The Few Touch Digital Diabetes Diary

User-Involved Design of Mobile Self-Help Tools for People with Diabetes

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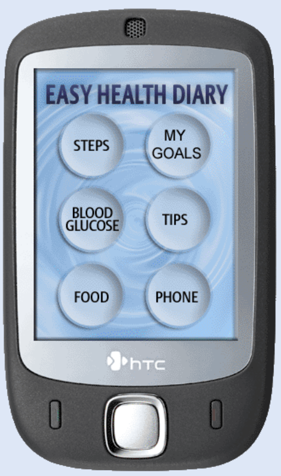

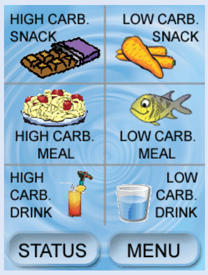

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Abstract

Introduction: Paradoxically, the technological revolution that has created a vast health problem due to a drastic change in lifestyle also holds great potential for individuals to take better care of their own health. The first consequence is not addressed in this dissertation, but the second represents the focus of the work presented, namely utilizing ICT to support self-management of individual health challenges. As long as only 35% of the patients in Norway achieve the International Diabetes Federation's goal for blood glucose (HbA1c), actions and activities to improve blood glucose control and related factors are needed. The presented work focuses on the development and integration of alternative sensor systems for blood glucose and physical activity, and a fast and effortless method for recording food habits. Various user-interface concepts running on a mobile terminal constitute a digital diabetes diary, and the total concept is referred to as the "Few Touch application".

The overall aim of this PhD project is to generate knowledge about how a mobile tool can be designed for supporting lifestyle changes among people with diabetes. Applying technologies and methods from the informatics field has contributed to improved insight into this issue. Conversely, addressing the concrete use cases for people with diabetes has resulted in the achievement of ICT designs that have been appreciated by the cohorts involved. Cooperation with three different groups of patients with diabetes over several years and various methods and theories founded in computer science, medical informatics, and telemedicine have been combined in design and research on patient-oriented aids. The blood glucose Bluetooth adapter, the step counter, and the nutrition habit registration system that have been developed were all novel and to my knowledge unique designs at the time they were first tested, and this still applies to the latter two. Whether it can be claimed that the total concept presented, the Few Touch application, will increase quality of life, is up to future research and large-scale tests of the system to answer. However, results from the Type 2 diabetes half-year study showed that several of the participants did adjust their medication, food habits and/or physical activity due to use of the application.

Studies presented: It has been important that active users, here both patients with Type 1 and patients with Type 2 diabetes, should be involved in as many parts of the design process as possible. Three main studies are presented, involving three different cohorts:

1) 12-15 Norwegian adults with Type 2 diabetes, aged 41-67 years at the time of recruitment – hereafter referred to as the *Type 2 cohort*;
2) 15 Norwegian children with Type 1 diabetes, aged 9-15 years at the time of recruitment – hereafter referred to as the *Type 1 cohort*;
3) Six American adults, three with Type 1 and three with Type 2 diabetes, aged 18–65 years – hereafter referred to as the *US cohort.*

In addition, a fourth cohort of 20 healthy people was used as a reference group in a small study, and a fifth group of 1001 informants was interviewed by telephone (CATI), as part of another survey.
The study involving the Type 2 cohort is the one that has informed the presented work the most, and has the most focused cohort.

The first sub-problem: "How can one involve real patients in a long-term design process, constructing mobile self-help tools based on real needs and preferences?"

has been addressed in three of the presented papers, i.e. Paper 1, Paper 2, and Paper 6. Frequently used methods from both medicine and computer science are used in the studies, and a framework for user involvement in the design process was designed on the basis of the experience with the methods. There has been a special emphasis on including real users. Paper 6 demonstrates the benefits of combining research on technological solutions for patients with thorough evaluations of perceived usefulness and implications in the medical/psychological research field.

The second sub-problem: “How can data capture systems for tracking blood glucose, nutrition habits and physical activity be designed in a way that will encourage patients to use them and benefit from them on a daily basis?” has been addressed in three of these dissertation papers, i.e. Paper 3, Paper 4, and Paper 5. A new and innovative sensor system has been designed for fully automatic transfer of blood glucose values, as well as a sensor system for fully automatic gathering and transfer of step count data, and a system that requires less time and effort for recording food habits than current mobile systems. The systems have been designed to interact with a touch-sensitive smartphone. The developed sensor system for fully automatic transfer of blood glucose values has been subjected to two clinical trials, the first of which revealed that the automatic functionalities are crucial for the use of the system. The sensor system for physical activity was therefore designed with a similar degree of automation for the data transfer, and even performs the data recording without needing attention from the user as long as the sensor is attached to the user. The application for recording food habits requires only two touches from the user’s finger to accomplish basic data capture.

The third sub-problem: “How can the three data capture systems be integrated into a mobile health diary, based on the new generation of mobile phones?” has been presented in Paper 1, Appendix 10, and in the Results chapter. A thorough process has been conducted to determine the components of the Few Touch application so that it would be possible to integrate them in a holistic tool for the target group. The patient terminal constitutes the most important element of the tool, and the process of choosing which kind of device to use is described in Paper 1. How the sensor systems should connect to the patient terminal is also important, and a description of alternatives and which wireless communication standard was chosen is described in Paper 3. The Type 2 cohort’s preferences for the tool as a whole are described in Paper 1, while the users’ preferences for the components of the Few Touch application are described in Paper 3, Paper 4, Paper 5, and Paper 6. All of the described components of the Few Touch application work together, configured for the same patient terminal – a mobile phone – and have been tested in the half-year study.

Conclusion: The suggested self-help tools challenges patients to think about how they can improve their situation, since it provides them a way to capture and analyse relevant personal information about their disease. The Few Touch application provides users with feedback on how they perform in relation to their own personal aims or general recommendations regarding nutrition habits, physical activity, and blood glucose levels – the three main basic elements that influence personal diabetes management. The system includes an off-the-shelf blood glucose monitor, a tailor-made step counter, and a mobile phone that functions both as the user’s ordinary mobile phone and as a diabetes diary. Feedback based on the half-year user intervention indicates good usability of the tested systems, and several of the participants adjusted their medication, food habits and/or physical activity due to use of the Few Touch application.

Preface

My motivation for working with this case, the development of self-help tools for people with diabetes, goes back to the beginning of my time at the Norwegian Centre for Telemedicine[1] (NST) in 2000. I had been diagnosed with Type 1 diabetes a few years earlier, and I saw some possibilities that wireless technologies and mobile terminals could provide, especially for vulnerable patients such as children and elderly people. The term *patient empowerment* was introduced to me by NST colleagues at the same time, and I have tried to focus on the patients as end-users ever since. I was fortunate to get several project proposals funded and established the NST Diabetes Team. My group and I worked with various self-help tools, both mobile and stationary, in the first five years. In 2005, I obtained funding for this PhD project focused on mobile terminals, and also the Diabetes Team's focus shifted towards mobile applications. I have been active in this team throughout the last four years as well, and we have tried to achieve as much synergy as possible within our project portfolio. It is certainly thanks to help from my very skilful colleagues that I have been able to cover such an extensive area in this dissertation, from the specific sensors, via mobile terminals and user interaction, to end-user participation, tests and evaluation. In sum, the work presented in this dissertation comprises almost a decade of my research and development within this field.

Basically, a combination of my ideas, the feedback on them from the patients involved, and the patients' own ideas led to the concept and innovations that are part of the proposed Few Touch application. Part I of this dissertation presents the concepts, the elements, and the evaluation of the Few Touch application, a mobile self-help tool based on a mobile phone and sensors, for people with diabetes. More specifically, the Few Touch application consists of a mobile phone that acts as a patient terminal, two patient-operated sensor systems, a patient-operated nutrition habit capturing system, wireless and automatic communication procedures, and user-interface software running on the mobile phone called the Diabetes Diary (in Norwegian: "Diabetesdagboka").

My main supervisor, Gunnar Hartvigsen, is a professor in the Medical Informatics and Telemedicine group at the Department of Computer Science, and my two co-supervisors, Per Hjortdahl and Anders Grimsmo, are medical doctors and professors at faculties of medicine – respectively the University of Oslo (UiO) and the Norwegian University of Science and Technology (NTNU). The dissertation includes methods, terms, and traditions from both of these two fields. A natural consequence of my focus is the human-computer relationships it implies. However, the special field "human computer interaction" (HCI) has not been directly addressed as research, but I have benefitted from several HCI methods in the design of and research on the systems. My competence within HCI is basically limited to the knowledge gained from the doctoral course "Advanced Topics in Human-Computer Interaction", the Thinking Aloud study together with colleagues at University of Washington, and the HCI methods employed at the focus group meetings with the Type 2 cohort. The methods used generally contribute either to the design of the systems presented, or to

[1] The Norwegian Centre for Telemedicine was integrated with three other departments of the University Hospital of North Norway (UNN) January 2009, and is now called Norwegian Centre for Integrated Care and Telemedicine, still abbreviated NST.

the research on the acceptance and effects of the systems. Since the systems are typically developed over fairly long periods in more iterations, many of the methods actually contribute to both design and research. The methods used have been a great help in bringing forward the end-users' feedback and ideas, and also in testing the various concepts.

All of the seven dissertation papers have been published. I am the first author of six of the seven papers. Much of my work has been presented in these seven papers [391],[385],[384],[389],[390],[124],[395], which are listed in Part II. Ten other scientific works are also included as appendices, as part of Part III of this dissertation: [357],[359],[380],[386],[387],[388] ,[392],[393],[394],[397]. I am the first author of eight of these, and they are included since they provide more detailed information about both the elements and the design process involved in the Few Touch application. They comprise four papers (one not published), two abstracts and oral presentations, one electronic poster, and three posters.

In addition, many Master of Science theses, projects, applications and other publications have been initiated and completed as spin-offs from this PhD project, e.g. [62],[63],[138],[147] ,[148],[149],[205],[266],[340],[379],[381],[382],[383]. As a result of my research stay at the University of Washington (UW), School of Medicine, Division of Biomedical and Health Informatics, Seattle, USA, I both performed common research together with my colleagues at UW [390],[385] (Paper 2 and Paper 5), and established collaboration between the research teams of our two countries in a US-funded research project [297]. During the past two years, my research has also been closely integrated with one of the projects at Tromsø Telemedicine Laboratory [277] and a project focusing on better use of blood glucose measurements financed by the health and rehabilitation foundation "Stiftelsen Helse og Rehabilitering" [278]. The cooperating projects are expected to continue in the years to come, enabling new user tests and subsequent publications on the Few Touch self-help concept.

Acknowledgements

I am deeply grateful to my employer, University Hospital of North Norway/NST, and the Northern Norway Regional Health Authority (Helse Nord RHF) for enabling and funding this research project. The Norwegian Diabetes Association has been of great support in arranging doctoral seminars and giving me positive encouragement for my work by allowing me to publish popular science articles in several of their magazines. It has been a great gift to be able to focus on my research topics for the last four years.

I would like to thank my excellent, encouraging main supervisor Gunnar Hartvigsen – you have taken care of me and my work in a highly professional way. I would like to thank my two great co-supervisors Per Hjortdahl and Anders Grimsmo – you have given my work the necessary links and quality assurance in the medical field, and have also been two very positive and encouraging supervisors. In particular, I would like to thank all the participants in the cohorts! Without you, my work would have risked becoming just another "techno-oriented gimmick". I would like to thank my invaluable colleagues and leaders for your support during these years: Geir Østengen, Ragnhild Varmedal, Niklas Andersson, Deede Gammon, Elisabeth Ellefsen Sjaaeng, Silje Wangberg, Jarl-Stian Olsen, Hilde Pettersen, Steinar Pedersen, Gunn-Hilde Rotvold, Sture Pettersen, Per Hasvold, Harald Øverli Eriksen, Naoe Tatara, Thomas Samuelsen and Heidi Nilsen. My half-year stay in Seattle, USA, was a really wonderful experience that would never have taken place if George Demiris and his colleagues had not taken care of formalities and offered warm hospitality – thank you, all great *U-dubbers*. Thanks to all of my co-authors who have given me and my work a very important additional element: Odd-Arne Olsen, Willy Mortensen, Johan Gustav Bellika, Taridzo Chomutare, Ove Granberg, Ole Anders Walseth, Torbjørn Sund, Eva Skipenes, Jim Tufano, James Ralston and Ruchith Fernando. Thanks to my lecturers Bruce Shriver and Dag Svanæs, to Margaret Forbes for helping me with the English language, and to the members of my evaluation committee; Randi Karlsen, Erik Johannessen, Ari Hasman and Susanne Bødker for very useful comments to the first version of my dissertation. Thanks to all of my colleagues at NST, all my friends and family for giving me positive encouragement during this period of working with the dissertation.

I would especially like to thank my three wonderful girls for their support: Marit, Siv and Gry. Thank you for giving me so much energy from elements of life beyond research. A huge acknowledgement also goes to my parents, who have given me a great basis for life and research.

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Eirik Årsand

List of abbreviations

BG – Blood Glucose

BGM – Blood Glucose Monitor

Bluetooth – Wireless short-range communications of data and voice between both mobile and stationary devices

CATI – Computer-Assisted Telephone Interviewing.

CGM – Continuous blood Glucose Monitoring

eHealth – Recent term for healthcare practice which is supported by electronic processes and communication

EHR – Electronic Health Record

GI – The Glycaemic Index describes how carbohydrates affect our blood glucose levels.

GP – General Practitioner, a physician who is not a specialist.

GPRS – General Packet Radio Service, radio technology for GSM networks that adds packet-switching protocols, offering the possibility to charge by the amount of data sent rather than the connect time.

GSM – Global System for Mobile communications, a standard digital cellular phone service in Europe, Japan, Australia and elsewhere

HbA1c - Haemoglobin A1c, also denoted glycated haemoglobin. The level, measured in %, reflects the average blood glucose level over the past 3 months.

HCI – Human Computer Interaction

ICT – Information and Communication Technologies

MMS – Multimedia Message Service

PDA – Personal Digital Assistant

PLD – Programmable Logical Device

RCT – Randomized Controlled Trial, scientific method used in testing efficacy or effectiveness of healthcare services

SMBG – Self Management of Blood Glucose, the most common way of measuring the blood glucose at present, which is an invasive method.

SMS – Short Message Service (text messaging on mobilephones)

UMTS – Universal Mobile Telecommunication System, a global family of third generation (3G) mobile communication systems.

UWB – Ultra WideBand, a wireless technology for transmitting digital data over a wide spectrum of frequency bands with very low power for a short distance

WiFi – Wireless Fidelity, a set of wireless standards for local coverage, known as 802.11

ZigBee – communication protocol using small, low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks

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Part I – Summary of the PhD Dissertation

1 Introduction

1.1 Medical Computer Science Challenges

The overall aim of this PhD project is to generate knowledge about how a mobile tool can be designed, using information and communication technologies (ICT), for supporting lifestyle changes among people with diabetes. This dissertation specifically focuses on the development and integration of alternative sensor systems for blood glucose and physical activity, since no publicly available tool currently seems to integrate more sensor systems that transfer these data fully automatically to a patient-operated self-help system. In addition, a fast and effortless method for recording food habits is addressed as the third data capture system component, since few systems seems to offer sustainable patient-operated nutrition recording. To "glue" these components together, wireless and automatic communication procedures, and user-interface concepts running on a mobile terminal are addressed as important issues in the process of designing a digital diabetes diary, referred to as the "Few Touch application".

1.1.1 ICT in Self-Management

Fuelled by the epidemic proportions of lifestyle-related diseases, many players are seeking to design low-cost and tailored ICT-based systems for supporting lifestyle changes. ICT seem promising as a platform for disease prevention and self-management interventions. For example, in 2004 the prestigious journal *BMJ* received a record number of articles – nearly 100 – when it asked for articles within electronic communication and health care [176]. A survey from 2003 identified 33 Windows-based software systems and 14 Web-based systems targeting diabetes [270]. The thorough review of computerized knowledge management in diabetes care by Balas et al. [21] showed that electronic tools are becoming vital in diabetes care, and have documented benefits in improving diabetes-related outcomes. The large (n=866) RCT -study by Williams et al. [366] also shows a significant positive effect of computer-assisted diabetes care on diabetes self-management. A study by Tatara et al. from 2008 [340] showed a significant increase in publications addressing mobile self-help tools within diabetes from year 2001 to 2008. Until recently, such tools for changing lifestyle behaviour typically were mainly based on stationary terminals (PCs and TVs).

1.1.2 Mobile Technologies

Today, the powerful handheld terminals that are emerging have provided a whole new foundation for "always available" tools, e.g. the Windows Mobile terminals [236] and the Apple's iPhone terminal [18]. "Mobile Web 2.0" is indexed more than 200 000 times by Google[2], indicating that mobile terminals represent a serious supplement to stationary terminals. A recent review by Blake [32] concludes that "mobile phones are encouraging a more dynamic connection between healthcare staff, patients and child-parent dyads. They have the potential to be cost-effective and wide-reaching in

[2] At July 2009.

application, targeting large samples or accessing hard-to-reach groups”. Mackert et al. [228] concludes that all subjects (n=50) in their study “understood the information in the ‘Diabetes and You website’(100%)” using a mobile terminal (Hewlett-Packard iPAQ RX1950 Pocket PC). However, few standards for mobile terminals as a platform have been highlighted as suitable for self-help applications, and there is still little research on the functionalities and characteristics such terminals should offer. Jensen and Larsen [180] introduce an article on their study by writing “User interaction with mobile systems and services is very complex as it depends on the environment and context in which it occurs.” Also, as stated by Bødker [52], the emerging new, small, movable interfaces – used in changing locations and contexts – may change the nature of human-computer interfaces in ways yet not fully understood. This indicates that research on mobile devices in health settings like the ones presented in this dissertation is a new and exciting area with many unsolved issues. The shortcomings in research on design of mobile technologies versus design of stationary technologies have much in common with the shortcomings in ICT for the home versus ICT for workplaces [70]. Both mobile technologies and technologies for the home are relatively new areas in research, with the more limited methodology, competence, literature and knowledge this implies. Many researchers express their optimism for the role that mobile technology will have in the future, such as Fogg [112], who believes “mobile phones will soon become the most important platform for changing human behaviour”.

