches my attention." After the spoken reminder of the interviewer, she found the continue button on the first screen. She also did not know how to start the video. She was not familiar with the video play button. The interviewer started the video for her and she could understand most of the video but she had the trouble with scanning. The strip could not be focused. Finally, she gave up trying.

5 of them noticed the video tutorial and pressed the video to watch. All of them understood the content of video and learnt how to use Tapir to test their blood sugar step by step according to the video. However, most of them watched at least 3 times of the "prick finger" video which was difficult for them to follow as the first-time user.

The majority preferred local language in video instructions even though for those who could speak and understand English.

In all, 5 of the first 8 subjects completed the task 1 successfully even though they required a few prompts and spent 16 minutes in average.

Main challenges subjects met during the task 1.
2 subjects did not notice the video tutorial on the screen. They kept pressing the "Done" button to the next page. When it came to the scan screen, users did not have ideas why and how to scan the strip. They did not get the concept of Tapir and how to use it to measure BG. Interviewer encouraged them to go back to the first screen and look for the video tutorial. Both subjects found the video and pressed to watch the video. One subject did not know how to pause and restart the video. He went back to the previous page then went to the next page again to restart the video. After watching video, both of them got the idea of how to use Tapir to measure their blood sugar. We found subjects with advanced smartphone usage experience would tend to miss the video. They found the button easily and went to next page continuously even though they did not get the idea of this app.

Most of the subjects did not notice the green progress bar below the video. Some subjects noticed the progress bar and tended to press it for navigating to the next step. While it did not work, they found the tick button on the bottom of the screen. Most of the subjects did not understand that the instructions needed to be followed by an action. They would tend to watch all the video tutorials at first and only took action after the spoken remind of the interviewer.

2 subjects applied blood to the wrong side of the testing strip which caused the failure of task 1. The script of the video narrator is 'Now apply the blood to the green area on the test strip and press DONE'. Since there is a green small dot on the wrong side of the strip as well, subjects did not notice the picture display the right side of strip with a big green area in the

video and only listened to the audio narrator. They applied the control solution to the small green dot on the wrong side of the strip. Therefor in the scanning phase, the camera could not realize the test strip which caused BG value could not be displayed on the screen either.

2 subjects did not notice they should flip the test strip after applying blood to the test strip (The fact is the camera should scan the other side of the test strip instead of the side applied blood) even though they applied the blood to the right side of the strip. Thus, they had some troubles in the scanning screen. After interviewer spoken remind, they went back to the scanning strip video tutorial and watched it several times and noticed the right strip side scanned. Finally, they flipped the test strip.

Figure 21 Green progress bar & small green dot & green area for applying blood

All of the subjects had troubles when scanning the strip to gain the BG value. They all watched the scanning video above twice. The main difficulties included not holding the smartphone in parallel to the test strip. Most of them held the smartphone slantwise so that the test strip could not be fitted the frame of the screen. After the interviewer's spoken remind, they held the smartphone in parallel but the smartphone was too close to the test strip. The strip still did not fit the frame on the screen. 3 subjects completed the scanning with the hand-holding help of interviewer. 2 subjects achieved the scanning with the help of interviewer's spoken remind (hold the smartphone higher). The problem was subjects did not get the idea that the test strip should fit the frame of the screen. And they found it was hard to fit the test strip to the frame.

Figure 22 User testing in the lab[1]

Figure 23 User testing at subject's home[2]

Design Improvements

After synthesizing the difficulties, the first 7 subjects met during the task 1, we improved the design of the screens "Apply blood on test strip", "Flip test strip over", "Scan test strip" and "Camera scan".

Figure 24 shows the new design of the screen "Apply blood on test strip". The green area of the test strip was clearer and more visible in the new video tutorial. The finger hid the green area in the old design which may lead subjects the small green dot was the "green area".

The video on the screen "Flip test strip over" was improved. The last screen was zoomed out which displayed the side of strip scanned more clearly.

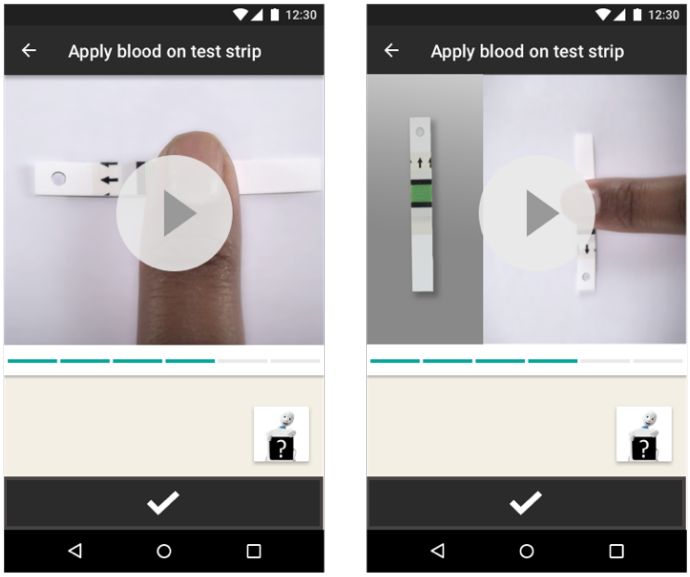


Figure 24 Apply blood screen (old vs new)

[1,2] The pictures are owned by Roche and only used in the report

The video on the screen “Scan test strip” was reshot. The video narrator was changed to ‘If press the Continue Button below, you will see a frame on the screen. Focus the camera on the test strip, and move the smartphone to a proper height so that the test strip will fit the frame.’ The new video emphasized that smartphone should be held in parallel to the test strip and should be moved to a proper height.

In the camera scan screen, automatically audio reminds were added. The scripts of the audio remind were, ‘Please hold your smartphone in parallel to the test strip’ ‘Maybe you could hold the smartphone a bit of higher’ ‘Maybe you could move the smartphone a bit of lower’. For example, if users hold the smartphone in parallel but too low, an audio remind of moving smartphone higher will play automatically. A new screen design of camera scan was proposed as well which aimed at guiding users to understand the test strip should fit the frame on the screen when scan. The screen improved can be seen as the Figure 25. Instead of the normal scanning frame, a realistic test strip was used as the frame when the camera starts. A realistic test strip was more noticeable for users which may help them understand the test strip should fit the frame.