1.1.3 User Interface and Usability

The biological revolution, with advances in both genetics and biomedical engineering, has brought us a number of new diagnostic tests and sensors. Advances in ICT in general have provided us with hardware and software which offer great benefits for sensor systems. Anticipation of this situation has led to many products directed solely at patients, e.g. devices for measuring blood pressure, blood glucose, respiratory peak flow, body temperature, and heart rate – intended for direct use by patients or potential patients. Most of the patient-operated health tools on the market do not fully utilise the potential that technology provides for a truly user-friendly and useful end-product. In Czaja and Lee’s review [72] of designs of computer systems for older adults, they conclude that issues such as screen design, input devices, and interface style are largely unexplored. They also emphasize the importance of knowing why the technology may be difficult to use, how to design for easier and more effective use, and how to teach users to take advantage of the available technologies. For the case of diabetes, my colleagues and I explored usability issues in relation to vision impairments and measurement of blood glucose in a feasibility study in 2004 [396], concluding that there was a need for better solutions than existed at that time. This work also made us realize the potential for improving user interfaces in general for people with diabetes.

1.1.4 Wireless Communication

Short-range communication technologies such as Bluetooth, WiFi, ZigBee and UWB as well as long-range communication technologies such as GSM, GPRS and UMTS create the potential for a new level of flexibility compared with what stationary applications have traditionally provided. The growth of short-range wireless communication standards has provided the possibility to connect the sensors with the handheld terminals. Bluetooth has been standard in most mobile phones and several stand-alone sensors and adapters have incorporated this wireless radio standard. There are still few systems where several sensors and feedback applications are integrated in an overall system, something that is especially needed in systems for the compound challenges such as those faced by people with diabetes. For a more detailed overview and recommendations regarding wireless technologies within healthcare, I recommend the paper by Doan B. Hoang [157].

1.1.5 Design

As argued by Höök [167]: "A design process that fails to involve end-users in the design loop, will fail to recognize the particular quirks and problems of how to design these artifacts." I will present studies where we have also involved users in the design process to a great extent in an effort to avoid bad designs. It is also my strong belief that it is important to know the field in which one aims to achieve good design. The noted designer Henry Dreyfuss described this well ([91] p.45): "...it is our job to be familiar with over-all trends that are above and beyond the particular industry with which we are dealing." Dreyfuss also emphasized the importance of testing ([91] p. 64), and provided many examples of how he and his staff spent time on testing and observing. In all designs presented in this dissertation, my colleagues and I have spent a great deal of time on testing – from early prototypes to near-finished prototypes right before the user interventions. Because I have Type 1 diabetes myself, many of the design choices are a product of experience from continuous testing – the whole day, the whole week, for long periods. This might both be a strength and a weakness in the design processes, since on one hand many malfunctions and ideas have been found this way, but on the other hand many decisions might have been taken on the basis of reasons that were too subjective.

1.2 The Selected Case: Diabetes

The scope of this PhD dissertation is in the intersection between medicine and informatics. While the design and implementation are within the informatics area, the application area is telemedicine and the end-users and their problems are within the medical field. The concrete case has been to design mobile self-help tools for people with the chronic disease diabetes. The focus has been on designing a patient-operated system rather than a system operated by healthcare personnel. Generally, the latter is found much more frequently, both in services and in research projects and topics. The importance of focusing on the patient is emphasized in Wagner's Chronic Care Model (CCM) [356], suggesting for example that the patient-provider interaction should "assure behaviorally sophisticated self-management support that gives priority to increasing patients' confidence and skills so that they can be the ultimate manager of their illness". Thus, the systems included in my dissertation have been designed from the *patient* perspective, in contrast to the *clinical* perspective. This implies involving the patient the most in the designs and research processes, and inspired by Liam J. Bannon [23], I refer to the cohort members as "active users" in the cases where the participants have had a role beyond that of informants. Thus, when referring to the cohorts in my work, I have used various terms, i.e. patients, users, active users, informants, participants, and people with diabetes. In some cases the term "patient" will stigmatize the person, since the person with diabetes is much more than a "patient". I have therefore tried to address the user as a patient mostly in clinical settings, where I think it is justified or clearer to use the term. I have tried to use the term “active user” when the user has been actively involved, and “informants” when referring to cohorts, or situations where the cohorts have not taken an active part in the tasks. The terms “end-user”, “participant” and “people with diabetes” have been used in more general statements. I have completely avoided the term “diabetic” (in Norwegian: “diabetiker”), due to a general opinion in the Norwegian Diabetes Association, and elsewhere, that this term can be perceived as stigmatizing.

1.2.1 Diabetes in General

It is estimated that 246 million people worldwide had diabetes mellitus, comprising both Type 1 and Type 2 diabetes, in 2007 [172]. The main disease case in this dissertation comprises people with Type 2 diabetes, aged 41-67. Type 2 diabetes constitutes more than 90% of the diabetes cases in Norway (the rest have Type 1 diabetes). Some of the solutions and components presented will in many cases be relevant for Type 1 diabetes as well, as described in Paper 3 and Paper 6. Overall, diabetes is estimated to cost Norwegian society NOK 10 billion each year [259]. Improved blood glucose levels among people with diabetes are important in reducing long-term diabetes complications [286],[287],[309] so that self-management of blood glucose (SMBG) is very important. Long-term effects of diabetes include progressive development of retinopathy with potential blindness, nephropathy that may lead to renal failure and/or neuropathy with risk of foot ulcers, amputations, sexual dysfunction and substantially increased risk of cardiovascular diseases [35]. In Norway alone, these types of complications account for huge annual expenses (NOK 7 billion) [254]. Prevention of these types of complications requires appropriate changes in eating habits, physical activity and medication in order to achieve a healthy blood glucose profile. In Norway only 10% of the NOK 10 billion in yearly expenses is used on prevention [119].

1.2.2 Type 2 Diabetes

Type 2 diabetes is a complex disease characterized by both genetic and environmental factors. The disease affects 5.9% of the world’s adult population [173]. This patient group generally comprises 85% to 95% of all people with diabetes in developed countries, and even more in developing countries [174]. Most of the remaining percentages represent Type 1 diabetes and a low incidence of gestational diabetes (onset or first recognition during pregnancy). The estimated number of people with Type 2 diabetes in Norway has recently been increased to 240 000 [153]. Diagnosis of Type 2 diabetes is usually made after the age of 40, and patients may not show any symptoms for many years. The disease is often, but not always, associated with obesity, and is strongly heritable. People with Type 2 diabetes may require insulin for regulation of their blood glucose, if healthy values are not achieved with diet alone, oral medication, or a combination of these [174]. A recent study in Norway showed that only 35% of the patients achieved the International Diabetes Federation’s goal for blood glucose (HbA1c); 52% reached the goal for blood pressure, and only 6% achieved all four goals, including plasma lipids [182].

1.2.3 Medical Recommendations

Below, I quote relevant excerpts from medical recommendations for people with Type 2 diabetes [343] from the National Institute for Health and Clinical Excellence[3] (NICE), referred to by the World Health Organization's (WHO) Health Evidence Network[4]:

- Recommendations: "For each individual, a target **HbA1c** (DCCT-aligned) should be set between 6.5% and 7.5%, based on the risk of macrovascular and microvascular complications" ([343] page 34);
- Recommendations: "Self-monitoring [of **blood glucose,** *author's note*] can be used in conjunction with appropriate therapy as part of integrated selfcare" ([343] page 35);
- Recommendations: "Weight loss and increased **physical activity** should be encouraged in those who are overweight or obese" ([343] page 40);
- General dietary recommendations: "**energy intakes** as % of total daily calorie intake, they are: 55-60% carbohydrate, 15-20% protein and 20-30% fat" ([343] page 41);
- Evidence statement: "Increasing **dietary fibre** intake can help improve glucose levels." ([343] page 40);
- Recommendations: "**Patient education** should be offered on an ongoing basis. Different approaches should be tried until the best methods for the patient are identified from the attainment of desired outcomes" ([343] page 48).

The recommended range for the content of glucose in the blood varies slightly between different organizations, and the American Diabetes Association is suggesting that patients with both Type 1 and Type 2 diabetes aim for a pre-prandial (before meal) plasma glucose between 5.0 and 7.2 mmol/l, and a peak postprandial (after meal) value less than 10 mmol/l [9]. It is important for people with diabetes to aim for the recommended ranges to avoid complications.

These recommendations above are in line with the Norwegian ones, provided by NSAM (Norsk selskap for allmennmedisin, now replaced by the Norwegian College of General Practitioners) [65]. The comprehensive review paper by Franz et al. [118] confirms these principles and recommendations for the treatment and prevention of diabetes. Other physiological parameters may also be relevant for people with diabetes to monitor by themselves, depending on their situation. Examples are body weight, waist measurements, blood pressure and cholesterol. In the future, patients with an increased risk of infections may even measure white blood cell counts at home. It is also documented that education is positive for the quality of life for people with Type 2 diabetes [77].

The recommendations and evidence statements listed are all part of the well known cornerstones in good diabetes management, namely healthy diet, blood glucose management, exercise and education. This is the background for choosing the

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[3] Their Web page is located at http://www.nice.org.uk/.

[4] Their Web page is located at http://www.euro.who.int/HEN.

elements – blood glucose, physical activity and nutrition habits – as the three main components in the Few Touch application presented.

1.2.4 Self-Management – Blood glucose

For Norway alone, with a population of 4.8 million, the National Insurance Administration records that in the year 2003 reimbursement was given for 36 million blood glucose measurement strips, with a total value of EUR 36 million [247]. This large sum of money results only in the patients' one-time use of the blood glucose measurements. No data is transferred to the health care services, even though there ought to be very good health and economic reasons for this in the long term.

Fig. 1. Measuring blood glucose using a lancet to puncture the finger.

Self-monitoring of blood glucose (SMBG) is considered an important and integrated part of disease management for people with diabetes. Common to most patient-operated blood glucose monitors today is that the measurement is done invasively. Specific devices have been introduced in the market, as early as 1941, with the introduction of urine testing. In the 1950s, Ames Company, a division of Miles Laboratories in Elkhart, Indiana, introduced strips to test for glucose in the urine, with the result being determined by comparing the colour change generated on the strip with colour patches. From 1965, blood glucose testing began using the Ames Dextrostix system, with paper strip that was read visually. Accurate reading by visual analysis was however found to be a problem and the same company introduced a meter to read the strip. This meter, the Ames Reflectance Meter, was first used by a patient at home in 1970. The first widely available meter, the Eyetone, manufactured in Japan by Kyoto Daiichi Kagaku (KDK), was sold by Ames from 1972. As SMBG became more popular, more companies began to produce more advanced meters; Boehringer Mannheim developed the Chemstrip strips, and later the first Accu-Chek meter to read those strips. LifeScan produced its first meter in 1980 [352]. Fowler [114] summarizes the evolution of blood glucose meters in the last 20 years as follows: "Glucose meters have changed considerably in the 20 years since their arrival. The time required to analyze a sample has dropped from minutes to just a few seconds. The quantity of blood required for analysis has declined to around 1/100 of that originally necessary, with some meters requiring as little as a fraction of a microliter of blood."

For most monitors, the measuring procedure involves the following steps: 1) Insert a measurement strip into the monitor; 2) Use a lancet to puncture one of the fingers; see Fig. 1; 3) Squeeze a small drop of blood out of the finger and apply it to the measurement strip; and 4) Wait approximately 5 seconds for the blood glucose value to appear on the LCD of the meter, and remove the strip. Blood glucose monitors are cheap to buy and generally available for all patients with diabetes. The use of the monitors is more expensive, costing approximately one euro for each measurement. This tends not to be a problem for users in Norway, who pay a maximum contribution of approximately 200 Euro each year for all health care services and medicines; the rest is paid by the Norwegian health care system.

1.2.5 Self-Management – Physical Activity

The Norwegian authorities [324], WHO [373] and authorities and experts from other countries, e.g. [178], recommend that the population in general should be physically active at a level corresponding to at least 10 000 daily steps or 30 minutes of moderate-intensity physical activity. The joint initiative between the WHO and the International Diabetes Federation, *Diabetes Action Now*, addresses increased physical activity as one of the key factors to prevent the disease [371]. Studies show that moderate or high levels of physical activity lower mortality, as documented by Hu et al. [163]. Physical activity is known to have a positive effect on the metabolic syndrome (a combination of medical conditions that increase the risk of cardiovascular disease and Type 2 diabetes) and its components, especially glucose tolerance. More specifically, longitudinal studies have clearly indicated that increased physical activity reduces the risk of developing Type 2 diabetes regardless of the degree of adiposity [372]. Moderately intense exercise is documented as having beneficial effects on insulin sensitivity [129].

1.2.6 Self-Management – Nutrition

Unhealthy diets and physical inactivity are among the leading causes of non-communicable chronic diseases, including diabetes, and contribute substantially to the global burden of disease, death, and disability [374]. Many people, however, find it difficult to achieve dietary improvement goals. The Nordic Nutrition Recommendations outline the average nutrient composition of the desired diet for the Nordic populations, but also state some challenges for the future regarding dietary changes. The major challenges are:

1. to increase the intake of fruit and vegetables, wholegrain cereals and fish;
2. to switch to soft fats, and lean diary and meat products; and
3. to decrease the consumption of sugar-rich foods [12].

Studies like the one by Donicova et al. [89] reveal details such as the fact that it is the breakfast that causes the greatest postprandial glucose excursions.

The large technical review including American evidence-based nutrition principles by Franz et al. [118] concludes with, among other, these major recommendations: “Foods containing carbohydrate from whole grains, fruits, vegetables, and low-fat milk are important components and should be included in a healthy diet”; “With regard to the glycemic effects of carbohydrates, the total amount of carbohydrate in meals or snacks is more important than the source or type”; “In insulin-resistant individuals, reduced energy intake and modest weight loss improve insulin resistance and glycemia in the short-term”; “Structured programs that emphasize lifestyle changes including education, reduced fat (<30% of daily energy) and energy intake, regular physical activity, and regular participant contact, can produce long-term weight loss on the order of 5 to 7% of starting weight.”

The recent Norwegian clinical diabetes guidelines [64] emphasize the importance of dietary fibre, and recommend an amount of minimum 25-35 grams per day. This may be achieved by eating “five-a-day”, i.e. two portions of fruit and three portions of vegetables/leguminous fruit. Added sugar should be a maximum of 10% of the daily energy intake. Total fat should not exceed 35% of the daily energy intake.

From the WHO’s technical report about diet, nutrition and the prevention of chronic diseases [372], the following nutritional goals are relevant: Total fat: 15-30% of total energy, free sugars: <10% of total energy, fruits and vegetables: ≥400 grams per day, total dietary fibre: >25 grams per day.

Thus, keeping a diary of daily eating habits can be of vital importance in improving one’s lifestyle and health.

1.2.7 Diabetes Self-Management

Nutrition and physical activity are closely related; Levine et al. [212] found that walking distance decreased by 1.5 miles (2.4 km) per day when users were overeating. Many people find making and maintaining changes in physical activity and eating habits difficult. The importance of achieving and maintaining healthy blood glucose levels was emphasized previously, and it is obvious how closely nutrition, physical activity and blood glucose are interrelated. Thus, it is important to address the challenge of how to motivate and give the target group tools and services to establish and maintain positive changes over time. On the basis of controlled evidence from multiple sources, the results of a study performed by the University of Missouri (USA) indicated that computer-patient interactions lead to improved outcomes in the areas of diabetes management [20]. Research on outcomes from large-scale studies on mobile ICT tools is still hard to find. A study from Texas, USA [113], involving 80 respondents with Type 2 diabetes who used a PDA in self-care, concluded that such use is feasible, but may be significantly challenging. The burden of daily data entry into the PDA self-care system made several participants so frustrated that they dropped out of the study. Preuveneers and Berbers [285] also found that potential users (diabetes Type 1) of a mobile phone in self-management had concerns about applications might would be too complicated to use. Two recent examples of ICT systems that had reduced usefulness due to their complexity are presented by Ballegaard et al. [22]: “The elderly were left with a system which was difficult for them to understand and use.” and by Istepanian et al. [175]: “Patients cited technical issues related to operating the equipment as the main reason behind the protocol violations.” This fosters my belief in this dissertation’s focus, namely designs for self-care systems that are quick to use and require as little effort as possible, to register health-related parameters, and provides valuable feedback to the users. To get closer to this aim, several problems have to be addressed.

1.3 Problem Definition

Today, paper-based patient diaries are still the most frequently used tool for keeping track of medication, food intake and blood glucose values among people with diabetes; see Fig. 2. As it is tedious to record such parameters, few patients use paper diaries over longer periods, even though this may actually provide a good overview and thus improve disease management. Using three main technology components: sensor systems, wireless communication, and handheld terminals such as the newest generation of mobile phones, I aim both to generate knowledge about how a mobile tool can be designed to replace paper-based patient diaries, and to construct specific elements that may constitute a user-friendly application.

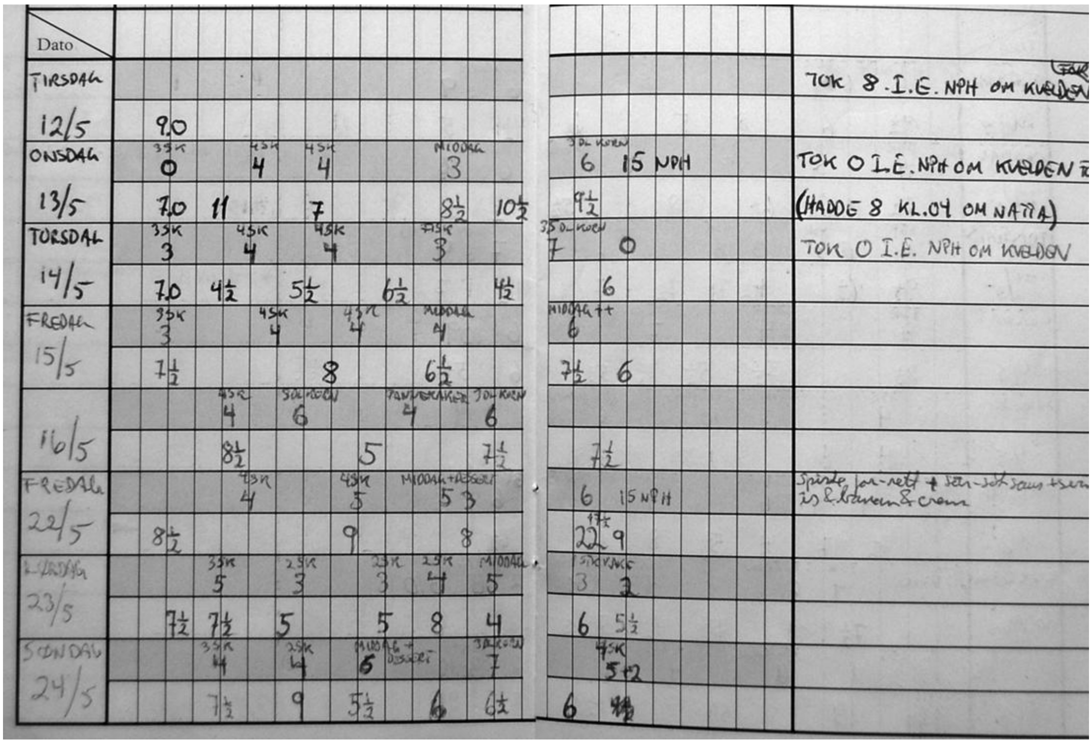

Fig. 2 An example of a paper-based diary for a Norwegian Type 1 diabetes patient.

The main challenge for this dissertation has been to design and adapt sensors to be part of a holistic mobile and patient-operated system, building on current standards for short-range communication and current mobile terminals. The focus has been on designing a system that is as easy to use as possible, but that still provides users with enough feedback and collated disease-specific information to be a tool they want to use on a long term.

Easy to use: The use of the term "easy to use" is disputed – especially within HCI communities – and I will therefore define my use of it throughout this dissertation: By "easy to use" I mean devices or procedures that require so little effort and time from users that they are likely to be used over a fairly long period, i.e. typically more than a month. Also, the principle "less is more" – in this case, reducing the burden of tedious manual recording operations – has been one of the main requirement specifications underlying my work. As Jakob Nielsen emphasizes [250], most of the functionalities in computer programs are not used and contribute to making them <u>harder</u> to use.

Self-help: My use of the term "self-help" is directed at personalized and patient-oriented use, i.e. where patients themselves use a tool, system or service to take better care of their health.

The well known cornerstones in good diabetes management are healthy diet, blood glucose management, exercise and education – the basis for choosing blood glucose, physical activity and nutrition habits as the three main elements in the proposed mobile diary system. I have deliberately not included more than these three parameters, both because designing three data capture systems is already complex, and because the aim was to design an easy-to-use system, i.e. mainly quick and effortless to use. The idea of providing patients with a better overview of their disease-related habits, in a unit that is “always” with them, is that it may improve their motivation to improve their health situation. B.J. Fogg [111] refers to the expression “persuasive technology”, which in many ways describes the aims for the proposed technological systems in this dissertation as well. Using Fogg’s terms, my work may be classified as “Captology”, i.e. “computers as persuasive technologies”, comprising “design, research, and analysis of interactive computing products created for the purpose of changing people’s attitudes or behaviours” [110]. Also, it is generally satisfying to understand relations between different actions and results, which may encourage patients to improve self-management of the disease.

The main problem addressed by the dissertation is:

How can mobile devices for supporting lifestyle changes among people with diabetes be designed to be perceived as motivating and helpful by the users?

The sub-problems are:

1. How can one involve real patients in a long-term design process, constructing mobile self-help tools based on real needs and preferences?
2. How can data capture systems for tracking blood glucose, nutrition habits and physical activity be designed in a way that will encourage patients to use them and benefit from them on a daily basis?
3. How can the three data capture systems be integrated into a mobile health diary, based on the new generation of mobile phones?

1.4 Mobile Self-Help Tools

The kind of patient-oriented self-help tools aimed for in this work need to provide users with a better overview of their current situation and the changes they make, and increased understanding of important components of their disease. Specifically, it means to be able to monitor their blood glucose, their physical activity and nutrition habits. With a tool that provides such an overview, it will be easier to discover relationships between e.g. food and blood glucose values, and physical activity and blood glucose values. The idea is to work towards a tool that gives the patients useful information so that they are in a better position to draw their own conclusions on how to improve their health situation. The tool should challenge the users to think about how they can improve their situation given a great deal of new information about themselves, in contrast to a tool that provides static advice or recommendations. It should furthermore avoid functionality that involves making recommendations because for people with diabetes it might be life threatening to suggest changes in the medication regime and it might make the patient more passive.

The Mobile Phone as a Basis: The size and ease of use of a tool for a group of people who already have to handle many additional devices is essential. People with diabetes have to handle more devices for measuring their blood glucose (sensor, lancet, measurement strips), some sort of medication (insulin/oral medication) and preferably a medium for recording their measurements and medication (a diabetes diary). In addition, most patients carry a mobile phone, which some use as a security device to get in touch with helpers. The logical implication of this situation with respect to the design of a self-help tool is to strive to keep the number of new devices for patients to a minimum or to reduce the number of devices. One of the ideas presented in this dissertation is to include an off-the-shelf blood glucose monitor and a mobile phone that functions both as the user's ordinary mobile phone and as a diabetes diary, i.e. a total situation with fewer units than before.

1.5 Methodology

The use of triangulation, applying not one but several methods, measures and approaches, has been emphasized in this doctoral project. Regarding the sequence of the methods involved, I have partly used the approach described by Höök [167] – the "two-tiered method": first get the interface and interpretation right (usability), then evaluate whether the aspects of the systems contributed to the goals. Methodologies used have mainly involved arranging focus groups, but also interviews and feasibility testing, questionnaires and prototyping of both the software and hardware components of the Few Touch application. In addition, human computer interaction methods such as paper prototyping, scenarios, and thinking aloud sessions have been used.

Involving methods from a variety of disciplines proved to work well for this case. The design process was done in an iterative way, addressing the designs several times, at an increasing level of detail. I have also cooperated with a colleague (G.D.) at the University of Washington, USA, regarding a framework for how to involve patients in designing a self-help tool. An important quality assurance measure in this process has been the close involvement of real users. For the main study, throughout the whole design period 12-15 active users were involved in focus group meetings, from the discussion of the problems to the tests of the designs. Including real users, i.e. people who have the disease themselves, was crucial for us to obtain first-hand insight into the challenges that the target group meets in everyday life. Besides, it would not have been possible to use people other than those who have this condition, when the aim was to test the blood glucose sensor system, and to see the correlation between food habits, physical activity and blood glucose values. The extensive use of focus groups as the main method for this cohort has provided valuable information about the target group's daily practices in a way that has informed the design of the systems, as advocated by Bell and Kaye [27]. The methodology used is described in detail in Chapter "3. Methods".

The main criticism of the methodologies used may be that the same Type 2 cohort has mainly been used as informants throughout the design process, without any control groups. In addition, the recruitment of the informants was addressed to members of the Norwegian Diabetes Association, resulting in a more motivated cohort than the general population with Type 2 diabetes.

1.6 Achievements

The Few Touch application presented is to my knowledge unique in its use of a mobile phone to collect and present information about the user's blood glucose values, daily steps taken and nutrition habit information. By combining knowledge about diabetes patients, involvement of the users, software and hardware concepts, and an iterative design process, various proofs of concept have been designed. The designs and research mainly address the Type 2 diabetes cohort, the Type 1 diabetes cohort, and the US cohort with both Type 1 and Type 2 diabetes. As part of the suggested Few Touch application, a system has been designed for fully automatic transfer of blood glucose data (Paper 3 [384]) and also a system for fully automatic transfer of step count data (Paper 4 [389]), which both transfer the sensor data to the users' mobile phone and present processed data in a user-friendly way on the screen. A system has also been designed for fast and effortless recording of nutrition habits (Paper 5 [390]), using the touch-sensitive screen on the patient terminal, a mobile phone. These systems integrated with a system for monitoring the three parameters, setting personal goals, and accessing general information – all functionalities accessible from the users' mobile phone.

Design and research methods have generated valuable results on how the technical designs were perceived by the active users. Guidelines for patient-centred design and a framework for how to involve patients in designing a self-help tool have been suggested (Paper 2 [385]). Automatic transfer of blood glucose data into the public health care system has been used as an example of one of the prospective functions of the Few Touch application (Paper 7 [395]). The potential for cross-disciplinary research has been demonstrated on the basis of the Type 1 cohort: children with diabetes, and their parents (Paper 6 [124]).

To sum up, the first sub-problem regarding the involvement of real users in the design process has been addressed in three of the papers included in my dissertation (Paper 1 [391], Paper 2 [385], Paper 6 [124]); the second sub-problem regarding the design of easy-to-use data capture systems has been addressed in three of the other papers included (Paper 3 [384], Paper 4 [389], Paper 5 [390]), and sub-problem 3 regarding integration of the data capture systems into a mobile health diary has been addressed in Paper 1 [391], Appendix 1 [387], Appendix 10 [392], and in the Results chapter – results that will be presented in coming papers in 2009 and 2010.

1.7 The Limitations of the Dissertation

This dissertation focuses mainly on services for the end-user, i.e. people with Type 1 and Type 2 diabetes, not on supporting health care personnel or other helpers. However, medical personnel have been involved to some degree in the design process. The focus is further limited to self-help tools, and does not include personal health record (PHR) systems. PHR systems usually comprise aids for patients themselves to keep a more detailed overview of their health and medical status and history, often with functionalities to share this information with health care workers. However, the long-term goal of the work presented is for the Few Touch concept to include communication with health care systems and health care personnel. The systems are designed for one kind of patient terminal only, i.e. programmable mobile phones with Windows Mobile OS and touch-sensitive screens. If future large-scale interventions of this concept prove that it has medical effects and patients are willing to use this kind of tool on a long-term basis, efforts will be made to generalize the Few Touch concept. This will involve making the concept available on multiple mobile platforms and preferably enabling integration with stationary platforms as well. It will also involve a design that allows use of multiple kinds of sensor systems connected to the patient terminal. So far, mostly usability tests of the concept have been performed [390],[391], as well as a small-scale intervention [124], but our research team currently has specific plans for larger-scale interventions. Educational theories and concepts have not been a focus of the design and research processes, but would be a relevant candidate for the Few Touch application in future.

1.8 Organization of the Dissertation

The Summary: This summary part of the dissertation, Part I, complements and ties together the main components of my PhD dissertation. It is structured in seven main chapters. Chapter 1 provides a brief introduction to the scope of my work, the disease case, the informatics problems and some words about the design and outcomes of the work with the mobile self-help ICT tools. Chapter 2 describes the state of the art of both self-help tools and their components. Chapter 3 outlines both the design-oriented and the research-oriented methods used in my work, from the prototyping process onward, involving active users. Chapter 4 provides the premises, the use cases and the designs for both the elements and the Few Touch application as the resulting application. Chapter 5 presents excerpts of the results from the seven papers and also the as yet unpublished results from the final half-year user test of the Few Touch application. In addition, I present some results that were not included in the papers due to lack of space, or because they were not relevant to the context in question. In Chapter 6 I discuss the overall choices I have made, the limitations and benefits of my studies and designs, the achievements, and the future plans and prospects. However, I discuss the specific results right after the different sections in the “5. Results” chapter, in order to make it easier to recapitulate the specific results. Chapter 7 sums up my contributions.

The Papers: In Part II, the seven papers chosen for this dissertation are presented: The system as a whole, the design and early evaluations (Paper 1), the methods used (Paper 2), the three data capture applications (Paper 3, Paper 4, Paper 5), user evaluation and cross disciplinary research (Paper 6) and prospects for future applications (Paper 7). I am first author of six of these, and for the one paper of which I am not the first author, Paper 6, my colleague Deede Gammon has performed and described the analysis of the interviews from a psychological perspective. My contribution regarding this paper is as an innovator and designer of the technical system, as manager and facilitator of the research project, as well as in the design and analysis of the questionnaire part of the project, and in describing these elements in the paper. This paper is included to illustrate how applied computer science may be combined with medical research, here psychology, and how a thorough evaluation of the end-users may be done. Paper 7 presents just one of the possible future innovations that could be based on the Few Touch concept, and further examples are presented in chapter “6.4 Future Plans and Prospects”.

There is some overlap between the seven papers, and the last four papers all refer to part of the Few Touch application. Paper 3, Paper 4 and Paper 5 describe each of the three data capture applications individually, but conclude with a discussion of their role in the whole system. Paper 2 describes some of the methods used, but repeats some of the findings associated with the Type 2 cohort in Paper 1 and the Type 1 cohort in Paper 6. Paper 6 is the paper that describes the findings from the Type 1 study in the greatest detail, seen from a psychological viewpoint. There is some overlap with Paper 3, which describes the technology of the system evaluated in Paper 6. Paper 7 also starts by describing the technology of Paper 3 as background information, but the focus is on future use of the technology as an indicator of epidemic disease outbreaks. The seven papers may be categorized into five main themes: A) Requirements, designs and early tests, B) Methods, C) Sensors and system design, D) User evaluation and cross-disciplinarity, and E) Future applications. Together, they present my main focus and contributions during the design and research towards the Few Touch concept.

The Appendices: As appendices to this dissertation, in Part III, I present 10 other scientific works: [357],[359],[380],[386],[387],[388],[392],[393],[394],[397], the plans and scripts for arranging the focus group meeting, the thinking aloud sessions, and the prototyping sessions, questionnaires, interview guides, the requirement specification for the Few Touch application, and the specifications for the Bluetooth adapter for the blood glucose sensors system.

2 State of the Art

2.1 Self-Help Tools

Most of the existing self-help tools for chronically ill patients aim to provide help by interacting with health care workers. Even though this is usually the kind of help that patients want most and is also the most effective, e.g. [53], [232] and [315], it is resource-intensive. A specific change of focus expressed by the European Commission (EC) a few years ago in the Information Society Technologies (IST) programme [98] was to orient R&D towards one process to integrate and use all relevant biomedical information for improving health knowledge and processes related to prevention, diagnosis, treatment, and personalization of health care.

I first give an overview of mobile diabetes-specific self-help tools, including publicly available tools, prototypes typically designed for research studies, and relevant patents and patent applications. Then, diabetes-related self-help tools as well as some systems for other chronic diseases are presented – but more briefly, in order to illustrate how technology is applied within the personalized health area in general.

2.1.1 Mobile Diabetes-Specific Tools

A search for patient-operated diabetes management software in general, including PC/Internet tools, shows that there are many systems available. No recently updated reviews were found, but a six-year-old study [270] identified 47 Web-based or Windows-based programs for assisting people with diabetes in their self-help regimen, excluding educational and informational software. Few reviews of mobile diabetes systems were found. A search of the *Cochrane Reviews* database [224] in June 2009 using the search words “diabetes” and “mobile” in all text fields yielded no relevant reviews, but some results with the status “Stage: Protocol”. Besides the review by Tatara et al. [340], two more general reviews covering the use of SMS in healthcare by Krishna et al. [193] and Fjeldsoe et al. [109] were found, identifying some additional diabetes-specific mobile systems.

Systems for and studies on self-help tools involving assistance by health care personnel are widespread, e.g. the DiasNet advisory system [87], the system developed by Axon TeleHealthCare [268], the telephone-linked care system [130], the PARIS_Diabtel system [295], the TeleObe programme [310], the Internet-based system BioDang [199], and the Healthcare@Home monitoring framework [328]. My focus has however been on patient-operated mobile self-help tools, an area that has exhibited relatively strong growth during the last three years, but is still rather immature. The main reason for the recent growth may be the evolution of mobile phones into small, programmable and function-rich computers. Several studies and prototypes as well as some publicly available products and services exist, directed at people with Type 1 and Type 2 diabetes, but few of these can actually be classified as self-help tools according to this dissertation’s definition. This unfortunately means that despite the possibilities that the mobile terminals, miniaturization and wireless communication technologies provide, there are still relatively few efforts to create mobile systems directed at personalized use.

Literature Search: The tools, projects and trials listed in Table 1 below were found by searching peer-reviewed journals or conference papers for combinations of the words "diabetes", "mobile", "PDA", and "cellular", mainly in the same data sources as used in [340]; i.e. PsycINFO, EMBASE, CINAHL, Pubmed (includes MEDLINE, which includes JMIR), Cochrane Library, ISI Web of Science, INSPEC (Ovid), ACM Digital Library, IEEE Xplore. In addition, ISI Web of Knowledge, Lecture Notes in Computer Science (LNCS), and the American Diabetes Association journals were searched. See reference [224] for the URLs to these libraries. More relevant literature was found by checking the references of the identified relevant papers. The search was performed in May and June 2009.
The inclusion criteria were:

- ✓ mobile, patient-operated, self-help tools (in the general sense of the term) for people with diabetes
- ✓ the system presented should be suitable for use outside hospitals for fairly long periods, typically more than a month
- ✓ include an evaluation or a description of the system
- ✓ the system should have been tested on at least one patient
- ✓ innovative diabetes self-help systems, also without functions for management of blood glucose measurements (different from the criteria for the systems included in Table 2, where the systems had to include at least functionality for blood glucose parameters)

The system may or may not involve interaction with the health care sector. I emphasize that there are many self-management systems for diabetes that are Web- and PC-based, as well as artificial pancreas systems, which are only used in hospitals, and are therefore not included in this section of relevant systems.

Publicly available Systems Search: There exist various relevant products and other publicly available systems, some of which are listed in Table 2. The systems were found by searching for prototype names, cooperative partners and companies mentioned in the cited literature listed in Table 1. Perhaps the best overview of diabetes management software and systems in general is provided by the diabetes guru on the Internet, David Mendosa (www.mendosa.com/software.htm), which has also served as a source for finding the publicly available products and services listed in Table 2.

The main criteria for inclusion were that the systems:

- ✓ were mobile (usually based on mobile phones or PDAs);
- ✓ were publicly available;
- ✓ had at least a function to monitor blood glucose values, and
- ✓ provided more help or information than ordinary blood glucose meters.

However, there are many small applications, typically developed in student projects and made publicly available, which not were included in this overview. BGMs communicating with insulin pumps were also excluded, due to their generally limited circulation among people with diabetes. The search was done in May and June 2009.

An example of one of the publicly available mobile diabetes management system is presented in Fig. 3, the Windows Mobile-based application "SiDiary" [320].

Table 1. Relevant studies and prototypes of mobile, diabetes-specific self-help tools, sorted by the year of publication.