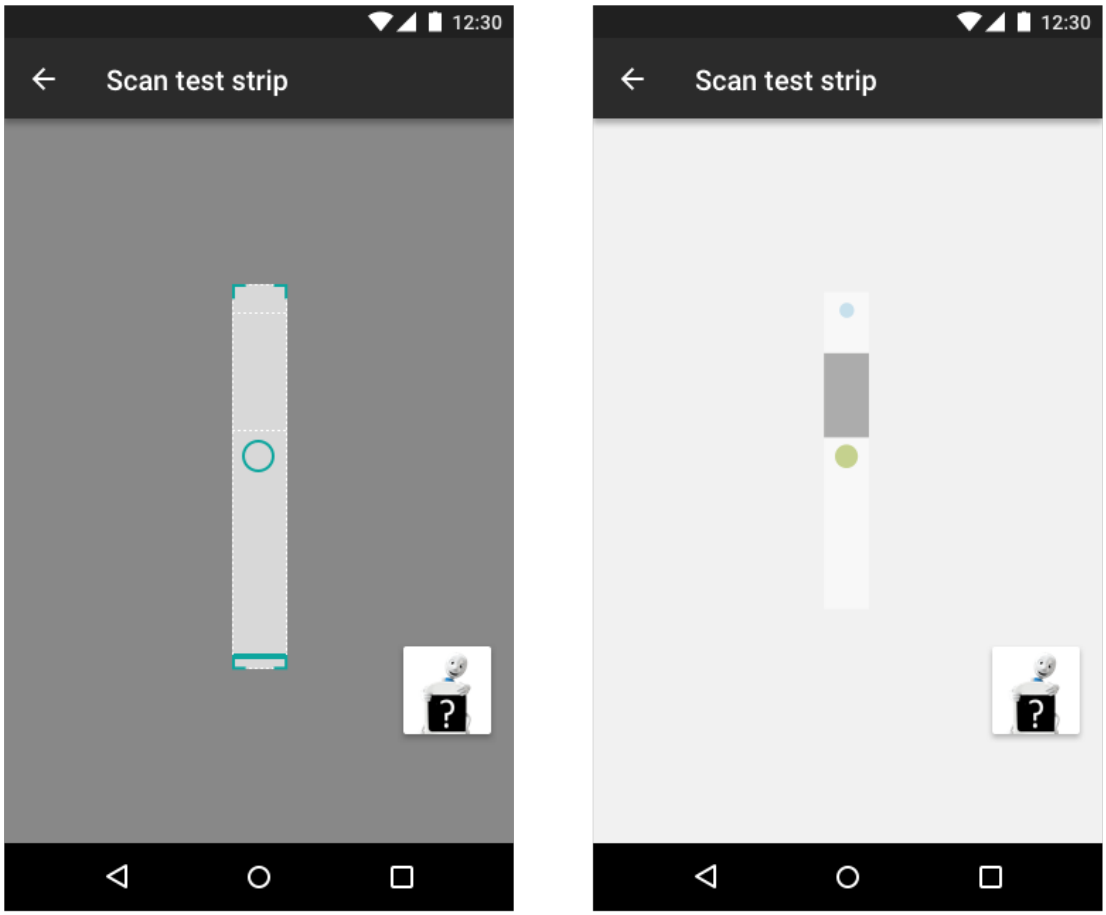


Figure 25 Camera screen (old vs new)

Task 1 – last 6 subjects

The last 6 subjects were tested with the improved design of Tapir. The overall results of task 1 are seen as the Table 10. After applying new design, all of the subjects could complete the task 1, both completion time taken and mean weighted prompts score decrease. They spent 13 minutes in average to finish the task 1.

Task completion	Time Taken*	Mean weighted prompts score*
100%	13 minutes	20

**Averaged across subjects who completed the task*

Table 10 Overall results of task 1 with design improved

Overall performance

All subjects applied blood to the correct area of the test strip with the improved "Apply blood" screen. The green area of the strip in the video was much clearer than the original one which guided subjects to find the right area of the strip to apply blood.

5 subjects flipped the strip correctly and put the strip on the table. Only 1 subject did not flip the strip because he first watched all the video tutorials then start to measure BG. He forgot to flip the strip. During the scanning, he could not get the BG value even though the hand gesture of holding smartphone was correct. In that case, interviewer reminded him to flip the strip. After that, he scanned the strip successfully.

When it came to the scan phase, with the new video tutorial of scanning test strip, 6 subjects all held the smartphone in parallel to the test strip at the beginning. They got the idea that they needed to hold the smartphone in parallel. 5 of them held the smartphone too close to the strip at first and had trouble with fitting strip to the frame. An audio played automatically (move smartphone higher) in that situation, it worked for all the 5 subjects. These 5 subjects scanned successfully with 2.8 automatic audio reminds in average. The other subject understood the video tutorial better and achieved the scanning successfully with 1 audio reminding. The realistic strip frame helped the last 6 subjects focus strip much quicker than the first 8 subjects which also helped decrease the time of completing task 1.

Task 2

India is a colorful country. Subjects liked to use various colors to present different BG values. Several BG value visualizations could be seen as the Figure 26.

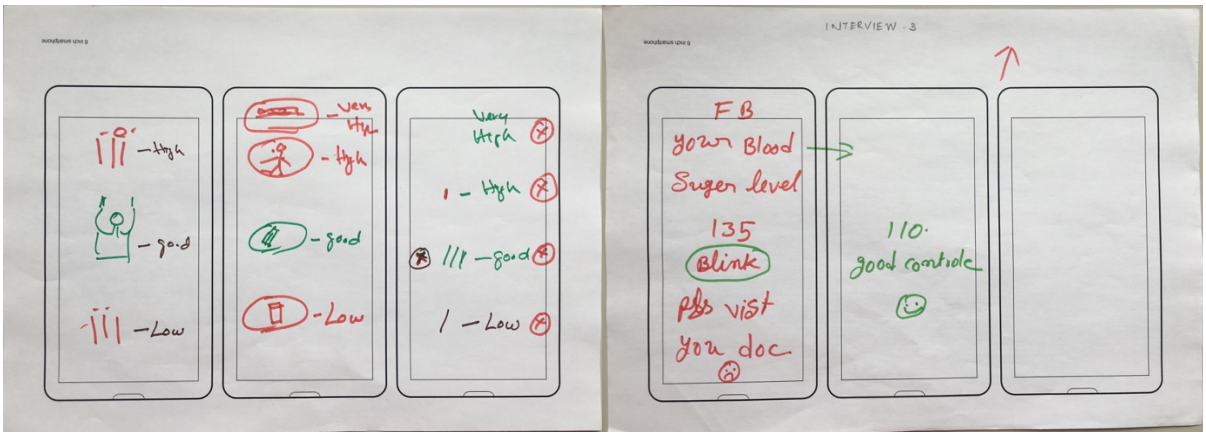


Figure 26 Samples of BG value visualizations drawn by subjects

Most of the subjects preferred to use the number to present BG value which was similar to the results they got from the BG testing in the lab. The knowledge about number varied among the subjects. Some perceived 220 mg/dL as a good BG result while some perceived 220 mg/dL too high. All subjects used green to present normal BG results and red was the symbol of a too high result. Blue, purple, orange, and yellow were used to present too low BG results. 3 subjects suggested that corresponding recommendations would display below the BG result.

Task 3

The accuracy rate of the answer for BG value is 78.3% in average among 14 subjects. A few subjects did not understand the mixed BG range and BG results initially. They judged the BG results mainly through the icon and the text beside the icon. When they did not understand the icon, most of their answers were wrong. As the icons display in Figure 27, most of the subjects did not understand the icons and felt confused. Even though a few of them understood the text beside the icons, the answers were wrong either. Because confused icons would inhibit them to look at the text. All of the subjects did not understand the warning symbol. The general feeling was that it was indicating direction.

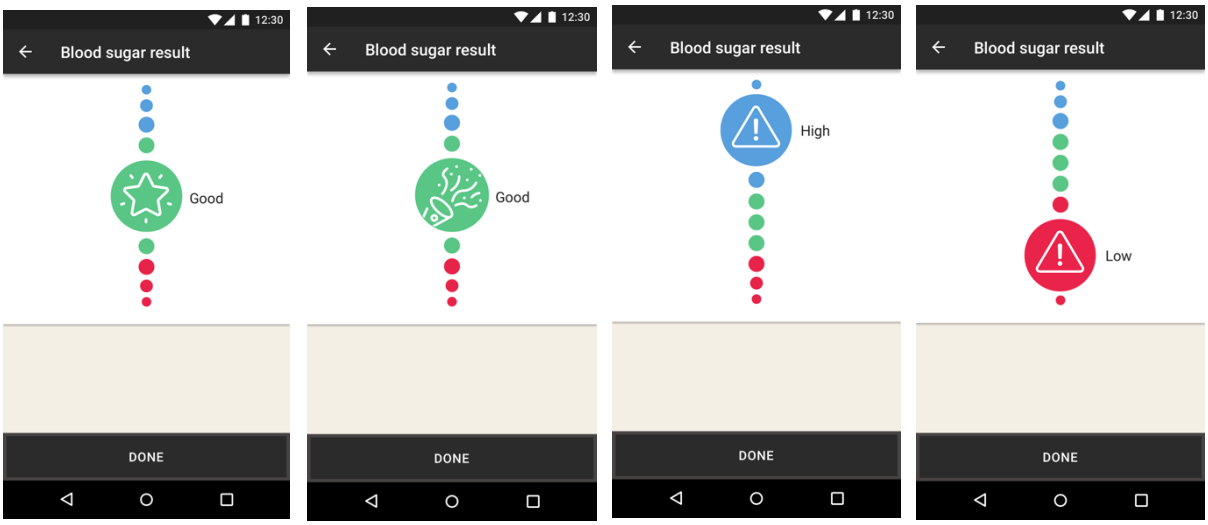


Figure 27 Icons hard to understand

After displaying 6 to 7 screens, most of the subjects got the idea of BG range dots gradually, but all of them thought the red color was too high and blue color was too low. From the designer's perspective, low BG values are more dangerous to the user in the short term, because they can become unconscious. High values are more dangerous in the long term because they can cause health problems like eye diseases. However, people with T2D who don't use insulin hardly ever experience low values, that's why they think high values are more critical and should therefore be red.

All subjects understood smileys and thumb up icon. However, most of the subjects got upset when the result was not in the normal range with the unhappy expressions. In general, the subjects who had knowledge about BG number would prefer "number" for result values and display in the range. They wanted the range & actual values to be displayed because it was serious and similar to the results they got from the hospital. For those who did not have clear ideas about BG number, they preferred smileys plus number and airplane graphic. Most subjects could understand the airplane even though without the text and smiled at it. Most of the users preferred trophy visualization for maintaining consistent good results. They thought it interesting if they could collect different icons for good BG results.

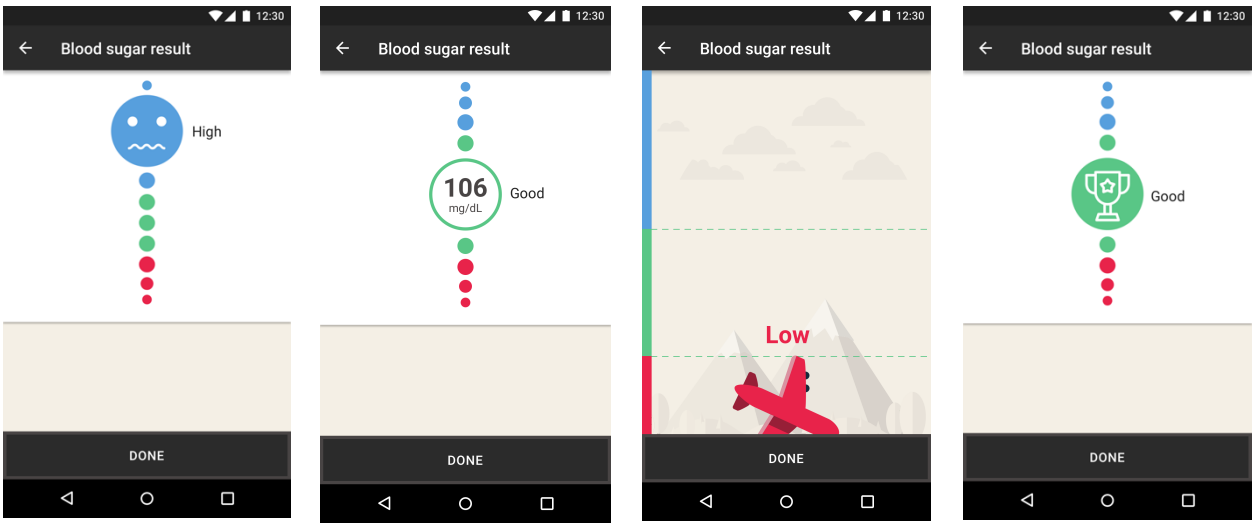
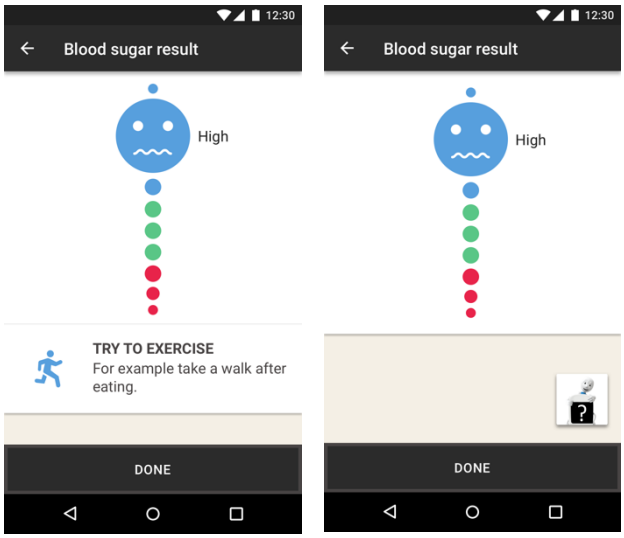


Figure 28 unhappy expression, number for results, airplane graphic, trophy visualization

Figure 29 Pictures taken when subjects were doing task 3

Task 4

When asked to search for the recommendations provided by Tapir, all subjects found the text below the BG result and guessed that this was the recommendation. For those who only spoke Kannada and did not know English, they did not understand the recommendations. For those who had basic knowledge about English, their answers were based on the key word, for instance, “exercise”. But a few of them still required the help of interviewer to explain the recommendation. When they got the concept of the recommendation, most of them commented that it would help people to grow knowledge and were willing to act according to the recommendation.



For the dotty version, all subjects had problems to find the recommendations. After the spoken reminder of the interviewer (search for the help button on the screen), most of them found the dotty button and pressed the button with interviewer’s encouragement. With the format of audio recommendation, subjects could understand it. However, the hidden audio recommendations were hard to be found initially. They did not know if pressed the dotty button, an audio recommendation would play.

Design improvements for recommendations

In terms of the content of recommendations: 1) action-oriented recommendations should be provided, for example, go to the doctor if test results are consistently high. 2) text should be clear, as simple as possible and reassuring while providing recommendations, e.g. do not worry! Visit a doctor, he would help you.

From the perspective of the format: 1) have an audio play icon beside the text, subjects could press the audio icon to explain the text. 2) have a doctor picture to provide recommendations because all subjects sincerely trust in doctor. 3) provide some reassuring graphics in recommendations if results are abnormal.

Character preference
All the subjects preferred the doctor as it meant that help and recommendations were coming from a professional. Most of the subjects could not recognize Dotty (robot) and connect with it. All the subjects thought Jagadeesh was a family member or a friend and said they would not take recommendations from a family member for something serious like diabetes. Most of the subjects took Alisa as mom or their wife. They would receive help from Alisa but would not receive recommendations for diabetes from her.

In India, people sincerely trust doctors, listen and follow doctor's suggestions strictly, thus doctor should be chosen as the help character in Tapir.

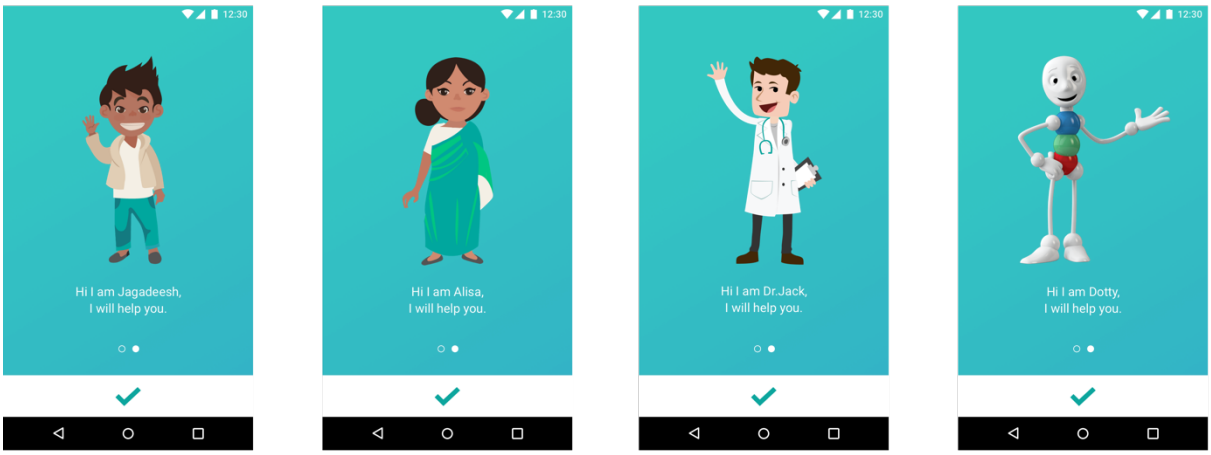


Figure 30 Help characters

13.6 Conclusion of user testing

13.6.1 General goals

Video, audio output and realistic visualization plus simple text (no terminology) are good design components for low-literacy people. Right arrow icon (Continue button) and tick icon (Done button) were understandable for low-literacy people in India which indicated these two icons are universal as well in India.

With the improved UI design, all of the first-time users were able to use Tapir to measure their blood sugar. Realistic visualization was easier for subjects to understand and interact.