No.	Main disease	Name of tool, project and/or trial (year of publication)	No. of users*	Reference
1.	Type 1 diabetes	CARDS: Computerized Automated Reminder Diabetes System (SMS, e-mail) **(2009)**	22	[145]
2.	Diabetes, type not reported	Using Zigbee and mobile phones for elderly patients **(2009)**	17	[208]
3.	Type 1 diabetes	The Diabetes Interactive Diary (DID) **(2009)**	41	[302]
4.	Type 1 diabetes	Wireless Personal Assistant for telemedical diabetes care **(2009)**	10	[125]
5.	Type 1 and Type 2 diabetes	Evaluation of a mobile phone telemonitoring system for glycaemic control in patients with diabetes **(2009)**	72	[175]
6.	Type 2 diabetes	Mobile communication using a mobile phone with a glucometer (HealthPia) for glucose control – comparison with Internet-based glucose monitoring **(2009)**	38	[61]
7.	Type 2 diabetes	Intervention study on the WellDoc's Diabetes Manager system (Mobile phone and Web) **(2009)**	185	[288]
8.	Type 2 diabetes	A short message service by cellular phone in type 2 diabetic patients **(2008)**	25	[376]
9.	Type 2 diabetes	WellDoc: Mobile Diabetes Management (Mobile phone and PC) **(2008)**	15	[289]
10.	Type 2 diabetes	Nurse intervention using SMS and Internet (PC) **(2008)**	18	[189]
11.	Type 2 diabetes	The NICHE pilot study (mobile phone and Internet) **(2008)**	15	[101]
12.	Type 2 diabetes	Continuous glucose monitoring to change physical activity behavior (CGMS monitor, accelerometers) **(2008)**	27	[7]
13.	Type 1 diabetes	Mobile Phones Assisting With Health Self-Care: a Diabetes Case Study **(2008)**	11	[285]
14.	Type 1 and Type 2 diabetes	MAHI (Mobile Access to Health Information) **(2008)**	25	[229]
15.	Type 1 diabetes	The INCA System (PDA-based patient intervention, study prior to closed-loop test) **(2008)**	10	[135]
16.	Diabetes and cardiovascular disease	MediNet: Personalizing the Self-Care Process for Patients with Diabetes and Cardiovascular Disease Using Mobile Telephony **(2008)**	Initial tests only	[239], [240]
17.	Type 1 diabetes	Diab-Memory: Mobile Phone–Based Data Service for Functional Insulin Treatment of Type 1 Diabetes **(2007)**	10	[192]
18.	Type 1 diabetes	The HealthPia GlucoPack Diabetes (mobile) Phone **(2007)**	10	[56]
19.	Type 1 diabetes	Using cellular phones (the GlucoNet system) in type 1 diabetic patients during insulin pump therapy: the PumpNet study **(2007)**	30	[29]
20.	Diabetes and other chronic diseases	MyMobileDoc - a Mobile Medical Application for the Management of Chronic Diseases **(2007)**	15	[255]
21.	Type 1 and Type 2 diabetes	Combining digital photography and glucose data **(2007)**	7	[321]
22.	Type 1 and Type 2 diabetes	The ProWellness Self-Care System - Information technology supporting diabetes self-care **(2007)**	9	[144]
23.	Type 1 and Type 2 diabetes, and other diseases	The Singapore health services experience (SMS and Internet/PC) **(2007)**	n/a	[313]
24.	Type 1 diabetes	Recording of hypoglycaemic attacks. (SMS, Internet/PC and diary) **(2007)**	19	[339]
25.	Type 1 diabetes	DiasNet Mobile (based on the DiasNet system) **(2007)**	1	[180]
26.	Type 2 diabetes	The CenTexNet Study: PDA Use in Diabetes Self-Care ("Diabetes Pilot" software) **(2007)**	42	[113]
27.	Type 1 and Type 2 diabetes	Mobile Dietary Management Support Technologies for People with Diabetes **(2007)**	6	[390]
28.	Type 2 diabetes	Usability of a Mobile Self-Help Tool for People with Diabetes: the Easy Health Diary **(2007)**	32	[391]
29.	Type 1 diabetes	Sweet Talk: Text Messaging Support for Intensive Insulin Therapy for Young People with Diabetes **(2006)**	64	[116], [115]

30.	Type 1 and 2, visually impaired	eDiab: monitoring, assisting and educating people with diabetes (PDA or mobile phone) **(2006)**	n/a	[106]
31.	Type 1 diabetes	VIE-DIAB: reporting blood glucose, carbo-hydrate intake, insulin dosage) via mobile phone **(2006)**	36	[291]
32.	Type 1 diabetes	DiasNet-PN (based on the DiasNet system) **(2006)**	1	[181]
33.	Type 1 diabetes	The telematic communication GlucoBeep system **(2006)**	20	[177]
34.	Type 1 and Type 2 diabetes	Diabetic e-Management System (DEMS) **(2006)**	13	[227]
35.	Type 1 diabetes	Diabetes education via mobile text messaging **(2006)**	11	[360]
36.	Type 1 diabetes	Parent-Child Interaction Using a Mobile and Wireless System for Blood Glucose Monitoring **(2005, 2007)**	15	[124], [384]
37.	Type 1 diabetes	A real-time, mobile phone-based telemedicine system to support young adults with type 1 diabetes **(2005)**	93	[104], [103]
38.	Not specified	Mobile phone text messaging (SMS) in the management of diabetes **(2004)**	23	[107]
39.	Type 1 and Type 2 diabetes	DiabNet: integration of handheld computer, mobile phone and Internet access **(2004)**	n/a	[303]
40.	Type 1 diabetes	The DAILY (Daily Automated Intensive Log for Youth) Trial: A Wireless, Portable System to Improve Adherence and Glycemic Control in Youth with Diabetes **(2004)**	40	[196], [197]
41.	Type 1 diabetes	Cellular phone transfer for blood glucose self -monitoring – the WellMate system **(2004)**	100	[355]
42.	Type 1 diabetes	Edutainment Tools for Initial Education of Type-1 Diabetes Mellitus: Initial Diabetes Education with Fun **(2004)**	58	[16]
43.	Type 1, Type 2 and Gestational diabetes	The M²DM project, includes automatic generation of reminders and alarms, transmitted by SMS to patients **(2003, 2006)**	38	[28], [204]
44.	Type 1 diabetes	DiaBetNet: a handheld computer (guessing) game for young diabetics (blood glucose, carbs., insulin) **(2003, 2004)**	40	[203], [274]
45.	Type 1 diabetes	DIABTel: evaluation of a Telemedicine system (PC and palmtop computer) **(2002)**	10	[134]
46.	Not specified	Diabetes Monitoring System (DMS) based on a hand-held, touch-screen electronic diary (meals, blood glucose) **(2001)**	19	[349]

* The number of users represents those who used the technology, not the total cohort, i.e. control groups are not counted.

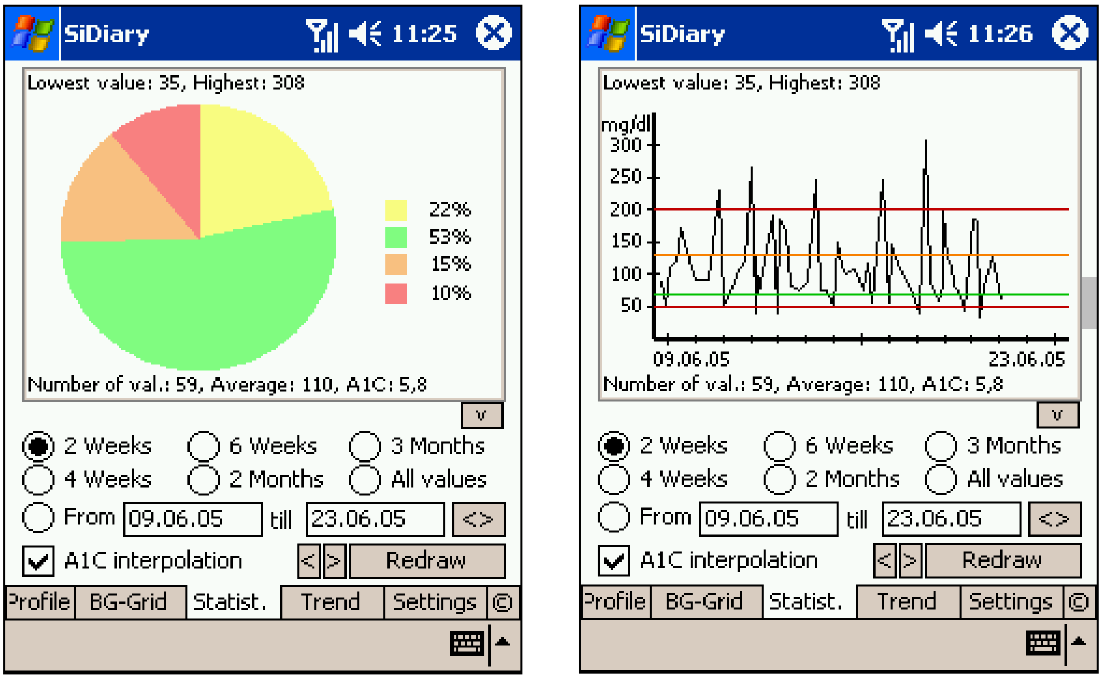

Fig. 3. Example of a user interface of the mobile diabetes management product SiDiary para Pocket PC (adapted from SINOVO's Web Page: http://www.sidiary.org/).

Table 2. Relevant and publicly available mobile diabetes-specific self-help systems.

Main disease	Name of vendor / product	URL
Products are for both Type 1 and Type 2 diabetes, or not specified	t+ Medical / t+ Diabetes	http://www.tplusmedical.co.uk/information/01Patients--04tplus_diabetes.html
	SugarStats LLC / SugarStats Mobile edition	http://www.sugarstats.com/
	Digital Altitudes LLC / Diabetes Pilot	http://www.diabetespilot.com/
	FutureWare / Personal GlucoseTracker	http://www.futurewaredc.com/products/FutureWare_PersonalGlucoseTracker.html
	Alive Technologies / Alive Diabetes Management System	http://www.alivetec.com/products.htm
	SINOVO Ltd. & Co. KG / SiDiary	http://www.sidiary.org/
	Diabetech LP / GlucoMON	http://mygluco.com/glucomonhowitworks
	HealthEngage / HealthEngage	http://www.healthengage.com/
	SymCare Personalized Health Solutions / SymCare	http://www.symcare.com/
	MYLEstone Health / Glucose Buddy	http://beta.glucosebuddy.com/
	Ace t&t / DiabGo	http://www.ace-tt.com/
	Elardo GbR / Elardo DiabetesProfiler	http://www.handango.com/catalog/ProductDetails.jsp?storeId=2218&productId=87853
	Mobile Diabetic Inc. / LogbookFX Diabetic Diary	http://www.mdiabetic.com/
	Glucose-Charter / Glucose-Charter Pro	http://glucose-charter.com/
	GlucoControl / GlucoControl 3.0	http://www.brothersoft.com/glucocontrol-27960.html
	GlucoTools / GlucoTools	http://glucotools.sourceforge.net/
	UTS / UTS Diabetes	http://utracksys.com/software-diabetes/
	HMM Diagnostics GmbH / smartLAB genie	http://www.smartlab.org/genie/
	Confidant Inc. / CONFIDANT Diabetes Solution	http://www.confidantinc.com/
	Entra Health Systems Ltd / myglucohealth	http://www.myglucohealth.net/
	Apple Inc. / iPhone Diabetes applications (60 applications were found by searching iTunes for "Diabetes", of which 16 supported manual input of BG data)	http://www.apple.com/no/ipodtouch/appstore/
	GlucoseOne / GlucoseOne Palm Application	http://www.glucoseone.com/
	Polymap Wireless / The Polytel System	https://www.polymapwireless.com/
	LifeScan Inc. / OneTouch UltraSmart	http://www.lifescan.com/
Juvenile diabetes (Type 1)	HealthPia USA / GlucoPhone	http://healthpia.us/
Insulin dep. diabetes	Insulet Corporation / OmniPod with Personal Diabetes Manager	http://www.myomnipod.com/
Type 2	WellDoc Communications / DiabetesManager	http://www.welldoc-communications.com/

Patent Search: A search for relevant patents and patent applications was performed in June 2009 in the US-based patent database "Patentstorm" [272], which claims to be updated weekly with the U.S. Patent Office's databases, and in the European patent database "esp@cenet" [99] (worldwide search).

A mobile diabetes self-help tool might be considered too rich in functionality to allow filing of a patent. To get further indications of whether this was the case, several patent searches were performed. A search of Patentstorm using the criterion "diabetes and mobile" in the patent's 'Title' field yielded no results, but the esp@cenet found two [155],[311]. Both of these describe a remote monitoring system between a user with diabetes and the health care system or a database. Searching the same two patent databases using the search term "diabetes and handheld" in the 'Title' field gave no hits in Patentstorm and two hits in esp@cenet. One of these was a pen-type injector and the other a device containing nutritional information.

A search in the patent databases' 'Full text' field was expected to return very many more hits, so more specific search terms were tested. The Patentstorm and esp@cenet had different search functionality for long search terms, so that I had to formulate the respective searches in two different ways. Patentstorm allowed long search terms in the 'Full text' field. A search for the criterion "diabetes and mobile and (self-help or self-management) and (tool or device or unit)" returned no patents. The shorter term "diabetes and mobile and patient-operated" returned 21 patents or patent applications. Most of these involved either "remote patient monitoring", or remote data storage or forwarding to a health care system. An interesting concept described in the patent application by Dicks et al. [85] from 2008 presents a smart way (introducing an additional device) to trigger automatic data transmission from a medical device. It actually also exemplifies the use of the system using a blood glucose monitor device ([85], Figure 4). A search in Patentstorm for "diabetes and mobile" alone returned 14275 results.

The esp@cenet database allows searches of the "abstract" and the "title" fields together as the option most similar to free text search, with a maximum of five keywords. Searching for the term "diabetes and mobile and patient-operated" yielded no results. Searching for the term "diabetes and mobile" returned 15 results. Of these, [292],[271],[301],[169],[155],[311] were relevant to the Few Touch application at a general level only, and involved remote data monitoring, which might be relevant in future if the Few Touch application is included in health care services.

2.1.2 Other Health Related Mobile Self-Help Tools

Fitness: For fitness and physical activity purposes, a variety of mobile devices and plans for utilization of existing devices is available, e.g.:

- the "TripleBeat" system [265] based on the "AliveTec" chest belt [264];
- the chest belt systems from *Polar* [281];
- the "Nike+ SportBand" [253], which has a sensor in the running shoe combined with a wristband that gathers and displays the physical activity data, and also allows USB transfer of the data to a PC for further analysis;
- *Garmin Ltd.* has more fitness products, including one system that combines both GPS and pulse information. The "Forerunner 301" system [126] has implemented this using a wrist-worn GPS and a chest belt, with functionality for downloading the data to a PC for analysis;

- the “PmEB” is a mobile-phone application for monitoring caloric balance as a part of weight management [207];
- the “Affective Diary” [327] is a kind of health-related diary, where both the commercially available sensor “Pulsewatch” from *Polar* and the “SenseWear” armband from *BodyMedia* [37] are used. One purpose of this diary so far is research on whether its representations supported and sustained the reflection of embodied experiences, i.e. the visual representations on the Tablet PC; and
- the “Mobile Health Diary” [8], a mobile phone-based prototype to keep track of the amount of food intake against the exercise output.

My general view on fitness-related self-help tools is that these usually are very rich in functionality, and because of this they are usually hard to use even for exercisers. Another obstacle to using such fitness tools as part of an eHealth system for people with chronic illnesses is that they are usually too obtrusive to be used as a daily tool, e.g. chest belts and special types of shoes. The review by Neville et al. [248] suggests that the use of self-help tools based on mobile phones is still immature in interventions aimed at physical activity behaviour change, since only one of the 16 computer-tailored interventions that they included used mobile phone technology.

Heart Related: Generally, heart diseases involve more immediate risks than the various kinds of diabetes and other lifestyle-related diseases. The use of technology for this disease case reflects this: usually, the sensors are constantly active, and communication to health care actors is involved. Some examples are presented below:

- The electrocardiogram (ECG) sensor from Alive Technologies has been used in combination with a smartphone to measure and wirelessly transfer QT intervals [222]. A prolonged QT interval on the ECG is associated with increased risk of arrhythmia and sudden death. The patient may then use this tool on her own, even though the data is transferred to a health care service.
- The concept described by Fensli et al. [105] is a construction of an ECG-sensor with a wireless, continuous event recorder for ECG-signals. The sensor manages wireless transmission of the recordings to a receiver integrated as a component within a hand held device, i.e. a PDA.
- Lee et al. [210] present another system based on mobile phones and pulse monitoring, which is designed to improve management of blood pressure. Their system comprises a rather large sensor unit, but demonstrates the use of Bluetooth technology to transmit blood pressure, pulse rate and temperature values to a mobile phone, and from there into the health care system.
- A simpler setup was chosen in the Singapore study [313], where patients’ health data are transmitted to a healthcare system by the patient or caregiver, through a Web portal or by SMS messages.
- The “eHit Health Gateway” proposed by Holopainen et al. [158] for wireless transfer, e.g. coagulation data (INR values), to health care professionals. Their concept involves wireless transfer of the data via the patient’s mobile phone, to the health care service.
- The “Wellness Diary” [256], which is a more general mobile phone-based application that enables recordings of blood pressure, weight, eating habits, exercise, and other parameters.

Thus, the nature of heart diseases often implies rapid measurements and strong involvement of the health care sector.

Asthma is a chronic disease which is generally treated by avoiding the things that trigger asthma attacks and taking one or more asthma medications. It sometimes involves use of a peak expiratory meter (PEF), and treatment varies from person to person. Examples of mobile systems and studies related to this disease include the following:

- A mobile phone-based monitoring system for self-management of asthma is described by Pinnock et al. [280]. This system consists of an electronic peak expiratory meter linked to a mobile phone, and the peak flow recordings and current symptoms are sent to a central server accessible to both patients and their clinicians.
- A study by Ryan et al. [304] also describes a system linking a mobile phone to an electronic spirometer/peak flow meter. It is said to have an easy transfer of peak expiratory flow rate- data, symptom scores and medication usage, and to provide immediate feedback to the user.
- Lee et al. [209] describe a Web-based mobile asthma management system, using a Pocket PC, mobile phone and desktop computer. Their study concludes that the combined use of fixed and mobile units showed about 10–30% higher frequency of server access than that from a fixed unit only.
- The company “BeWell Mobile”designed an asthma management application for children and teens, which used a mobile phone to monitor symptoms and to collect relevant medical information [39],[40]. Data are sent to a server, which initiates an automatic response based on predefined clinical parameters.

Even though the consequences of poorly managed asthma are not as critical as for heart-related diseases, the identified examples of mobile tools all involved the health care sector. The reason for this is probably that asthma generally does not need as close monitoring and attention as diabetes and heart diseases do, but for people with more serious cases of asthma, contact with the health care personnel is required.