13.6.2 Specific goals

Most of the subjects knew they could start the video to see the tutorials, 3 subjects did not know how to start the video. The play button is the standard icon used in the Android platform. Maybe the play button could be more prominent so that users notice there is a video and that it is clickable. Many subjects strained their eyes to see the video since they could not see very clearly (far to the camera when the recording was done). Most of the subjects aged above 40 had eyesight issues as well. Maybe the video should be shot with closer focus on the steps.

Most of the subjects could understand the content of the video and learnt how to measure their BG via Tapir. 1 subject commented that "the video is a bit fast to follow and it is better that

the video narrator is slower." Most of the subjects prefer the local language (Kannada) thus, local language option should be provided for all video instructions and audio help.

None of the users noticed the text on the navigation bar. It was not helpful for them to understand the current state. They got the information mainly from the video. They could understand the icon on the button and did not have difficulties with navigation. It was not easy for them to find the help button in its present localization and visualization. Most of them ignored the help button and did not know it was clickable. Only with the spoken remind of interviewer – asked them to find the help button, subjects would notice the help button. And most of them required encouragement to press the help button.

When users had troubles in the current interface, they did not know they could ask for a help from the app. Only after spoken remind, they would search for the help button negatively. In general, the help button did not work well.

Some subjects with advanced knowledge of diabetes understood the BG value as a number well while the graphical visualization of the BG value was easier understood by subjects who only had basic knowledge of diabetes. They liked smileys plus a number most and the airplane graphic was the second favorite one. Smileys' visualization was easier for them to understand. If plus number, it also could help educate users the number of BG value.

The audio output of recommendation was easier to be understood, however, none of the subjects knew they needed to press the dotty help button to gain the audio recommendation. The improvement could be the combination of graphic, text and audio explanation which could be more noticeable for users.

13.6.3 Value validation of Tapir

Most of the subjects were happy with Tapir and were willing to use Tapir to measure their BG at home because it cost 60 rupees if they went to test BG in the lab. And one strip only cost 15 rupees. It saved money and time for them. Additionally, the data was stored in the smartphone which was convenient for the doctor to check. One subject said, "I would like to use Tapir because the BG value is stored in the smartphone and I could show it to the doctor."

14 Context Support

We organized a doctor meeting, went to the public hospital, private clinic, pharmacy and retails as well during the visit in Bangalore. It helped us gain the overview of the healthcare system, relationship between doctor and patients, and how patients bought their medicine in India. From the perspective of urban society and economics, it also proved the value of Tapir and the strong motivation of the target group.

14.1 Doctors meeting

We invited 7 doctors to the meeting in the hotel. Key points from doctors were summarized as the following. It proved the value of Tapir from doctors' perspective. And if doctors recommend patients to use Tapir, most of patients would follow doctor's suggestion since patients in India sincerely trust in doctors.

- Doctors will recommend Tapir to their patients only when it has been proven that the testing is accurate
- 4 out of 7 doctors thought Tapir concept would help them treat their patients with T2D.
- All the doctors feel that Tapir will help patients in managing their Diabetes better.

14.2 Hospital visits

From a doctor interview in a private clinic, we learned that he often communicated with diabetes patients through WhatsApp. Patients send the blood sugar results to the doctor via WhatsApp. They may write down the BG value on the paper and send a picture or type manually in WhatsApp. Three doctors visited in the public hospital also indicated that they would communicate with patients through WhatsApp. Patients like to send the BG results and consult from doctors through WhatsApp. Doctors also indicated that most of their patients had smartphones. One doctor said "at least one smartphone in a family." In the public hospital visit, we also saw that many patients were looking at their smartphones while waiting. If patients used Tapir to measure their blood sugar, the results would be stored automatically. They could send the digital data to the doctor through WhatsApp directly and there would be no need to write them down on the paper or type manually. Doctors also mentioned that there was no intermediary person who could educate patients about diabetes. All knowledge about diabetes of patients is from the doctor. Patients do not trust nurses and nurses are not allowed to educate patients either because they are not qualified. Therefore, doctors are super busy and they indicated that if the app had educational function, it would be better.

Figure 31 Doctor meeting & Doctor interview in private clinic & Public hospital visit

14.3 Pharmacy visits

There are various small pharmacies or retailers in Bangalore. Patients like to buy medicine in a pharmacy nearby. They also go to the lab nearby to test their BG. The frequency for them to the hospital is low due to the terrible traffic. We visited 10 pharmacies in Bangalore. All of the shop owners indicated that the strip was affordable for everyone even for those who had lower income. One strip costs 15 rupees and one BG meter costs 1599 rupees. “The price of BG meter may be unaffordable for poor income class while the strip is affordable for everyone,” one shop owner said. We also got the language clues from pharmacy visits: since India is a country with multiple languages, the customers who came to the pharmacy may speak English, Kannada, Hindi or other Indian languages. But all of the customers at least knew simple English. They could read some simple English even though they could not speak. The pharmacists also explain their customers how they need to use the BG meter and lancet. If they do this with the Tapir app as well, this might help low-literate people to better understand Tapir and use it.

Figure 32 Pharmacy visits

14.4 Mobile data

Compared to Europe, the difference of mobile data package in India is that people could get access to 1 GB mobile data with a cheap price. JIO is a quite popular mobile signal company in India. Users could get access to unlimited mobile data for free in the first 6 months by using JIO SIM card. Tons of advertisement of mobile data could be seen on the streets in Bangalore. There is no any issue in using mobile data in Bangalore. Almost everyone could get access to the mobile data and it is affordable. The advertisement of smartphone can be seen everywhere as well in Bangalore. The smartphone users in India will keep increasing in the future.

Figure 33 Mobile data package advertisement

In all, the context in Bangalore supports the value of Tapir in terms of the society and economics. Infrastructure in Bangalore allows people get access to the smartphone and the internet easily. Lower income patients have strong motivation to use Tapir since it helps them save money and time. And most low-literacy people have lower income according to the interviews with subjects. Therefore, Tapir could bring value to low-literacy people with T2D.

15 Conclusion

15.1 Validation of expanded model

We designed the UI of Tapir based on the expanded model which was tailored for low-literacy people in India as the Figure 9. The expanded model was summarized from the previous design guideline for low-literacy people. Through the user testing in Bangalore, most parts of the expanded model which were applied to the Tapir UI design was verified and some of them need to be improved. The conclusion is as the following,

- The logic structure of the expanded model fits the reality of India. It provides general clues to designers when starting to design a digital product.
- The linear navigation is easy for low-literacy users to understand as the model suggested, turn single user task into linear navigation.
- None of them found the navigation drawer on the navigation bar (other functions were hidden in the navigation menu). Single function is preferred in the app. If there is more than one user task, it is better to turn tasks into several apps instead of splitting the tasks into separate tracks via navigation drawer.
- It does not help when applying BACK, HELP button with the same visualization and location on each screen. Subjects did not notice back and help button initially and they only knew them after the encouragement of interviewer. Maybe the visualization and location of the help or back button should be improved. But the function of them is not sure.
- It helps to apply continuity in design, for instance, the Continue Button is on the same position and has the same size. Most subjects found the continue button easily and did not have difficulty in navigation.
- It is better to use text as little as possible and use realistic graphics. Realistic graphics help low-literacy users understand better. But some simple texts also help low-literacy people to understand the current state of the screen. For instance, they could understand “Good” “Low” “High” in the BG results page. Terminology should be avoided in the app.
- Video and audio output worked well in the user testing. Low-literacy users could understand video and audio easily. The video should be shot slowly and with real people. More realistic, the better they could understand.
- Common UI visual language should be combined with user preference and cultural background. The warning symbol is universal in western countries but it is not understood by Indian users in this study.
- Local language support was verified as well in the user testing. Subjects prefer Kannada (their native language).
- For users who have lower autonomy, nurse or staff in pharmacy could teach users how to use Tapir. Support module is verified as well.

Therefore, one output of this thesis project is the expanded model which was tailored for low-literacy people in India. The modified version from the user testing is in the Appendix H. This model is verified in Indian urban context.

15.2 Tapir design for low-literacy type 2 diabetics

Another output of this thesis project is Tapir app. The modified version of Tapir can be seen in Figure 34.

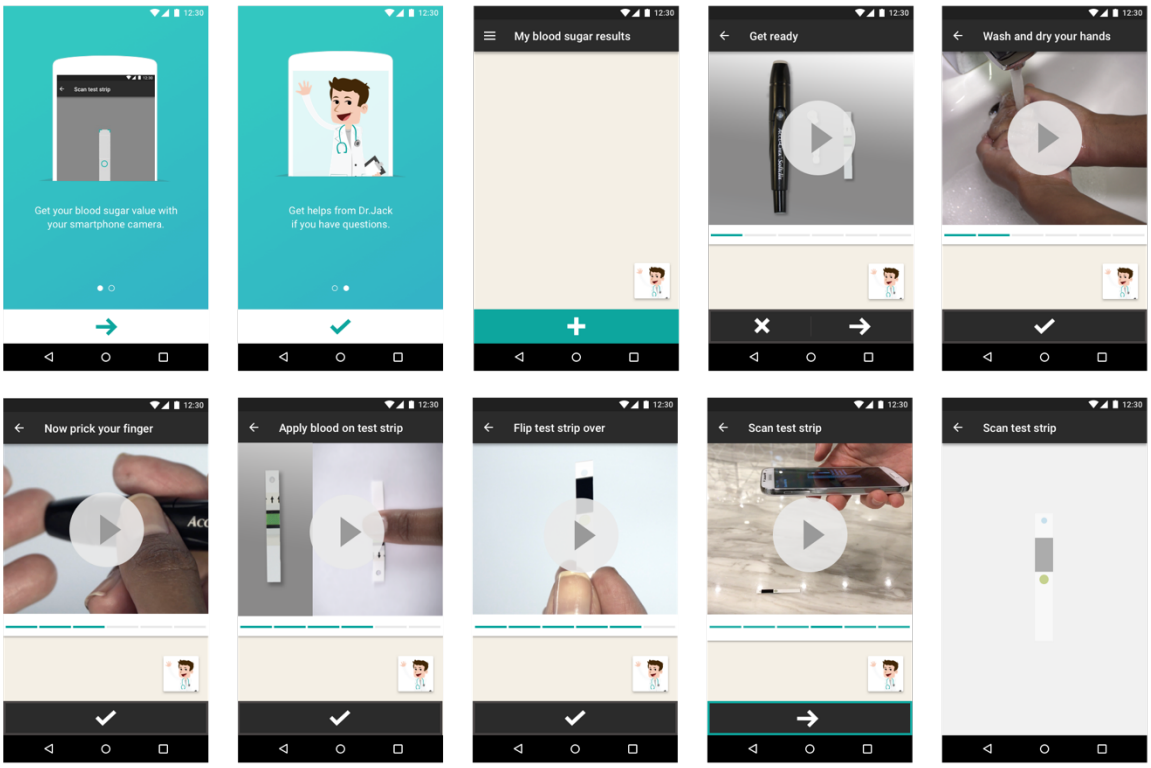


Figure 34 Modified Tapir version validated among the last 6 subjects

The value of Tapir was verified in the user testing and context research in Bangalore, India. As for the usability of Tapir, we found some problems, then improved and tested it among the last 6 subjects. The improved version of Tapir is seen as the Figure 34. Comparing the testing outcomes of first 7 subjects and last 6 subjects, we can see with improved version of Tapir, all subjects could measure their blood sugar via Tapir successfully and both completion time taken and mean weighted prompts score decreased. Through the experiments with last 6 subjects, the usability of modified Tapir version is validated to be better than the original version.

Considering other problems, for example a few subjects did not notice there were videos in the screens and most of them did not understand they should act according to the video tutorial in parallel step by step. After this user testing, an improved version of Tapir was proposed as the Figure 35. The help character was changed to the doctor but no better idea was proposed for the position and visualization. The shadow of the help button was increased to make it more noticeable and clickable. The color of the play button was changed to the primary color of this app which aimed at increasing the notability of the video tutorials. Additionally, we made the progress bar bigger and a tick mark was added. The tick mark indicated “Done” which aimed at helping users understand they should act according to the video tutorial in parallel. When they finished the task on last screen, a tick mark would appear in the next screen.

Considering the feedbacks gathered from task 3, explain what they think about the BG value presented in different ways, the design improvements could be seen as Figure 36. New face expressions were proposed because subjects indicated that face expressions for high or low BG deliver negative emotions to them. The unhappy face was replaced with a surprised expression. Since subjects prefer an appropriate number indicating BG result, the target range

is display on the screen. The BG is low when it is under 70 while it is high when the number is above 130. Since most of the subjects did not gain the current state from the navigation bar and ignore it. The color of navigation bar was changed to the corresponding BG result color and the text of navigation bar shows the BG result which aims at being more noticeable by users. The recommendations were display as text which could be noticeable by users. If they do not understand the text, the voice icon left could be pressed to explain the recommendations. But we are not sure if users will notice the voice icon and press it or not.