Smoking: There are currently few studies that address use of tailored mobile self-help tools in smoking cessation. Some however address use of the standard, built-in functionalities of mobile phones, typically SMS or MMS (multimedia messages).

- One of these is the study of Rodgers et al. [299], where users in the intervention group received regular, personalized text messages providing advice, support, and distraction designed to help them give up smoking. Conclusions from this study were that the results were better for the intervention group than the control group and that this tool offered potential for a new way to help young smokers to quit, being affordable, personalized, and not location dependent.
- Another example targeted US college students, described in [32], where mobile phones and Web were integrated to deliver a smoking-cessation intervention for 46 smokers. After six weeks, one fifth of the group had quit smoking.
- Also targeting US college students, a prototype text-messaging program and a Web-based program were used in a tailored intervention to support smoking cessation by 31 young adult smokers with positive results [296].
- A study by Lazev et al. [206] examined using mobile phones to improve access to smoking cessation counselling in a low-income, HIV-positive population (n=20). These authors conclude that “Unfortunately, the lowest income groups, whose smoking prevalence is the highest, are being excluded.

However, this group could possibly receive the greatest benefit from telephone counseling."

- Whittaker et al. [365] describes a concept of sending multimedia messages to participants' mobile phones, as part of a smoking cessation programme. It was concluded that this concept was feasible and acceptable to young people. Nine of the 15 participants stopped smoking during the four-week pilot study.
- The mobile phone-based "QuitSmokingMobile" (QSM) application, which is commercially available, is described as "using the principles of behavior modification and gradual nicotine withdrawal" [290].

Use of multimedia tools in smoking cessation interventions seems to be more frequent than mobile tools, and the study of Brendryen and Kraft [45] shows long-term treatment effects. This intervention lasted 54 weeks and comprised more than 400 contacts by e-mail, web-pages, interactive voice response and SMS. Otherwise, mobile technology used in smoking cessation programmes seems to be limited to SMS, MMS or the ordinary phone functionality.

Other areas where mobile self-help tools are used are:

- Mental health – e.g. the "Mobile Mood Diary" [347];
- Chronic obstructive pulmonary disease (COPD) – e.g. in the study described by Liu et al. [225];
- Cancer – e.g. for managing chemotherapy-associated side effects [362];
- Obesity – e.g. the TMS system [241], the Sensorphone system [354], and two SMS systems for overweight users [273] and [127];
- Eating disorders – e.g. the use of SMS as a therapeutic intervention [150];
- Dementia – the GSM- and GPS-based mobile "rescue locator" [223];
- Epilepsy – the PDA-based application for reporting side effects of treatment [120]; and
- Elderly people and healthcare in general – e.g. a mobile phone-based system for helping people with early dementia with everyday activities, described by Donnelly [90], and the mobile medication adherence system "SIMpill" [319], which sends SMS reminders about patient's medication.

Generally, mobile self-help tools or diaries within these areas seem to encompass few new concepts, but rather to utilize the ability of mobile phones or PDAs to record parameters or symptoms electronically, and to communicate such data within health care personnel-operated services.

2.2 Mobile Terminals

Until recently, mobile health applications have been based on PDAs, e.g. [58], [105],[187]. Due to the rapid evolution of mobile phones into phones with PDA facilities, so-called smartphones, mobile phones have become the preferred mobile health terminal to a growing extent, e.g. [192],[326],[364]. An alternative might be to design a patient terminal using reconfigurable components, as I have described elsewhere [386]. Using programmable logic devices (PLD) would enable the user and the logic of the system to change both the functions and the hardware in real time. The patient terminal system can then be designed in a very dynamic and tailored way, but the costs and time involved in prototyping such a system have so far been beyond our limits.

2.2.1 Mobile Phones

The concept of using an already available and "always" present terminal like the mobile phone is ideal for usability and economic reasons. This choice eliminates the need and cost of an extra device to carry and charge, and also eliminates the need to educate users in the additional hardware features and to some extent the software features of the self-help applications. Both despite and due to the rapid evolution of mobile phones, there are still bottlenecks in their use in eHealth applications. Issues like limited computing power, short battery lifetime, lack of robustness, and troublesome user interaction are causing unwanted limitations. The lack of standards among terminal providers also causes difficulties in reusing and building on each other's eHealth applications.

There are dozens of operating systems running on mobile phones, compared with two main operating systems for 95% of the world's stationary computers [332]. The best known mobile operating systems are the Symbian OS (S60/UIQ), Windows Mobile, Linux, Palm, and iPhone OS. Applications for mobile terminals may be written in Java 2 Micro Edition, C++, C# using .NET Compact Framework, and Visual CE, among others. The promising new OS "Android" is said to enable modifying the mobile phone similarly to a desktop computer [93], holding the potential for further enhancement of the design of health applications on mobile terminals. The Android operating system is a multiprocess system, open source based, created by Google for the Open Handset Alliance[5], and may evolve into an important platform.

2.2.2 Current Relevant Mobile Phones

Mobile phones like the Nokia 5500 Sport [257] or the Sony Ericsson W910i [322], both with a built-in accelerometer – that is, a physical activity sensor –are good candidates as terminals. The reason is that one of the external sensors in the Few Touch concept would then be an integrated part of the patient terminal and not a separate unit. Thus, a solution based on such phones could be a positive factor for usability, if the users would accept wearing the phone in a way that enables proper registration of their physical activity. The HealthPia GlucoPack Diabetes Phone [56] also constitutes a patient terminal that can eliminate one of the elements of the Few Touch application, i.e. the built-in blood glucose sensor would make the external glucose sensor redundant. However, these kinds of phones typically do not have touch-sensitive screens, limiting the user interaction to the physical keypad[6] [184]. Also, their smaller screens both limit the amount of text or graphics to be displayed and limit the visibility of the information. In addition, their operating systems have not shown the same flexibility for designing tailored applications, especially regarding Bluetooth communication with external sensors. These factors have so far been considered so important that the benefit of omitting one of the external sensors has not compensated for them.

The iPhone, see Fig. 4, is widely regarded as a ideal platform for lifestyle-changing applications, e.g. as described at the unwiredview.com's web page [326]. The problem with using the iPhone is that until very recently this terminal has not been

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[5] http://www.openhandsetalliance.com/

[6] Standard for mobile phones is the ISO keypad layout, with 12 keys, 10 for the numbers 0-9 plus the * and # characters.

open for developers, so that it has not been possible for us to implement any eHealth-tailored software on it. Another problem is that this terminal has until recently not been on sale in many countries, including Norway. Although the terminal is promising with regard to user interaction in particular, this has unfortunately made it impossible to test the iPhone as a candidate for the Few Touch application and for mobile eHealth terminals generally. None of the existing 60 diabetes applications for the iPhone identified at “Apple Store” – see Table 2 – supported automatic transfer of blood glucose data, or covered all the cornerstones of good diabetes management: healthy diet, blood glucose management, exercise and education.

Other relevant large-screen mobile phones are the LG *Ke850 Prada* [141], the Motorola *MOTO Q 9* series [242], the Nokia N series [258], the HTC Touch series [160], the Sony Ericsson *X1* [323], the Samsung *Omnia* (SGH-i900) [308], and the HTC *Touch Diamond* [161]. The Few Touch application has been tested and found to work on the latter two phones, and also on the HTC *Touch Dual*; see Fig. 4. The *Touch Diamond* has a small size and would fit in many pockets, but without any physical keypad. The *Omnia* is larger and has a larger screen, also without a physical keypad, but larger softkeys. Both of these two kinds of phones will be good candidates for future studies of the Few Touch application concepts. The chosen terminal is the HTC *Touch Dual* for the reasons described in Chapter “4.2.3 The Patient Terminal”.

Fig. 4. The HTC Touch Diamond, the Samsung Omnia and the HTC Touch Dual (adapted from www.htc.com/europe and www.letsgomobile.org). All three support the Few Touch application.

2.3 Sensors and Data Capture Systems

The state of the art for the three data capture systems used in the Few Touch application is described below. The area of focus for the data capture systems is limited to systems that can be tested on patients with the approval of the regional ethical committee, and systems that can be operated in everyday life by the users themselves, i.e. as self-help. This excludes non-approved blood glucose sensors, some “body sensor network” systems, implantable sensor systems, and other systems that will not fit into the everyday life of patients.

2.3.1 Blood Glucose Sensors

Over the last few years, blood glucose test times have been reduced from 45 seconds to only 5 seconds, and the blood sample size from 10µl to less than 1µl. There are at least 20 different types of blood monitoring devices available today [352]. A thorough review by Farmer et al. from 2004 [102] identified 539 papers describing telemedicine interventions to support blood glucose self-monitoring in diabetes. After filtering the papers for their inclusion criteria (systematic capture and transmission of blood glucose results to a health-care provider) they found that none of the trials used a mobile phone. However, there are now many blood glucose measurement systems based on mobile phones, and I will describe some of them below.

The majority of systems for achieving better blood glucose control have required the patient to type the blood glucose value into a terminal, typically a mobile phone, PDA or PC, e.g. [107],[201]. This is often perceived as a tiresome process and seldom has the potential to be used on a regular basis. Although about half of all the personal blood glucose monitors do have an interface for directly communicating data, applications utilizing the interfaces suffer from functionality that is too complex for most patients to use. Of these meters with an interface, almost all are based on wired RS232 communication, with a few using IR (Infrared communication). The majority of systems that utilize the interface are designed for cable connection with a PC. Recently, systems for mobile communication of blood glucose data have appeared, e.g. “GlucoMON” [82], “T+ Diabetes” [94], “Polymap Polytel” [234], see Fig. 5, and “CyberFab” [71].

Fig. 5. Systems for mobile communication of blood glucose data: The GlucoMON system, the T+ Diabetes system and the Polymap Polytel system (adapted from [82], [336], and own photo).

The "Polymap Polytel" system [234] is according to my knowledge the only commercially available system that enables a fully automatic transfer of blood glucose data as in our prototype (see Paper 3, [384]), and has for this reason been chosen as the Bluetooth adapter for the Few Touch application.

The "GlucoMON" system [82] is a long-range wireless data transfer system, based on *Diabetech*'s long-range wireless network. A long-range radio transmitter is attached as a "jacket" to the serial port (RS232) of the blood glucose meter. The system requires the user to detach the meter from its jacket (serial-port adapter), measure the blood glucose level, and replace it in the jacket to initiate an automatic transfer of the blood glucose data. Alerts may be sent to e-mail systems, cell phones and pagers, and the system is primarily intended for children with Type 1 diabetes.

The "T+ Diabetes" system [94] is based on short-range communication between a serial Bluetooth cradle connected with the blood glucose meter and a mobile phone. A Java program installed on the mobile phone enables GPRS transfer of the measurements (and optionally nutrition, insulin, illness and physical activity data) to a secure web server. At any time, the data can be examined both from the Java program on the phone and on a Web page. Optionally, a clinician can monitor the patient data on the web page. The primary user group for this system is young adults (18 years and older). The user must initiate the transfer of blood glucose values and other data manually via the phone's menu, and must manually switch on the power of the Bluetooth cradle.

The "CyberFab" system [71] also consists of a Bluetooth adapter that is connected to BGMs, enabling wireless data transfer, though not fully automatically. I have not found this system on sale, but from March to September 2008 we were using it as part of the cooperative project with the University of Washington [297].

The study by Mamykina et al. describes a similar system used in their research, called MAHI [229], based on a "modified and custom-programmed Brainboxes[7] BL-819 RS232 Bluetooth Converter". However, this is said to need a battery change once a week, and is thus not relevant for the purposes of our application. Another Bluetooth-based blood glucose system that might be relevant is the "smartLAB genie" [156], but no descriptions of clinical use of this system were found .

For patients who use insulin as medication and get it delivered through an insulin pump (mostly those with Type 1 diabetes), the "CONTOUR LINK" from Bayer HealthCare [25] is able to wirelessly transfer the blood glucose values to the pump. The pump then uses the blood glucose values to help the patient in adjusting the right amount of insulin. This system was recently introduced to the Norwegian market (August 2008). The same is true of the system from *Animas Corp.* [15], which was in July 2008 cleared by the FDA[8] . This system, called "OneTouch Ping", features an insulin pump that wirelessly communicates with a BGM. It helps the user to calculate insulin doses and optionally wirelessly instruct the pump to deliver insulin without touching the pump.

Continuous blood Glucose Monitoring (CGM) is evolving and is dominated by four manufacturers: *DexCom* [81], *Medtronic* [235], *Abbott* [2] and *A. Menarini* [1]. It seems that smaller companies or initiatives find it difficult to maintain a position in

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[7] www.brainboxes.com

[8] FDA, the U.S. Food and Drug Administration.

this market, e.g. the promising innovation product "GlucoWatch" was withdrawn from the market by the latest owner *Animas Corporation* recently [84]. The FreeStyle Navigator BG sensor [3] from *Abbott* has built-in wireless communication with the receiver, though the protocol is proprietary. This sensor can be worn for five days, and the receiver has built-in Bluetooth communication, so that it is theoretically possible to transfer data to a mobile phone or other terminal. Due to the proprietary standard, this is in practice not possible. Generally, CGM sensors need to be calibrated against ordinary BGMs up to several times a day, and are also considerably less accurate than the conventional BGMs. A more detailed overview of studies and experiences with CGM systems appears in the article by Bloomgarden [33].

2.3.2 Physical Activity Sensors

In addition to the use of axial movement sensors, using heart rate monitors or global positioning system (GPS) devices has increased in popularity and availability as products. Heart rate monitors have the disadvantage that the user has to wear a transmitter chest belt, something most people find too obtrusive to wear on a daily basis. GPS is a good tool for measuring the user's movement, but is mainly useless indoors due to lack of signal strength from its satellites, and also needs frequent recharging due to a relatively high power consumption compared with the other sensor types. Besides innovative research applications, for practical reasons traditional step counters still seem to be the chosen device both for people aiming to monitor their physical activity in general and for clinical studies. Even though they are typically somewhat inaccurate and show too few steps [231], some devices have acceptable measurement qualities and are practical for use in either clinical practice or research, with good results, e.g. [19], [50], [78] and [294].

The growing awareness of the increase in obesity and Type 2 diabetes as well as a general concern with health and fitness have resulted in a strong focus on the use of step counters/pedometers as a tool for self-monitoring of physical activity. Step counters and pedometers are usually referred to as the same physical device, where the difference is only in functionality. Pedometers also calculate the distance walked, but this requires the user to enter the stride length. Today, step counters are mainly attached to the belt on the hip and have a built-in LCD to display the number of steps taken. Step counters are probably one of the cheapest (approximately €30) and simplest devices used to measure physical activity, containing mainly a mechanical 1-axis movement sensor. Since the design is so simple, step counters also hold the potential to be easy to operate and understand, robust, and long-lasting, fully in line with the goals of the Few Touch application concept. The current trend is that step counters are integrated into MP3 players and mobile phones, marketed as a fitness feature. A large overview of research based on step counters/pedometers may be accessed at New-Lifestyles' Web page.[9]

[9] http://www.new-lifestyles.com/research.html.

Examples of Systems: A totally unobtrusive system for easily attaching physical activity measurement sensors to people may be hard to find. Examples of innovative systems that approach user-friendly and/or motivating ways of activity measurements are:

1. the SensVest [191], which requires the user to wear a specific vest with embedded sensors;
2. the PAMS system [213], which captures data on body posture and movement by embedding six sensors in a harness worn as underwear;
3. the combined GPS and accelerometer (activPAL) system [228];
4. the My Tracks application based on Android phone(s) and its built-in GPS [136];
5. the MPTrain system [265], which uses music to improve exercise performance and is a combined heart-rate monitor and movement monitor device;
6. the mobile-phone-sized NEAT-o-games application [122] using Bluetooth for transfer of the accelerometer data to a PDA;
7. the Houston system [69] for encouraging activity by sharing step counts with friends, consisting of the Omron HJ-112 pedometer and the Nokia 6600 mobile phone;
8. the multi-modal sensor board and Bluetooth unit enclosed in a box worn on the waist for wireless monitoring [211];
9. the “Suzuken” physical activity monitor with infrared data transmission, fitted with a button allowing subjects to introduce event markers [344];
10. the SportBrain First Step pedometer [325] where one uploads the data to a personalized Web site using a USB cable or an ordinary phone line, used in the study aimed at nutritional counselling and weight loss [294];
11. the Fitbit Tracker [108] which is a small three-dimensional motion sensor for tracking various activities, where data may be uploaded wirelessly to a Website;
12. the Actiwatch AW7 [55], a waterproof wrist-mounted device which detects and logs movement intensity and duration, and data can be downloaded to a PC for analysis. The paper by Hurling et al. [166] states that the authors together with Cambridge Neurotechnology Ltd. have developed the Actiwatch further into a Bluetooth-enabled wrist-worn device;
13. the Pam – Personal Activity Monitor [74], a pedometer-like device that also uploads activity data to the Pam coaching site [269] via a USB cable, but features more advanced data capture as it distinguishes between walking and running, and also measures energy expenditure as the metabolic equivalent (MET);
14. the ex3 Plus pedometer from Silva [318] which can be positioned anywhere and still counts the steps correctly, it also has automatic one-week storage and zeroing of the day’s values each night;
15. the Omron Walking Style X [267] – which also can be positioned anywhere. The Walking style X actually also measures the *Metabolic equivalents* (METs), i.e. the intensity of exercise as a ratio to the intensity used when resting;
16. the Wellness Diary element of the Nuadu system [5],[233]. Nuadu is an ICT-based personal wellness management system with start-up functionalities for personal assessment and tools for making wellness-related self-observations during and after the intervention;

17. the GoWear fit system [38] from BodyMedia, which is an armband plus a display unit, that measures several physical activity-related parameters, also during sleep. Data is uploaded by plugging it into the PC and uploading to a Website. A fitness version of this system called “BodyBug” is also available;
18. the Shakra prototype tested in a pilot project study [11], proposing a system to measure physical activity without using sensors, i.e. using an artificial neural network to analyse GSM cell signal strength and visibility to estimate a user’s movement; and
19. the ActiS sensor node system [185] described by Jovanov et al., which includes accelerometers for motion monitoring, based on ZigBee wireless technology, and designed to maximize battery life by using “event-driven” messaging rather than constant transmission of data. This system enables continuous monitoring of physical activity for 31 days before battery replacement is needed.

Fig. 6. Examples of physical activity measurement sensors: SportBrain Tracker with USB Transmitter, the Pam, and the Silva ex3 Plus (adapted from [325],[269],[318]).