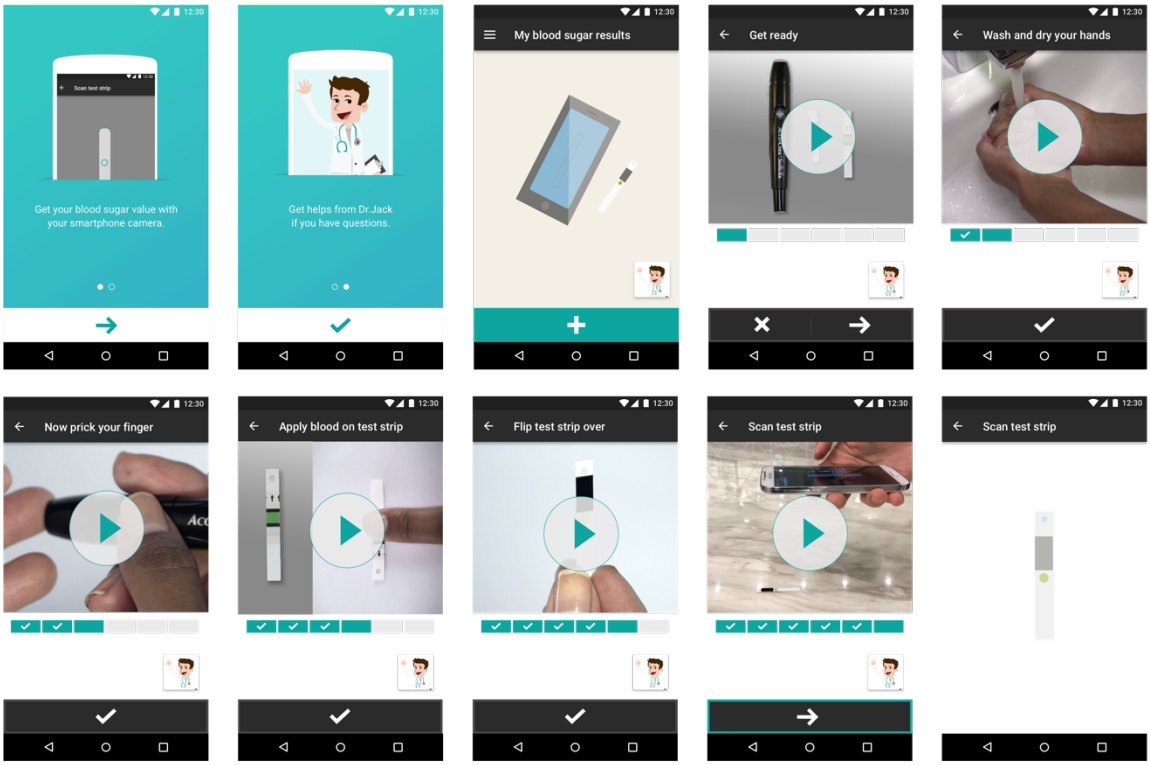


Figure 35 Improved version of Tapir

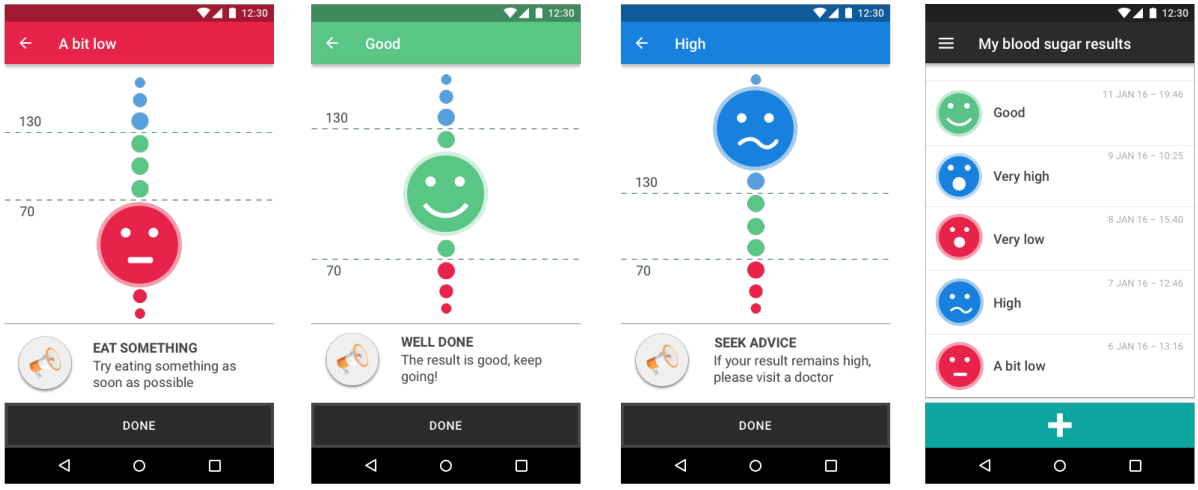


Figure 36 BG visualization improved

15.3 Recommendations concluded from this study

The expanded model verified from this study could be used as a general guideline for designers when they design mobile apps for low-literacy people. However, this model just provides a general overview to conduct an app design. For instance, realistic visualization is better understood by low-literacy users. But how to design the realistic graphic and which visual language should be used depends on different situations. A better solution recommended is to conduct participant design and always coordinate with the target users during the process. We always can learn a lot from the user testing. Observe users' reaction and synthesize their errors could help create right UI visualization.

Multiple interactions also help, such as video and audio output. The recommendations of shooting the video and recording audio better would be: 1) the video should be shot clearly and slowly. 2) Taking local conditions into account, users' familiar conversation should be applied. 3) Improved video and audio design through user testing.

In general, agile design is recommended. When designing a mobile app for low-literacy people, involving the target group during the process is quite important. Because when users are low literate, the UI design is heavily dependent on visual language and media interaction, which requires local context and users' feedbacks to get it right. Thus, agile design is a good option. It means to test with real users and gain feedback quickly. Analyzing feedback and apply it to improve design then test it again.

15.4 Research questions

When taking Indian context research, user testing, doctors interviews, the hospital and pharmacy visits into account, we form a conclusion to answer the research questions. First the sub-questions:

1. Language barrier: various local language in India; No standard for local font and alphabet; diverse presentation of the alphabet in the keypad.
   How to define the graphical components in user interface which can be easily interpreted and used by low (semi)-literacy people?

   Realistic visualization is better understood by low-literacy people. Actively coordinate with target users and conduct user testing is beneficial for detail visual design.

2. Novice users: have no or few experience with applications on the smartphone, simply use a smartphone to make or receive a phone call.
   How to design the navigation structure which is understandable for novice users and what types of navigation tree is appropriate for low (semi)-literacy people?

   Linear navigation is verified to be a better option for low-literacy people. They could understand linear navigation easily.

3. People who lack of knowledge of diabetes: do not understand diabetes well, such as blood sugar testing, have no idea about the normal range of blood sugar, and do not know how to manage their diabetes in daily life properly.
   How to present the mobile interface which can interpret the disease well to low (semi)-literacy people?

   Using analogies to talk about illness will be better understood by low-literacy people,

such as the airplane graphic used in Tapir to explain the BG results. Terminology should be avoided when explain the illness. Taking local conversation into account, use sugar instead of glucose.

4. Culture differences: people in India have different cultural background compared to people from modern western societies, they also have different religions.
   Is there a considerable cultural difference concerning how people from modern developed countries versus people from India would use a mobile interface?

   India is a colourful country, subjects' cognitive with colour is different from modern developed countries. All subjects in the testing placed red as too high BG results and blue as too low BG results. They also prefer colourful interface. Some common UI visual language could not be recognized by Indian. When propose visualization, user testing is necessary.

5. Technique and economic aspects: Which are the dimensions of the user interface specifically targeted for low (semi)-literacy users in India, and what kind of constraints should be taken into accounts, such as bandwidth limitation or device capability?

   Take Bangalore as an example, there is no constraints in terms of technical and economic aspects. Smartphones and mobile data are almost available for everyone. Even thought for people who have lower income, they would have at least one smartphone shared with the family. The situation in the village may be different. Due to the poor facilities, mobile data is not available in remote villages.

Lastly the main research question,
How should the user interface of an m-health application be designed for low (semi)-literacy Indian users, with type 2 diabetics in particular?

The modified version of expanded model in the appendix H could be used in the initial design phase. During the process, the local context should be taken into account. It is better if researchers could go to a local place and conduct the context research. Additionally, it is suggested to conduct the participant design and user testing which could help improve the design a lot.

16 Discussion

16.1 Limitation

One of the limitations of this thesis project was the remote design of the mobile application in the initial phase. We designed the application in the Europe instead of being directly involved on-site with the users and conducted user participants design. We did the research of Indian context, user and expert interviews remotely. Combined with real user data and assumption of local context from literature review, we proposed the first prototype, conducted a pre-user testing in Europe and improved the UI design. With these results, we went to Bangalore, India to conduct a user testing with real users and context research. We only tested and improved the main function UI design of Tapir due to the time limitation. The UI design of other functions may be done in the future and synthesized into other apps. For instance, diabetes education oriented app which meets user's requirement as well.

16.2 Future work

Since we only did the context research and user testing in urban area (focus on Bangalore), the rural areas in India should be explored in the future. In the next period, we should test Tapir with low-literacy people in rural areas of India to verify the value and usability of Tapir in a rural context. The improved versions of Tapir from this user testing should be tested again in the India context.

Other functions which meet users' requirements need to be built in the next phase, such as food monitoring and diabetes education. They can be built into a separate app which is easier for low-literacy people to understand.

There might be more research needed to validate the model in another contextual environment. This model was targeted to mobile phone application design for low-literacy people. Maybe it could be expanded to applying the model on websites, tablets and computer software. Research could be conducted to validate the model in these areas.

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Appendix A Pre-user testing consent form

Principal investigator: Tapir Project
Roche Diabetes Care GmbH
Sandhofer Strasse 116
68305 Mannheim/Germany
Phone +49 1742803443
Email chenghong.xie@roche.com

Purpose of the Study: The goal of this study is to explore the usability of Tapir Mobile App design. How the first-time users react to the app and how this app could help users to measure blood sugar.

Procedure: Participants in this study will measure their blood sugar by using Tapir and control solution then provide their feedbacks about Tapir. Participants are encouraged to speak loudly what they think about the Tapir screens and ask questions or a help during the process of using Tapir.

Benefits: It is hoped that the results of this study will be helpful for type 2 diabetics to measure their blood sugar easily, conveniently and manage their diabetes better.

Alternative to Participation: Participation in this study is voluntary. You are free to withdraw or discontinue participation at any time.

Cost and Compensation: Participation in this study will involve no cost to you.

Confidentiality: All information collected during the study period will be kept strictly confidential. No publications or reports from this project will include identifying information on any participant.

Any Proprietary Information related to Tapir is extremely confidential. By consenting to this Form, you agree to protect and to hold any confidential Proprietary Information provided, and used. You agree that you shall not use or disclose Proprietary Information, unless such Proprietary Information becomes part of the public domain. You specifically agree to keep in absolute confidence and not to disclose or discuss with anyone, even family members:

- any information about the Tapir that you provide
- any information regarding any Elements which you are testing or have tested.

If you agree to join this study, please sign your name below.
--I have read and understood the information on this from.
--I have had the information on this form explained to me.

Name subject: _____ Signature: _____

Name researcher: _____ Signature: _____

Thank you!

Appendix B Scripts of video & audio output

Part 1 Tapir video records

1, Get Ready
As you can see in the photo displayed on the screen, the first step is to get a lancing device, lancet and an Accu-Chek Active test strip. When you are ready, please press the “Next” button

2, Wash hands
In second step, you need to wash the hands and dry them afterwards

3, Prick the finger
Now you need to prick your finger to get a drop of blood. First, remove the cap from the lancing device, then insert the lancet into the lancet holder, twist and move the protective cap from the lancet to expose the needle. Place the cap back to your lancing device. Then, twist the cap to set lancing depth and set the number for instance to 3 and press the plunger at the end of the device all the way down. This turns the button in the middle of the device to yellow, which means the device is ready to use. Now, press the yellow button to prick your finger for a drop of blood.