There are certainly many interesting prospects for wearable and embedded sensors for physical activity, where the sensors are woven into the clothes (smart clothes), e.g. [312]. Today, the state of the art is that there are several fitness products commercially available, e.g. the ones mentioned in Chapter 2.1.2. However, patient-operated sensors for medical purposes that measure physical activity are most often at proof-of-concept level, like the one described above, and not all of these have been offered for clinical trials.

2.3.3 Systems for Capturing Nutrition Habits

Understanding one’s eating habits, the nutritional content of foods, and the impact that dietary habits and choices have on blood glucose is especially important in managing diabetes. Information and communication technologies (ICTs) designed to capture, record, and provide feedback on individuals’ eating habits may enable people with diabetes to better manage their condition, and several Internet-based systems are available [284]. Although relatively little is known about the relative strengths, weaknesses, or effectiveness of specific approaches to the design of mobile ICTs, recent early-stage design research studies and commercial products indicate that these questions warrant further exploration. Automatic systems for nutrition registration are of course difficult to design, but some attempts have been made. An interesting system is presented by Amft et al. [10], involving acoustic analysis of chewing sounds to detect food intake. This system involves placing a microphone inside the ear canal – said to be an unobtrusive location – and the authors claim that “up to 99% accuracy is achieved on eating recognition and between 80% to 100% on food type classification". Another example is the "Diet-Aware Dining Table" [59] – where RFID sensors and algorithms were used to detect and distinguish how people eat, with a recognition accuracy of around 80%. The more widely used nutrition habit registration concepts may however be classified into these three groups:

A. Web- and PC-based nutritional registration. This concept requires a relatively thorough registration of food intake, e.g. kind of food, size of each of the meal components, and preparation methods. The keyboard of a PC is used as the input device.

B. Mobile phone photo blog registration. With this concept the registration process requires use of a mobile phone only, but the feedback or analysis is often made by accessing a Web site. The registration is performed by taking one or more photos with the mobile phone's built-in camera, and annotated as needed.

C. Mobile phone-based nutritional registration. This concept is an easier version of A, but the aim is still to register in some detail the kind and size of the food portions eaten, using the small-sized or softkey keyboards on the mobile phone.

It is likely that mobile phones will become the preferred hardware platform for eHealth obesity interventions, as concluded for example by [350]. The reasons given for this are that this kind of mobile terminal both enables effective intervention design features and promotes rapid public adoption and acceptance.

It is however also hard to find examples of mobile phone-based systems for diet or nutrition registration, and most of the ones that I found are in their infancy, in the form of pilot studies and student projects. Examples of this are:

1. a working prototype of a nutrition registration system for mobile phones, intended for children and their parents – described by Hanson-Smith et al. [146];
2. the "PmEB" mobile application focused on caloric balance, food lookup, and activity information – described by Tsai et al. [348];
3. the concept of a virtual health specialist available on a mobile phone – described by Silva et al. [317];
4. the use of disposable and digital cameras for documenting eating habits and relevant daily routines that affect the blood glucose – described by Smith et al. [321];
5. the mobile phone-based carbohydrate counter application "HelpDiabetes" [73]; and
6. the semi-automatic system "DiaWear" for food recognition using mobile phones described by Shroff et al. [316].

There are also some commercially available mobile products or services, such as:

1. the blood glucose monitor “OneTouch UltraSmart” [218] for making a note of meals;
2. the “MyFoodPhone” [244],[338] system where one can take a picture of the food using the phone’s camera, sending it to a community or nutrition advisor and getting feedback or advice back;
3. the “Wellnavi” [358] – a mobile food-picturing system based on a PDA, where pictures of the food before and after the meal are sent to dieticians for analysis;
4. the “vClinic Mobile Diets” [341] – a mobile phone-based diary for managing your diet, e.g. setting calorie aims, fat intake limits, or cholesterol limits;
5. “SugarStats” [330], which is a Web-based system that is adjusted both for browsers on mobile phones and PCs, and one can register different kinds of meals together with other information relevant to diabetes;
6. “CalorieKing Handheld Diet Diary” [54], which is a Palm OS-based diary for both diet and exercise including a food database; and
7. “DietMatePro” [26], a system for monitoring patients or study participants who are making dietary changes by integrating Palm and Web technologies.

2.4 Conclusions Regarding the Current Self-Help Tools

The majority of the mobile phone-based self-help solutions are either utilizing the very simple functionalities such as SMS, or more content-rich functionalities such as pictures and illustrations managed by the MMS services or mobile Web. The designers of existing solutions seem to be too ambitious on behalf of the users, since they often expect the users to be willing to perform a great deal of manual data gathering by using small keypads or by using the softkeys or stylus on the small touch-sensitive mobile-phone screen. Fragmented functionality is available across a variety of systems, but it is hard to find solutions incorporating sensors, analysis, feedback, and general information in a holistic way. Bluetooth as a short-range communication standard is spreading rapidly, but as long as the Medical Device Profile for Bluetooth [34] is not fully established, the sensor connections are neither easy enough to implement, nor adequately standardized.

In the next chapters I will present the way I have involved patients in the design and research processes, in arriving at a suitable patient terminal, three data capture systems, and wireless and automatic communication between the elements.

3 Methods

I have combined both methods from medicine and computer science in my study, i.e. traditional research methods like focus groups, interviews and questionnaires, HCI methods like paper-prototyping, thinking aloud sessions and user-participatory design, and prototyping and iterative design on both the software and hardware components of the Few Touch application. Using various methods is in line with the recommendation from Wilson [368], who states that patient-centred studies should definitely use triangulation, i.e. using not one but several methods, measures and approaches, in the process of designing good patient-centred tools. Love [226] emphasizes both that most HCI research has been carried out on non-mobile systems and applications, and that the needs of all actors should be considered in the design process. Many of the methods used are further described in Appendix 9 and examples of use and general experiences and recommendations are presented in Paper 2 [385].

3.1 User Involvement

3.1.1 Approval by Ethical Committees

The World Medical Association Declaration of Helsinki [375] states among other things: “The health of my patient will be my first consideration”. This declaration is essential in clinical research (involving patients) and it is administered by local ethical committees. For all of the three studies that involved patients (the Type 2 cohort, the Type 1 cohort and the US cohort), an application describing the protocol and the risks of the project was written and sent to the local Regional Ethical Committee (REK). For the main cohort, (Type 2) this was done in February 2006 and approved later that year. After receiving a detailed explanation of the project as a whole, the right to withdraw at any time, and other practicalities, the study participants gave written informed consent to their participation. For the Type 1 cohort, the protocol was approved by REK in 2003, and for the US cohort, approval was received in 2007.

3.1.2 Recruiting the Cohorts

For the Type 2 diabetes study, 15 people with Type 2 diabetes were recruited through letters sent to all members of the local diabetes association (Tromsø area) who were between the ages of 40 and 70 years. A small number of these were also recruited at a meeting for members of the local diabetes association, where a presentation of the project was held with an option to sign up for the study after the meeting. This Type 2 cohort is regarded as the main user group for my work, and the individuals participated actively in many of the design processes that resulted in the Few Touch application. When they were recruited (December 2006), the 15 participants were aged between 41 and 67 years. During the focus group meetings in spring 2007, one of the informants withdrew, and two others withdrew during the spring of 2008, leaving us with 12 participants for the main test of the Few Touch application from September 2008 to March 2009. This explains why I refer to 15, 14 and 12 informants respectively at different stages. Four of the participants were men, none of whom withdrew from the study. The eligibility criteria comprised having Type 2 diabetes, being between 40 and 70 years old, being confident about measuring their blood glucose and doing this on a regular basis. The exclusion criteria were having serious late complications and other serious illnesses.

For the Type 1 diabetes study, invitations to participate in the pilot study were sent to all of the 55 families of children with Type 1 diabetes who were patients at the University Hospital of North Norway. The first 15 parents who responded positively were accepted as participants. The group of children consisted of 11 boys and 4 girls, aged 9 to 15 years. The main intervention period was from October 2003 to February 2004.

The US cohort was recruited via paper flyers posted on bulletin boards at various locations in buildings of the University of Washington, Seattle, USA. Participants included three people with Type 1 and three people with Type 2 diabetes, aged 18–65 years. In addition, the fourth cohort of 20 healthy people was presented with an early version of the Few Touch application at a telemedicine conference in June 2006, followed by a request to fill in a questionnaire. They were recruited while they were looking at our poster (Appendix 5).

3.1.3 Overview of Methods Used

A detailed overview of the methods used for the various issues addressed is presented in chronological order of use, in Table 3. The table also shows the number of participants or informants involved, and provides references to the published paper as well as the appendix describing the use of the method.

3.1.4 Use of Various Methods

Design and evaluation of health-related systems, prototypes and services are often performed without reference to human-computer interaction (HCI) theories and methods. Furthermore, the usability of IT systems for healthcare and computer-controlled medical devices is not always checked, with the result that systems are error prone, causing adoption and safety problems along with a high probability of negative workarounds [31]. It is thus clear that using more adequate design and evaluation methods can maximize the potential of telemedicine and eHealth applications.

User-participatory design applying the focus group method was the approach most frequently used throughout the design of the Few Touch application with the Type 2 cohort. The focus group method was chosen in order to provide in-depth insight into the knowledge, experience and views of the Type 2 cohort, as well as to involve real patients in the whole design process for mobile self-help systems. A set of other methods was also used, to achieve triangulation – the use of more than one data gathering and analysis approach on the same set of data (or cohort), to reach more rigorous and defensible findings ([300] p. 293).

The presentation of the methods is divided into two. First, the design-oriented methods are presented, i.e. the main methods that informed the designs achieved. Then I present research-oriented methods, i.e. the methods that informed the user perceptions and effects of the designs to the greatest extent. However, these two categories of methods are not distinct in function – we obtained many research-related results from the design methods, and a wealth of ideas and feedback on the designs from the research methods. Thus, the approach may be characterized as “design research" ([306], p.70), defined as "the act of investigating, through various means, a product or service's potential or existing users and environment".

Table 3. Issues addressed and methods used, listed in chronological order.

Issue	Method	Cohort	Duration (year)	No. of partici-pants	Published in	Related Appendix
Blood glucose measurement	Questionnaire	Type 1	4 months (2003-4)	15	Paper 6, Paper 3	Appendix 14
Blood glucose measurement	Interview	Type 1	4 months (2004)	15	Paper 6, Paper 3	Appendix 16
Likelihood that mobile diabetes tool would be used	Questionnaire	Healthy people	(2006)	20	Paper 2	Appendix 15
Physical activity	Focus groups	Type 2	2 x 2 hours (2007)	15	Paper 1	Appendix 11
Mobile phone screen design – physical activity	Paper prototyping	Type 2	2 x 1hour (2007)	15	Paper 1	Appendix 13
Blood glucose measurement	Focus groups	Type 2	2 x 2 hours (2007)	12	Paper 1	Appendix 11
Food habit registration	Focus groups	Type 2	2 x 2 hours (2007)	13	Paper 1, Paper 5	Appendix 11
Mobile phone as a self-help terminal	Focus groups	Type 2	2 x 2 hours (2007)	12	Paper 1	Appendix 11
Mobile phone usage	Questionnaire	Type 2	(2007)	12	Paper 1	Appendix 15
Feedback on early prototype (html)	Questionnaire	Type 2	(2007)	12	Paper 1	Appendix 15
Feedback on the self-help tool prototype, ver. 1	Focus groups	Type 2	2 x 2 hours (2007)	13	Paper 1	Appendix 11
Food registration methods	Think aloud	Type 1 and 2	6 x 90 min. (2007)	6	Paper 5	Appendix 12
General use of self-monitoring devices	Telephone interview	People in general	(2007)	1001	Paper 4	Appendix 17
Feedback on the self-help tool prototype, ver.2	Focus groups	Type 2	2 x 2 hours (2008)	11	-	Appendix 11
Usability – current mobile phones	Questionnaire	Type 2	(2008)	11	[63]	Appendix 15
Instructions for use of the Mobile phone	Focus groups	Type 2	2 x 2 hours (2008)	10 + 2	-	Appendix 11
Instructions for use of the Few Touch application (FTA)	Focus groups	Type 2	2 x 2 hours (2008)	10 + 2	-	Appendix 11
Lifestyle parameters before introduction of the FTA (*)	Questionnaire	Type 2	(2008)	12	-	Appendix 15
Presentation of the Tips functionality	Focus groups	Type 2	2 x 2 hours (2008)	12	-	Appendix 11
Lifestyle parameters before introduction of the Tips functionality	Questionnaire	Type 2	7 weeks (2008)	12	-	Appendix 15
Midway Feedback on the use of the FTA	Interview		4 months (2009)	12	[392]	Appendix 10
Lifestyle parameters before introduction of the Step counter functionality	Questionnaire	Type 2	4 months (2009)	12	[392]	Appendix 10
Feedback from the 6 months usage of the FTA	Focus groups	Type 2	2 x 2 hours (2009)	12	-	Appendix 11
Usability - Few Touch application	Questionnaire (SUS)	Type 2	6 months (2009)	12	-	Appendix 15
Usability - Few Touch application	Questionnaire	Type 2	6 months (2009)	12	-	Appendix 15
Lifestyle parameters after ½ years usage of the FTA	Questionnaire	Type 2	6 months (2009)	12	-	Appendix 15
Actual use of the Few Touch application	Automatic logging	Type 2	6 months (2009)	12	-	Appendix 18

* FTA = Few Touch application

3.2 Design Methods

3.2.1 User-Involved Design

User-involved design is especially addressed in the HCI research and communities. The HCI field is relatively young, and emerged in the early eighties [23]. Many HCI-oriented researchers and actors focus on involving users of future products and services to a much greater degree than is often the case in other areas, e.g. Bannon [23], Bødker [52], Nielsen [251], Ballegaard et al. [22], and Kyng [200]. The "Scandinavian tradition" is known within HCI as design with especially active engagement of users, and is said to go back to the 1970s [51]. There are many other terms referring to design where users are involved in a particularly active way, e.g. user-participatory design, participatory design, cooperative design, user-oriented design, and user-centric design – although this last term is said to be "weaker" in that it implies that the users are centred but not necessarily involved. In light of this focus and the reasons given in the Introduction chapter, I aimed to involve patients closely in the design process of the Few Touch application. In addition, for all processes of the design, both regarding software and hardware design, the system developers have also either participated in the user meetings or been provided specifications as output from the user meetings, questionnaires, interviews, thinking aloud sessions or other user-oriented methods.

After the recruitment of the cohort, the efforts to involve and keep the patients in the Type 2 study have been: sending invitation letters the week before the user meetings; sending SMS reminders a few hours before the meeting the same day; making phone calls to the participants when needed; having two different alternatives for meetings so that as many participants as possible were able to attend; having no more than eight people at each meeting; and providing the active users with feedback from the results of some of the tests that had been conducted. The latter was considered important for letting the participants feel that the input they provided was really used and appreciated. The drop-out rate was low; only one of the 15 participants chose to leave the study, while two others had to leave because they were moving to another part of Norway. Originally, the study of the use of the Few Touch application among the Type 2 cohort was planned to last four months, but was extended to six months, to enable collection of more and better data. An important argument for this is given by Jensen and Larsen [180]: "Some issues will not be apparent before the user has used the service for a while and incorporated it into the daily routine." Ideally, the patients should have used the system for a whole year, to compensate for seasonal fluctuations, especially autumn, Christmas and summertime.

Thus, the reason for involving users so actively in the design process corresponds to the overall aim of the study: to generate knowledge about how a mobile tool can be designed for supporting lifestyle changes among people with diabetes. During the various user interactions, they gave feedback on how they would like a comprehensive mobile phone-based self-help application to be put together as a sustainable tool. The Few Touch application was tested in real-life settings over a period of half a year, to avoid the problem caused by testing restricted to the laboratory, well described by Jensen and Larsen [180]: "users might say, that they will be interested in using a given feature after trying it a couple of times, but in reality they might scrap it after a few weeks or find some workarounds to do the same task in a more convenient way. Not because they are intentionally lying, but simply because they cannot imagine how it would be to use the given feature in the long run.” As Muller [243] used the PICTIVE technique to involve users in a rapid-prototyping environment, we used various methods for the same purpose, e.g. paper prototyping, use of a paper diary, SMS interaction, and html demos, which are all described below.

3.2.2 Scenarios

Scenarios are described as “stories about people and their activities”; scenarios should highlight goals and behaviour of the system, what people try to do with the system, and how people interpret what happens to them [57]. Instead of observing the everyday life of the principal character of the scenario, e.g. using an ethnographer as Carroll suggests in [57], we gained such knowledge through focus group meetings with the Type 2 cohort, and from the knowledge gained from previous projects and interventions for diabetes patients. The typical eHealth application scenario is a small story describing the history of a patient prior to the main problem. Then it presents the main problem followed by an introduction of the eHealth application. Finally, it presents some examples of how the proposed application eases the patient’s everyday life, for example as was done for the SuperAssist project [142].

For my research, scenarios were used in the design process of the application, and in oral presentations to audiences at conferences and meetings. Thus, this method has been useful in communicating concepts, facilitating fruitful discussions both internally in the project team, and externally with peers, health care personnel, industry and others. The scenario method has also been used for coordinating actions internally by the research and development team. At the request of one of the programmers (R.V.) of the Few Touch application, I wrote a scenario that exemplified the functionalities and settings for the software, as part of the requirement specification (Appendix 18). This scenario is further refined and presented in Chapter “4.3.2 Functionalities”.

3.2.3 Paper Prototyping

Paper prototyping is a very quick and inexpensive method for obtaining users’ feedback on concepts and solutions. Retting [293] has provided a useful description of how it can be integrated in the design process. Tohidi et al. [345] present a variant of paper prototyping called the “sketching exercise”, and their conclusion is impressive. Compared to traditional test methods like the thinking aloud protocol, interviews and questionnaires, using the “sketching exercise” to discover and communicate design ideas required a fraction of the time and money. Another argument for using paper prototyping is that when users are presented with a paper version of a digital concept, they are more likely to get the right impression, namely that this is a rough sketch and the solution has not yet been built. If presented with a digital demo such as an html or Microsoft PowerPoint demo, they might think that the application already exists, and that their feedback will not be so important and valuable for the research team. In sum, paper prototyping gives the users a genuine feeling of participating from the beginning in the design process, and having an impact on the end solution. An example of paper prototypes that were given to the Type 2 cohort at an early stage is presented in Fig. 7.

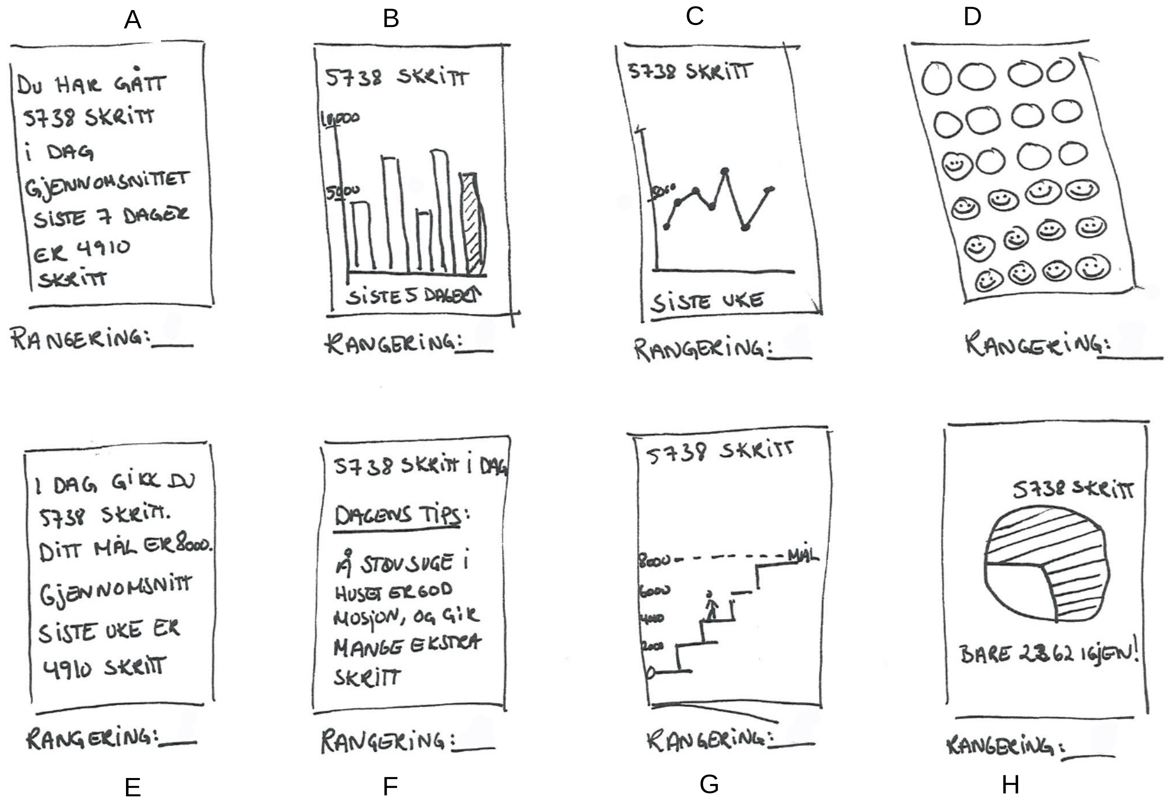

Fig. 7 Paper prototypes given to the Type 2 cohort for ranking preferred ways of receiving feedback on physical activity.

In addition to asking for their rating of the predefined examples of mobile-phone feedback screens, we asked for their own suggestions. This generated 17 new suggestions for other ways of getting feedback on their daily physical activity. Two examples of these are presented in Fig. 8.

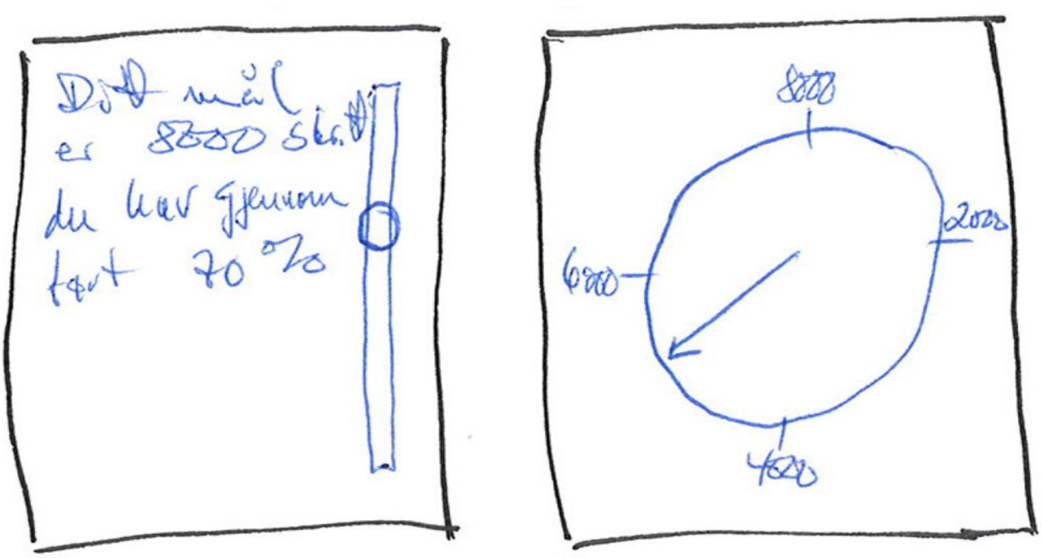

Fig. 8. Some of the users' suggestions for feedback screens for physical activity – regarding how the number of steps so far today may be presented.

Thus, by using the paper prototyping, or more specifically the sketching exercise method, we found the way that our Type 2 cohort preferred to receive feedback on their mobile phone about their daily and weekly physical activity. We also obtained knowledge about other ways they would like to get such information presented.

3.2.4 Prototyping towards Proof of Concept

Prototyping may encompass several stages of realising a concept, from early mock-ups as described by e.g. Ehn and Kyng [95], to fairly mature, near-finished products. Despite the low functionality of mock-ups, they facilitate active user involvement; they are cheap and efficient ([95] p.172), and have been used by industrial designers for decades, e.g. Dreyfuss [91]. One idea of prototyping in general is that early usability evaluations can be based on cheaper and faster implementations, avoiding unsuccessful full-scale implementations ([250] p.93).

Prototyping towards proofs of concepts, i.e. to demonstrate that a particular configuration of ideas or approaches achieves its objectives, has been used throughout the whole process of designing the Few Touch application. An engineering approach is used for implementing the various prototypes to be tested in user studies. This iterative approach has been based on multiple development cycles of analysis, design, implementation and testing. For all the presented concepts, I have been the main organizer of the user interactions; I have documented the user feedback, concluded with the concepts, and completed high-level programming, hardware design and requirement specifications. The concrete software programming and hardware implementation have been done as part of several projects, mainly the projects: The Diabetes ICT Health Motivation Project [277], Automatic transfer of blood glucose data from children with type 1 diabetes [276], Chronic Disease Medication Management Between Office Visits [297], and Improved use of blood glucose data [278]. In addition to involving the active users in pre-tests of the concepts and prototypes, my colleague (G.Ø.) and I, who both have the related disease Type 1 diabetes, have conducted thorough and frequent tests throughout all of the design processes. This includes the Few Touch elements (blood glucose, step counter, food habits, goal setting, general information and the sensor and mobile phone) as well as the application as a whole. In this way it has been possible to conduct an iterative design process with a short user-test response time, even outside the main periods with focus group meetings, ending up with the requirement specification (Appendix 18) for the Few Touch application.

Prototyping the Wireless and Automatic Blood Glucose Data Transfer System
This design process was started as a feasibility project in 2001 [334], based primarily on my own experience with Type 1 diabetes, and secondarily on feedback from a super-user from the Type 1 cohort (n=15). Since blood measurements are performed in the same way for Type 1 and Type 2 diabetes patients, the same general concept has been used for both the Type 1 cohort and the Type 2 cohort. For the Type 1 cohort described in Paper 3 [384] and Paper 6 [124], the sensor data were sent as SMS messages to the patient’s relative(s), using a self-made Bluetooth adapter prototype (see Appendix 19). The more mature Type 2 concept that is part of the Few Touch application transfers the sensor data to the patient’s own mobile phone, described in Paper 1 [391]. For the Few Touch application, a Bluetooth adapter from Polymap Wireless is used [282], with the mobile phone HTC Touch Dual [162], which made it necessary to update the design and software from the Type 1 study. The new

prototype of the blood glucose data transfer system was presented and tested on the Type 2 cohort in April 2008, and system functionality and patient terminal feedback screens were accepted by the users. Small adjustments were made on the basis of the experience that my colleague and I obtained with the prototype until September 2008. The prototype was then finally tested on the Type 2 cohort during the half-year main study, September 2008 to March 2009.

Prototyping the Wireless and Automatic Physical Activity Data Transfer System
This design process started in September 2006 with the aim of finding a solution for achieving the same "No-touch" data transfer concept as for the blood glucose system, described in Paper 3 [384]. In addition to using input from the Type 2 diabetes cohort, specific hardware component solutions were found and initial microcontroller procedures were programmed in cooperation with the local electronics company *Senso-Tek*; hardware components utilization and further microcontroller algorithms were programmed and adjusted in cooperation with a master's student ([266], Paper 4); and 20 units of a "no-touch" step counter application were produced as part of the Diabetes ICT Health Motivation Project [277], with the help of another local electronics company, *Polar Elektronikk*, and the collaborative partner *Telenor R&I*. The final step counter version was then presented to the cohort in April 2008, and the feedback led to changes in the fastening method, i.e. a snap fastener instead of a clip. The prototype was tested on the Type 2 cohort for two months from January to March 2009.

Prototyping the System for Easy Capture of Nutritional Habits
An early concept for using the touch-sensitive screen of a mobile phone to register food habits was sketched in May 2006 and tested on a cohort of 20 healthy people in June 2006 (Appendix 5). This main design process was based partly on the user-participatory design process in the user interaction (see Appendix 11) with the Type 2 cohort in February 2007, as reported in Paper 1 [391], and partly on the feedback from the thinking aloud study (see Appendix 12) on the US cohort presented in Paper 5 [390]. The food habit recording application was first implemented as an html demo to be tested on the cohorts, and has now been implemented using .NET/C# as a part of the Few Touch application. Feedback from the involved cohorts was transcribed, coded, and analysed; conclusions were then drawn. The user-participatory design process resulted in three main functionalities of the nutritional habit recording application: goal setting, data entry, and user feedback. These functionalities were tied together: when the user logs data about food that has been eaten, the feedback provided is based on the personal goals of the user and the actual details recorded. The near-finished prototype of the food habit registration system was presented and tested on the Type 2 cohort in April 2008, and system functionality and patient terminal feedback screens were commented on and accepted by the users. Small adjustments were made on the basis of the experience that my colleague and I obtained with the prototype until September 2008. The prototype was then tested on the Type 2 cohort during the half-year main study, September 2008 to March 2009.

Prototyping the Few Touch Application
The main elements of the Few Touch application, i.e. the two patient-operated sensor systems, the nutrition habit capturing system, and wireless and automatic communication procedures, were realized for the active users through the software called the "Diabetes Diary" (in Norwegian: "Diabetesdagboka") running on the mobile phone. In addition, a goal setting element, a general disease information element and a shortcut to the phone functionalities are part of the application. The

user thus has a total of six main choices from the main menu, and no underlying menu choice will lead the user more than three levels down. This design is based both on the early prototyping and experience described in Paper 2, Paper 3, Paper 6, Appendix 4, Appendix 5, and Appendix 9, and on user feedback from the main cohort between February 2007 and September 2008, partly documented in Paper 1 [391] and Appendix 10. Through the focus group meetings and the other methods described, the participants clearly expressed a wish for an application that was easy to use, but with the main elements mentioned.

User-involved design, paper prototyping, html prototyping, software and hardware prototyping, facilitated by involving the patients in focus groups, have thus been the main design methods used to arrive at the current version of the Few Touch application.

3.3 Research Methods

3.3.1 Focus Groups

Focus groups are unstructured interviews with small groups of people, where interaction with each other and the group leader(s) may stimulate discussion, provide insight and generate ideas [42]. Krueger and Casey explain the purpose of a focus group as “to listen and gather information” and “a way to better understand how people feel or think about an issue, product, or service” [194]. Twelve years ago, Gibbs [128] noted that this method had a long history in market research, was under-used in social research, and had more recently entered medical research. As stated by Nielsen [251], the focus group method is suitable for assessing user needs and experience both before interface design and a long time after implementation, which is how it was used in our studies. A typical size of each group in the meetings is between six and nine users, and the duration is typically around two hours. Kuhn [195] emphasizes the creative process that often takes place during the session, the intense exchange of ideas, perceptions, and experiences, and also that focus groups are an instrument for convincing developers and policymakers to take user needs into account.

The focus group method, which entailed frequent gathering of real patients in focus group meetings was the main method of involving the Type 2 cohort in the design and research on the Few Touch application. The plans for each of the focus group meetings arranged with the Type 2 cohort are described in Appendix 11. They lasted for two hours, and the number of active users varied between five and eight. Especially in the beginning of the intervention with the Type 2 cohort, we focused on letting the focus group meetings work as explorative studies, to get hold of the patients’ views and suggestions on ICT and self-help. As also emphasized by Kitzinger [190], we encouraged the participants to talk to one another during the meetings, asking questions, exchanging experiences and commenting on each others’ points of view.

The concept of giving the patients homework between the focus-group meetings, as described in Paper 1 [391], worked well. Approximately 80% of the participants did put an effort into this. The kinds of homework given were: wearing an ordinary step counter, increasing the use of blood glucose monitoring and reflecting on the results, and sending the project team SMS feedback with (non-sensitive) personal goals between the meetings. The research group followed up on the homework at the subsequent meetings, thus showing that the patients' input was highly appreciated. This was presumably the reason that they remained highly motivated to put an effort into their subsequent homework as well.

The meetings with the focus groups have all been audio- and/or video-taped. Some of the recordings from the focus groups have been transcribed and analysed, and used as data material in Paper 1 [391] and Paper 5 [390]. During most of the meetings, three project members have participated, where two of us have mainly been responsible for asking questions, initiating discussions and managing the themes of the meeting, while the third participant has taken notes during the discussions. These notes have been valuable in helping us to recall what has generally been discussed during the meetings, and also to aid in finding specific discussions in the 2-hour long recordings. The focus groups were arranged in the NST's assembly rooms, and were usually hosted by a project manager of related projects, a system developer and myself acting as the main facilitator. The timeframe of each focus group meeting was two hours, divided into two sessions separated by a break of 10 minutes. The patients did not receive any incentives other than refreshments at the meetings. In total 20 sessions of focus groups with the Type 2 cohort were arranged, divided among 10 main thematic issues, as described in Appendix 11, i.e. a total of 40 hours of structured interaction with this cohort. These sessions gave us good insight into the cohort's disease, their views and suggestions on how to change lifestyle factors using mobile technologies, and feedback on the Few Touch application.

However, basing one's conclusions solely on information from focus groups is not recommended, "since there are often major differences between what people say and what they do" and "you shouldn't use them as your only source of usability data" [251]. My work and conclusions were therefore based on other methods as well, as described below.

3.3.2 Questionnaires

Benefits of using questionnaires are that they are inexpensive, easy to administer to large samples of users, and can quickly provide both quantitative and qualitative data. Even though it is an obvious advantage to be able to compare your own data with others researchers' data when using a standard questionnaire, my colleagues and I have mostly designed specialized questionnaires in all the studies presented. However, when possible, specific questions from known questionnaires have been included. As claimed in the widely cited book *Asking Questions ([43] p. 23)*: "It is always useful before creating new questions to search for questions on the same topic that have been asked by other researchers." An argument for designing specific questionnaires is given by Bradley in the *Handbook of Psychology and Diabetes* [44]: "...when designing measures specifically for people with diabetes we can focus on those issues which are especially important for them and avoid irrelevancies that will cloud the picture. In this way we can produce diabetes-specific measures that have greater sensitivity than generic measures." For our research, it was important, in addition to asking health-related questions, to address issues such as how the users evaluated using the mobile phone as a self-help terminal, their experience in using the attached sensors, and how they experienced the self-help tools as a whole.

Questionnaires, pre- and post-intervention, have been used both in the Type 1 diabetes study described in Paper 3 [384] and Paper 6 [124], and in the Type 2 diabetes study described in Paper 1 [391], in the latter study both on the active users and on the reference group. Most of the questionnaires have been tailored to the specific user groups and the aims of the studies. The recommendations for designing customized questionnaires outlined in the ETSI standard EG 201 472 [100] were used as guidelines. However, the questionnaires for the Type 2 study have been designed on the basis of selected items from the questionnaires in the "HUNT[10] 1" study [261], the "HUNT 2 study – diabetes" [262], the "MoRo[11]" study's questionnaire [260], the "Diabetes Quality of Life Measure" (DQOL) [44], and the "Perceived Competence Scale" (PCS) [367], in addition to the questions we formulated ourselves that were tailored to explore the experience with the aspects of the Few Touch application. The SUS usability scale [48], a simple, 10-item questionnaire, has been used to achieve information about the Type 2 cohort's subjective assessments of usability of the Few Touch application. For subsequent patient trials, where the aim is to quantitatively test medical effects of the Few Touch application, it will be relevant to apply widely used and validated questionnaires like the "SF-36 Health Survey" [361], the "Summary of Diabetes Self-Care Activities" (SDSCA) measure [346], and similar. The use of well-known and often used questionnaires such as the SF-36 Health Survey makes it possible to compare the results from different studies. However, by standardizing the measures to a 100-point scale, it has been shown that it is possible to compare between different measures as well [337], i.e.:

$$\text{Standardized score} = \frac{\text{actual raw score - lowest possible raw score}}{\text{possible raw score range}} \times 100$$

This has not yet been done for the results from the studies in this dissertation, but may be a candidate for further publications based on this and the subsequent data collected after the formal end of the PhD project studies. The questionnaires used in the described studies are presented in Appendix 14 and Appendix 15. They provided valuable specific and quantifiable feedback from the cohorts, which supplemented the information obtained using the other more qualitative methods. Much of the statistical information presented in the "Results" chapter is based on the questionnaires.

3.3.3 Interviews

The interview method can be time consuming and costly. There are generally three types of interviews: structured, semi-structured and open-ended interviews, the latter also referred to as in-depth interviews [46]. The interview types used in the presented studies were either semi-structured or open-ended, and typically consisted of pre-formulated questions as a help to focus the discussion on the problems under study. Most questions were broadly formulated in order to stimulate content-rich answers, and ad-hoc questions were also asked – since in the interview the researcher sometimes obtained information that made it possible to develop valuable new questions, an approach recommended by Witzel [370].