4, Apply blood
Now apply the blood to the green area on the test strip and press DONE.

5, Flip the strip over
In this step, we first need to wait a few seconds, then flip the test strip over to the other side and put it on the table.

6, Camera Scan
If press the “Start Camera” below, you will see a frame on the screen. Focus the camera on the test strip, and move the smartphone to a proper height so that the test strip will fit the frame.

Part 2 help button audio

1. My Blood Sugar Results
Hello, welcome to Tapir to begin, we will start with video tutorials to help you measure your blood sugar! Press the Plus Button below to begin.

2. Get Ready
To begin we will show you how to measure blood sugar step by step in the video. Press the play button above to start the video. If you have prepared these materials well, please press the right arrow below to continue. If you already know how to measure blood sugar, you can press the exit icon to skip the tutorial.

3. Wash and dry your hands
Next you need to wash and dry your hands. Once complete, please press the continue Button. If you want to see the previous step, Press the left arrow on the left top corner.

4. Now prick your finger

In this step, you need to prick the finger. Please press the play button to start the video. Prick the site with a lancing device, once completed, please press the Continue Button below to the next step. If you want to see the previous step, Press the left arrow on the left top corner.

5. Apply blood on test strip
Now please apply your finger blood to the green area on the test strip. Once completed, press the continue Button. If you want to see the previous step, Press the left arrow on the left top corner.

6. Flip test strip over
In this step, you need to flip the test strip over. Press the play button to learn how to complete this step. If you are done, please press the continue button below to view the next step. If you want to see the previous step, Press the left arrow on the left top corner.

7. Scan test strip
In this final step, your blood sugar value will be revealed. Press play button to learn how to scan your test stripe. Press the Right Arrow button below to start your camera.

8. Camera Scan
Place the test strip within the frame on the screen, when the test strip is clearly focused, your blood sugar result will be reviewed automatically.

9. Blood sugar result
Good.
Well done. The blood sugar result is good! Keep going and lead a healthy life.

Too high
The blood sugar result is a bit high. Test again in 2 hours to see if the result is still too high.

Too high
The blood sugar result is high. This is not good for your health. Try to involve more exercise in your day. For example, take a walk after eating.

Too high
The blood sugar result is too high. This is not good for your health. Consider taking the results to the doctor.

Too low
The blood sugar result is too low, this is dangerous. Please eat something as soon as possible, for example, a candy.

Appendix C Subjects' information table

Info. / Num.	Name	Age	Gender	Occupation	Education	Religion	Income	Diagnosis year T2D	Diabetes knowledge			Smartphone usage level		
									No	Basic	Middle	No	Basic	Middle
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														

Appendix D User testing consent form

Principal investigator: Tapir Project
Roche Diabetes Care GmbH
Sandhofer Strasse 116
68305 Mannheim/Germany
Phone +49 1742803443
Email chenghong.xie@roche.com

Purpose of the Study: The goal of this study is to evaluate different design suggestions of Tapir Mobile App. How the first-time users react to the app and how this app could help users to measure blood sugar.

Procedure: Participants in this study will perform 4 tasks, 1) Measure your BG via Tapir. 2) Draw on the paper about the visualization of BG results from your perspective 3) Explain what they think about the BG value presented in different ways, numbers or graphics 4) Search for the recommendations provided when the BG value is out of range. Participants are encouraged to speak loudly what they think about the Tapir screens and ask questions or a help during the process of using Tapir.

Benefits: It is hoped that the results of this study will be helpful for type 2 diabetics to measure their blood sugar easily, conveniently and manage their diabetes better.

Alternative to Participation: Participation in this study is voluntary. You are free to withdraw or discontinue participation at any time.

Cost and Compensation: Participation in this study will involve no cost to you.

Confidentiality: All information collected during the study period will be kept strictly confidential by Roche. No publications or reports from this project will include identifying information on any participant.

Any Proprietary Information related to Tapir is extremely confidential. By consenting to this Form, you agree to protect and to hold any confidential Proprietary Information provided, and used. You agree that you shall not use or disclose Proprietary Information, unless such Proprietary Information becomes part of the public domain. You specifically agree to keep in absolute confidence and not to disclose or discuss with anyone, even family members:

- any information about the Tapir that you provide
- any information regarding any Elements which you are testing or have tested.

'I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the user testing as described in the consent form. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely

anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact chenghong.xie@roche.com.'

If you agree to join this study, please sign your name below.

Name subject: _____ Signature: _____

'I have provided explanatory notes about the user testing. I declare myself willing to answer to the best of my ability any questions which may still arise about the user testing.'

Name researcher: _____ Signature: _____

Appendix E Questions for general interview

General Questions Section, Total time required ~ 25-30 min

Section I - Basic Information ~3 min

Subject ID/Interview Number	
Gender	
Age	
When did you find out that you have diabetes?	
What kind of medication do you take for your diabetes? *(Diet; Diet & tablets; insulin)*	
You said you own/use a smartphone? Which brand is it? Do you use it by yourself or do you share it? *(e.g. with family member)*	
Do you own a blood sugar meter? If yes, which brand? How often do you use it?	

Section II - Diagnosis & Diabetes Mind set, Aspirations, Challenges ~15 min

1	How did you find out about your diabetes? *(e.g.: doctor tested blood, went to the doctor because of symptoms/ other health issues)*	
2	How did you feel when you received the diagnosis?	
3	What did your doctor tell you? Which recommendations did you get?	
4	How is it to follow the recommendations? Have you managed to fit them in your life?	
5	How often do you see your doctor?	
6	Have you adjusted your diet/food because of diabetes? Why/why not?	
7	What else do you do to control your diabetes? *(e.g. exercise, walking, running, nothing)*	
8	Do you have any health conditions related to your diabetes? *(e.g. heart disease, kidney disease, nerve damage, eye problems)*	
9	Have you told your family/friends about your diabetes? Why/why not? If yes, how did they react? Do you feel supported?	
10	Could you tell us something about your wishes and goals in life? Do you think your diabetes affects them? If yes, why and how? If not, why?	

11	How do you feel about your diabetes now? *(e.g.: confident, worry, in control, not in control, think about it a lot/hardly ever).* Why? You said you worry about your diabetes. Are there specific times when/reasons why you worry?	
12	Do you remember the last time when you had trouble because of your diabetes? If yes, could you describe the story to us? *(guide interviewee to remember and tell the story)*	
13	In your opinion, how would an ideal person with diabetes be, who takes the same medication as you? Do you see you are close to this ideal? Why/why not?	
14	Would you like to change something in your current diabetes treatment? If yes, what? Does something keep you from making the change? Why?	

Section III - Current therapy & testing blood sugar ~5 min

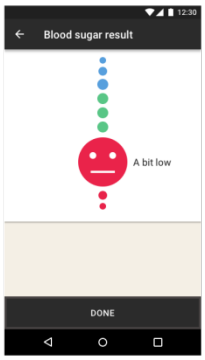
15	How often do you test your blood sugar?	
16	Is testing your blood sugar important to you? Why? What is the benefit for you? Why not?	
17	Are you familiar with blood sugar meters, test strips and lancets?	
18	How do you test your blood sugar? *(e.g. at pharmacy, hospital, doctor's office, at home yourself, at home family member helps)* If you test at home, do you test with your own blood sugar meter? What do you use to prick your finger?	
19	Do you know what to do if your blood sugar is high or low? What would you do?	
20	Do you have to pay for your medication and blood sugar testing yourself or is it paid by insurance? If you have to pay yourself, how much do you pay for medication and blood sugar testing?	
21	Where do you buy your diabetes medicine and test strips?	

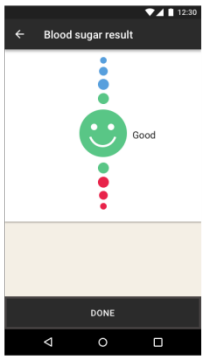
Section IV - Smartphone related questions ~5 min

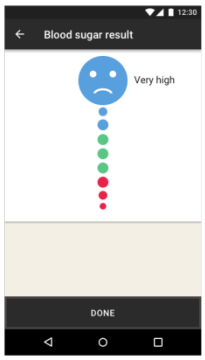
22	You told us earlier that you have a smartphone. What did you do with your smartphone today? *(guide interviewee to remember and tell the story)*	
23	What do you mostly use your smartphone for?	

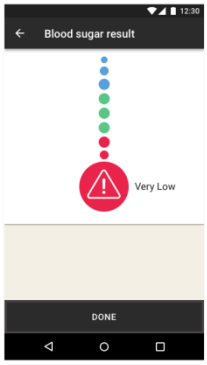
	(e.g. call/text/WhatsApp, Facebook (social media), online shopping, mobile banking, search for information)	
24	Do you use any health-related apps? For example, do you monitor/improve physical activity or nutrition?	
25	Have you had any issues with using your smartphone, such as reading the text in the apps, finding topics in the menu? Could you tell us about them?	
26	You said you use smartphone to connect to internet. If you buy a mobile data package, how much do you need to pay for it? Is the price reasonable for you? Are you concerned about how much data the mobile data connection uses? If you use wifi (wireless connection), do you have wifi connection at home or work? How much do you need to pay for it? Do you think the price is reasonable for you?	
27	Do you download apps regularly into your phone?	
28	Are you concerned about how much storage apps use up in your phone?	
29	What is the last application you downloaded? Why did you want to download it? What did you consider when you downloaded the new app? Such as available storage, if the new app is useful, easy to use, etc.	

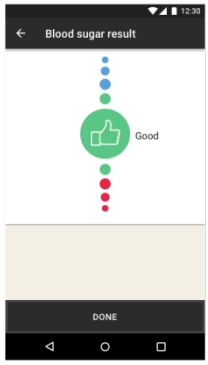
Appendix F BG result screens shown to users

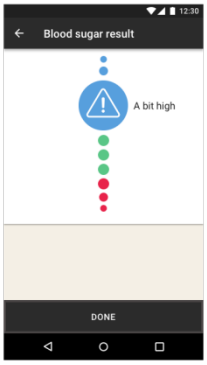


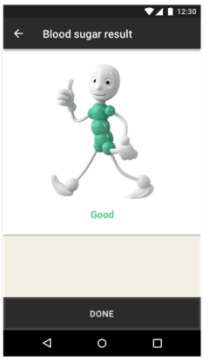


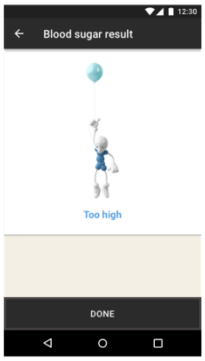


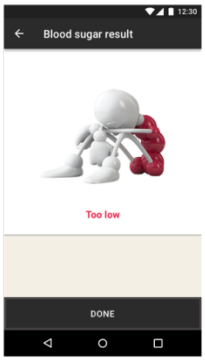


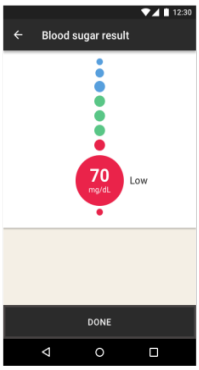


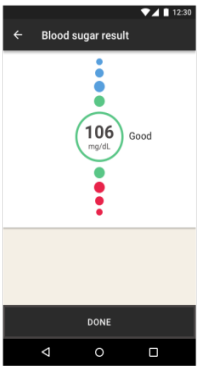


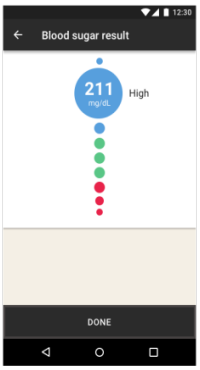


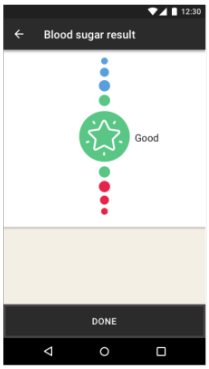


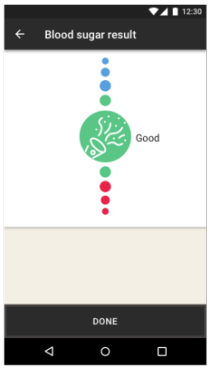


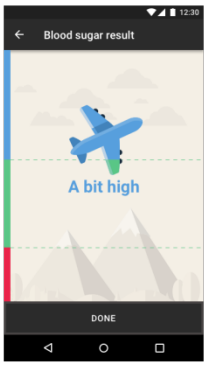


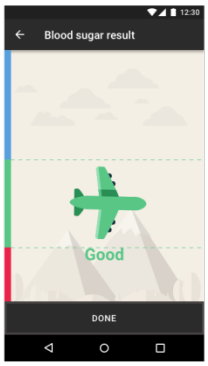












Appendix G UI Experiment Recording Table

Date _____ Subject ID/Interview number _____ Gender _____

Start Time: _____ End Time: _____ Time Taken: _____

Task completion: YES/NO Researcher: _____

Task 1: Test blood sugar with Tapir app

Prompts provided by interviewee

Types of prompts	Number			Effect			Comments
Simple encourage	1	1		✓	X		
Help button remind							
Spoken remind							
Hand-holding							

Feedback to Task 1.
Interviewer asks for feedback from interviewee on the below listed topics.

1	How easy was it for you to use Tapir to test blood sugar?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy

2	Could you understand the video tutorials? Would a video in English be enough for you?	

3	How did you like the testing with the Tapir app?			
1	2		4	5
dislike it very much	fairly dislike it		fairly like it	like it very much
Why?				

4	Did you notice there is a help button which provides audio help for you?	
5	There were also icons. Were the icons clear to you?	

	(Such as continue, okay (show the prototype again, tell subjects to explain what they think about the icons)	

Task 2: Interviewee's ideas and suggestions for how the blood sugar result could be visualized

Interviewee's drawing(s) and explanations/descriptions are to be collected and recorded.

Notes (Q8):	

Task 3: Interviewee should explain what he/she thinks about the different ways (numbers/graphics) the blood sugar result is presented

6	Please go through the screens A and describe in your words what you think about the way the blood sugar result was displayed. Can you estimate or guess what concrete blood sugar value could be behind the image? In your opinion, what would be the blood sugar values for comments "a bit high" or "high"? What would you do if you get this result after a measurement?	

7	How easy was it for you to understand the displayed blood sugar result?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy
Why?				

8	Please go through the screens B and describe in your words what you think	

	about the way the blood sugar result was displayed. Can you estimate or guess what concrete blood sugar value could be behind the image? In your opinion, what would be the blood sugar values for comments “a bit high” or “high”? What would you do if you get this result after a measurement?	

9	How easy was it for you to understand the displayed blood sugar result?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy
Why?				

The same questions for screen C, screen D. etc. Total 21 screens were shown to users.

10	Which of the 6 different options would you prefer and why?	

11	Instead of seeing the same symbol for good values, how would you like to see different ones each time? Can you understand what the symbols mean?	

Further questions related to Task 3

12	What would you do with the blood sugar result in your day to day life? Would you change anything in your lifestyle, food, or activities? Would it help you in your diabetes management in general? Why/Why not?	

Task 4: Search for the recommendations provided by Tapir when the blood sugar result is out of target range

13	Please go through screen A and search for recommendations relating to results that are out of range. What do they mean? How would you interpret them? Would you act according to the recommendation?	

14	How easy was it for you to find the recommendations provided by Tapir?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy
Why?				

15	How easy was it for you to understand the recommendations provided by Tapir?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy
Why?				

16	Please go through screen B and search for recommendations relating to results that are out of range. What do they mean? How would you interpret them? Would you act according to the recommendation?	

17	How easy was it for you to find the recommendations provided by Tapir?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy
Why?				

18	How easy was it for you to understand the recommendations provided by Tapir?			
1	2		4	5
very difficult	fairly difficult		fairly easy	very easy
Why?				

The same questions for screen C, screen D. etc. Total 8 screens were shown to users.

Question for help characters

19	If you compare the four screens, which visualization of the virtual helper do you prefer? Why?	

Appendix H Modified version of expanded model