For the Type 1 study of the effects that the wireless blood glucose data transfer system had on the patients and their parents, as described in Paper 6 [124], a semi-structured guide for parent interviews was designed; see Appendix 16. After interviews with 10 parents, no new information emerged, data saturation was reached,

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[10] One of the world's largest-ever health studies, see www.ntnu.no/research/research_excellence/hunt.

[11] The Romsås in Motion study, see www.fhi.no/artikler/?id=56624.

and further interviews were unnecessary. No predefined code scheme was used, but the data were coded with respect to the patterns emerging, an approach often used for feasibility studies, e.g. the study by Mamykina et al. [230].

For the study of the effects that the Few Touch application had on the Type 2 cohort, a semi-structured interview guide and a structured interview guide were used for two different purposes and at two different times. To obtain reference data on the actual use of relevant sensors in the Norwegian population, I took the initiative to include a question on the use of health monitoring devices in the “European citizens' use of E-health services” [14] study April 2007. A question on the prevalence of use of health sensors among an arbitrary selection of 1001 Norwegians was asked in telephone interviews (CATI); see the question in Appendix 17: “

Interview Guide 2 – Added question to the 2007 survey on eHealth trends”. A professional polling agency performed the interviews, and in addition to the other questions they asked how often the informants had used a step counter/pedometer, pulse monitor, blood pressure monitor and blood glucose monitor during the last half-year. Using this method gave us a good indication of how widespread the use of self-monitoring devices is in Norway, and thus confirmed one of the assumptions for the Few Touch concept.

Secondly, interviews aimed at exploring general impressions during the study were conducted individually with each of the 12 active users; see the attached interview guide in Appendix 17: “Interview Guide 1 – Individual talks 4 months after the introduction of the Few Touch application, prior to test of the step counter application, Jan. 2009”. These interviews also made it possible to discover elements to refine for those patients who wanted to continue using the system throughout 2009 (all of the 12 patients volunteered to continue, and are now part of a subsequent long-term study of the Few Touch application).

3.3.4 Logging

Video recorders, audio recorders, manual forms and automatically recorded systems are useful tools for capturing data – tools that were also used in this PhD project. A practical consideration regarding tools like these was stated by Dumas [92]: “the goal is to record key events while they happen rather than having to take valuable time to watch videotapes later”. Dumas refers to three ways of recording data more efficiently: using good data collection forms, using data logging software, and automatically capturing activities in log files. When users are testing prototypes over a fairly long period in their home environments, it may be feasible for them to write a diary. However, it is challenging to motivate users to actually write down their experiences, concerns or impressions. In the DELTA project described by Venturi and Bessis [353], only 5 out of 16 users returned their diaries at the end of their project, even with the use of awards as an encouragement.

In the Type 1 diabetes study described in Paper 6 [124], the patients and their respective relatives were asked to document experiences, ideas and other relevant aspects related to no-touch concept they were testing. Instructions for doing this were provided at the beginning of the four-month long study, but were not followed up during the study or at the end of the study, with the consequence that none of the 15 families involved returned diaries from the study. As part of the initial phase of the

Type 2 diabetes study, the patients were asked to document their nutritional, blood glucose and physical activity experiences, prior to the next focus group meeting. Most of the 10 patients who were provided with a diary (an ordinary appointment diary) did put an effort into it, bringing the diary to the next user meeting and referring from it.

During the six-month user test in the Type 2 study, the Few Touch application automatically logged all entered or automatically transferred user data in a local database on the mobile patient terminal (mobile phone). This method of gathering data on use of the system has been very useful in the process of drawing conclusions on the lifestyle-changing effects and usability issues. However, there was no logging of general use of the application, e.g. when users were just looking at the step count data, blood glucose data or food habit data to see their progress or achievements, as implemented for the “DiasNet Mobile” system [180]. As the project manager and main contact person for the cohort, I manually logged excerpts from all phone calls, SMSs and contact with the participants during the six-month user test, to make it possible to sum up data such as error rates of the tested systems.

3.3.5 Thinking Aloud

The thinking aloud method originates from the field of psychology, where the authors Ericsson and Simon were early publishers of the method. Within the HCI field, Nielsen ([250], p.195) classifies the thinking aloud method as maybe “the single most valuable usability engineering method”. He explains that by asking the test users to verbalize their thoughts when they use a computer system, one obtains information about how the system is perceived, and misconceptions can be identified. According to Dumas [92], the thinking aloud method used in usability testing, in contrast to cognitive psychology, focuses on reporting not only thoughts, but also expectations, feelings and other things that the test subjects want to report. It is important that the informants are told that the test probes the usability of the prototype, and not the user’s skills or experience.

In the cooperative study together with University of Washington [390], the thinking aloud method was used on the US cohort consisting of six patients. The investigators performed laboratory-based usability testing based on a modified thinking aloud protocol [186]. The December 2007 study (designed and conducted by the co-author J.T. from Paper 5 [390] and me) incorporated user testing of an early version of the Few Touch prototype and a functional prototype of the Food Photo Moblog system in addition to a commercial Web-based nutrition application for PCs. The six-user test sessions were performed in the Laboratory for Usability Testing and Evaluation (LUTE), averaged 90 minutes in duration, and were video-recorded and audio-recorded. Participants were observed and interviewed while using the prototype ICTs under scripted simulated conditions (see Appendix 12) to elicit their perceptions of ICT design strengths and weaknesses, ease of use, and potential utility in supporting their diabetes management goals. In addition to responding to open-ended interview questions and thinking aloud while performing these scripted test cases, participants were also asked a series of pre-defined questions after completing each test case. The recordings of the patient interaction were subjected to thematic analysis. Open coding by the authors yielded unique emergent concepts, which were clustered to form summarized themes presented in Paper 5 [390].

The thinking aloud method provided valuable feedback on the Few Touch application concept, specifically the nutrition habit registration system. Even though the nationality of the cohort was different from that of the main cohort for the Few Touch application study, useful tips and information, as well as confirmations of the views and preferences that the Norwegian Type 2 cohort had expressed, emerged from this study.

3.3.6 Usability Assessment

Several of the methods mentioned previously are used to gather usability data. Nielsen and Molich [252] describe heuristic evaluation as an quick and informal method of usability analysis, requiring a small group of evaluators. The idea is to present user interfaces and let the evaluators express their opinion about what is good and bad about the interfaces. Evaluations should be done individually and the evaluators do not need to be usability experts, according to Nielsen – an approach that we followed (or one could argue that the real users – the patients – are the real experts in this case).

In the design of the Few Touch application, we used variants of heuristic evaluation to obtain rapid feedback on which concepts were sound and applicable. As evaluators, in total 40 people were used, both with and without Type 2 diabetes. Several user interfaces and functions were first implemented as html prototypes, and tested on 20 people without diabetes at a telemedicine conference in 2006, using the tailored form in Appendix 15: "Questionnaire A – Early Feedback on the HTML demo". An improved version of this html prototype was demonstrated for the (then) 14-patient Type 2 cohort in 2007, followed by asking them to fill out the same questionnaire (Questionnaire A). In December 2007, a further refined prototype, with emphasis on the nutrition part and on setting of personal goals, was presented for the six-patient cohort in Seattle [390], using the thinking aloud method; see Appendix 12.

One of the conclusions from the case study described by Jokela et al. [183] was that most industrial development projects have specific constraints and limitations, so that an ideal use of usability methods is not generally feasible. They stated that usability methods should be selected and tailored based on the specific context of the project. For our case, a tailored usability-focused questionnaire was designed and administered to the Type 2 cohort at the last focus group meetings (March 2009). In addition, the original SUS usability scale [48] was translated into Norwegian and administered to the cohort at the same meetings (see Appendix 15).

Using heuristics thus provided us with necessary information about how to proceed to the current version of the Few Touch application, in an efficient and inexpensive way. Making html demos instead of fully functioning applications in an early phase of the design process saved us much time and energy. The thinking aloud method was rich in content, and gave us a great deal of insight into wanted and unwanted concepts and functionalities. We found this information very useful, even though – or perhaps because – the users were of another nationality. The SUS usability scale and the tailored usability questionnaire provided subjective and specific assessments of usability of the Few Touch application's elements.

3.4 Criticism of the Methods Used

The Cohorts: The main criticism of the methodologies used may be that it is mainly the same cohort that has been used as informants throughout the last part of the work towards the Few Touch application, which has generated the most results. Except for the Type 1 cohort described in [124], the US cohort described in [390], and the reference group described in [391], the Type 2 cohort comprises the patients who have provided information about how their everyday lives, which kind of tools they would be likely to use to improve their health, and what they think of the designed prototypes. In addition, the recruitment of the informants was addressed to members of the Norwegian Diabetes Association, resulting in a more motivated cohort than the general population with Type 2 diabetes. No control groups for the studies have been recruited, which would have increased the validity of the findings.

Lack of Field Studies: No ethnographic study or everyday evaluation in the field has been performed for any of the cohorts, as advocated in e.g. [70] and [57]. An ethnographical analysis of the Type 2 cohort in particular could have improved the scenario presented, enabling adjustments to the results, and even leading to new conclusions. As Carroll [57] argues: “Ethnographic field studies often bring to the light facts in the background of the context of use, circumstances and relationships of which the actors themselves may be unaware.”

Bias: Two of the members of the project group, acting as designers, interviewers, moderators and facilitators of the focus groups and the other methods have diabetes themselves (Type 1). Generally, using interviewers with in-depth knowledge of the subject may bias the questions and thus the results. This criticism was addressed, in that the facilitators were aware of this situation; they were very careful to avoid asking leading questions, and to keep the questions as open-ended as possible. Also, in some of the methods, unbiased colleagues were engaged. The facilitators’ high level of relevant knowledge may have led to more detailed questions and answers. Another bias is the self-selected cohorts. In future, the designs should therefore be tested on informants who have not previously participated in trials of this nature, and people with diabetes who are not necessarily members of any association for patients.

Questionnaires: Specially designed questionnaires were used in all sub-studies of the PhD project. Using standard questionnaires would have enabled comparison of this project’s results with data from other studies. This was however difficult to do due to the fact that similar interventions were hard to find. The quality of the self-designed questionnaires used is also debatable, and should be considered before re-use. Questionnaires like the widely used and validated questionnaire SF-36 Health Survey [361] could have been used for monitoring changes in health status, nutrition and exercise for the Type 1 intervention. Candidates for questionnaires for subsequent Norwegian interventions testing the medical effects of the Few Touch applications may involve a combination of questions from the SF-36, the main questionnaire from the Romsås og Furuset Health Study 2003 (MoRo) [154], and the “HUNT diabetes” questionnaire from the Nord-Trøndelag Health Study (HUNT2) [342].

Prototyping: The paper prototyping method was quick and efficient, and resulted in many interesting suggestions from the active users. It yielded many other ideas for presenting the sensor data to patients, but I did not manage to summarize the 17 new suggestions into any new ways of presenting data that many enough agreed on as ideal. However, some of the 17 suggestions confirmed the conclusions that a combination of graphics and text was most appreciated by the active users, like the B alternative presented in Fig. 7. The paper prototyping method was efficient and could have been used more, e.g. for the food habit registration functionality, the goal setting function and the general information function.

Thinking Aloud: Using the thinking aloud method regarding registration of food habits on a national cohort other than the Norwegian cohort may be open to criticism. A counter-argument is that most of the functionality was suggested in the Norwegian focus groups, and the thinking aloud sessions with the US cohort functioned as a test of this functionality on a completely different cohort, which also gave rise to new views and comments on requirements for the application. Examples include the need for a way to cancel food habit entries and the wish to be able to specify and personalize the goals and the categories of data to be recorded.

Work Load on the Participants: Giving the participants tasks to do between the focus group meetings may be perceived as a burden on the participants. Although we made it clear to the cohort that the assignments were completely voluntary, some participants might nevertheless have felt obliged to perform the given tasks. There was no negative feedback at the following user meetings that indicated that this was a negative way of increasing the user input. Also, at each new change in the study, the participants were given a new informed consent form (which happened three times for the Type 2 cohort), reiterating that they could withdraw from the study at any time, without giving any reasons for this.

Data Analyses: Regarding the background statistics presented in Paper 4, the informants were all Norwegian, and the questions were single questions with no possibilities to ask follow-up questions. The high prevalence of people using step counters/pedometers may have been influenced by the media focus for 1-2 years prior to this survey on the benefits and ease of use offered by such devices for measuring physical activity. The analysis of the user data from the six-month study on the Type 2 cohort was basically done by one person only (me), but one of my colleagues (N.T.) analysed the same dataset for more in-depth usability issues in her research. Also, the dataset and aggregated result files were made available internally and I encouraged my colleagues to comment on these, which they did. Thus, even though time did not allow a full process where two or more investigators analysed the data and transcripts, this way of sharing both the raw data and the aggregated results hopefully worked as a quality assurance mechanism to prevent wrong interpretation of the data. The process of letting cohort participants be involved in the interpretation of the data, as argued by Sundström et al. [331], was not used for our study.

Usability Assessment: The SUS usability questionnaire was originally designed to be used right after a user test, but for the Type 2 diabetes study it was used after the half-year intervention. One can also question my translation of the original SUS scale [47]. When considering re-using it, one should be aware that when doing the translation I had our Type 2 cohort and our Few Touch application in mind, and consider the arguments by Erkut et al. [97]. How well the questionnaire used to assess the specific usability issues of the Few Touch application (Appendix 15, Questionnaire H) is designed is also open to debate. Furthermore, to achieve more thorough feedback on usability, the more detailed questionnaires like the 50-question Software Usability Measurement Inventory (SUMI) evaluation questionnaire [164], the 27-item Questionnaire for User Interaction Satisfaction (QUIS) [60], or the 19-question Computer System Usability Questionnaire (CSUQ) [214] could have been used.

4 Design

Below, the cohorts, the use cases, the concepts and ideas, as well as some characteristics and facts relating to the diabetes cases that have formed the final design choices, are described. The designs are to a large degree rooted in an understanding of the disease cases, the target groups' daily challenges, and the possibilities that ICT holds. This knowledge about the target group's challenges and preferences is derived partly from the fact that I have diabetes myself, partly from the 8-10 diabetes projects I have participated in the last eight years, and partly from the interventions and findings from the cohorts presented in this dissertations. This approach may be in line with Winograd's view of focusing on the conceptual model in software design: "The most important thing to design properly is the user's conceptual model. Everything else should be subordinated to making that model clear, obvious, and substantial." ([369], p.17)

Some of the premises on which I have based the presented designs are the following (the main issues are shown in bold type):

1. Most people with diabetes have the same need for **mobility** as people without the disease, meaning that self-help tools for this group must be portable and flexible in use.
2. People with diabetes need to measure their blood glucose (to varying degrees), which itself is a cumbersome task, and may even be experienced as a stigmatizing task in some situations. ICT-based tools aimed to improve their health should therefore be **pervasive**, i.e. not add additional burdens, and they should be as inconspicuous as possible.
3. For some people, being able to view the historical trend of their **blood glucose** values easily will inspire them to improve these values.
4. People with Type 2 diabetes generally need to increase their **physical activity**, but motivation for such a change is often hard to find. ICT-based tools to motivate this group should therefore be ever-present, easy to activate, easy to wear and easy to operate.
5. People with diabetes generally need to be conscious of which **food types** they eat, to reduce the amount of carbohydrates, increase the amount of fibre, fruits and vegetables, and eat many, but small meals.
6. Nutritional habits have to be recorded manually, and an ICT tool to help with the recordings should be as **effortless and fast to use** as possible, but still provide useful feedback after registration. The same usability premises apply to the blood glucose and physical activity elements.
7. An ICT tool should give some kind of **feedback** regardless of whether the user has done well or badly, and the feedback should not be rude or impolite, to avoid making the user feel negative about the tool.
8. The main premise for being able to change nutritional habits is **knowing the** current nutritional habit **status**. The same premises apply to the blood glucose and physical activity status.
9. It is more valuable for the patient to monitor her/his food habits in less detail over a **long period** than in great detail over a short period. The same premises apply to blood glucose and physical activity data.
10. People with diabetes are in general more conscious and **knowledgeable** about nutrition, physical activity and blood glucose levels than people in general. If they are not, they have a responsibility to gain such knowledge.

11. If people with diabetes always have **access to information** about their disease, and accessing this information is free, then they are more likely to look up this information, and learn from it.

Despite the given premises, the awareness that everyone's daily routines are different has pervaded the design process. The challenge has been to arrive at a common set of functions that is still useful to the individual patient.

4.1 The Use Cases

4.1.1 The Type 2 Diabetes Cohort

People with Type 2 diabetes are as individual as everyone else, but they can be categorized in various groups to help us understand design challenges and the validity of the designs for other groups and purposes, e.g.:

A) newly diagnosed;
B) motivated, healthy patients who want to improve their condition;
C) patients who are motivated, but have considerable additional health problems;
D) people who want to avoid getting Type 2 diabetes;
E) health care personnel who want to help their patients;
F) less motivated patients;
G) relatives/friends who want to help a patient

The main cohort in my study falls into the category B, since it comprises members of the Norwegian Diabetes Association who volunteered for the study. The results from the user-interaction part of my work must therefore be interpreted with caution, taking into account the high level of motivation in this user group. Including patients from some of the other categories, e.g. F, is more difficult since the design approach used, user-participatory design, requires long-term patient participation. The use cases A and D would probably be easier to include than E, F and G, and may be candidates for subsequent studies of the Few Touch application.

In addition to the seven "motivational profiles" described above as various user groups, people with Type 2 diabetes may be classified into other relevant profiles such as: young/old, active/inactive, insulin regulated/oral medication regulated/food regulated, fit/overweight/obese, employed/unemployed/retired, primary disease/just one of several diseases, well educated/less educated, little/extensive knowledge about diabetes, etc. These profiles should be kept in mind in particular for the design of a tailored and/or self-configurable system (e.g. Appendix 6), which my work addresses to a lesser extent, but they are sound candidates for future designs and studies. The main use cases for the design of the Few Touch application and the Type 2 diabetes study are illustrated in Fig. 9. The diagram in Fig. 9 also shows the functionalities that are mandatory in the system, indicated by the <<Include>> arrows, and the optional functionalities, indicated by the use cases linked to the main use cases by the <<Extend>> arrows. The five main use cases describe the three data capture systems: blood glucose, physical activity and food habits, as well as goal-setting and general information. An example of this notation is the first use case – automatic transfer of blood glucose data to the users' mobile phone. The system always "displays the blood glucose data history after measuring", marked with the <<Include>> arrow, while the system provides an option for the user to "display blood glucose data graph on request", marked with the <<Extend>> arrow.

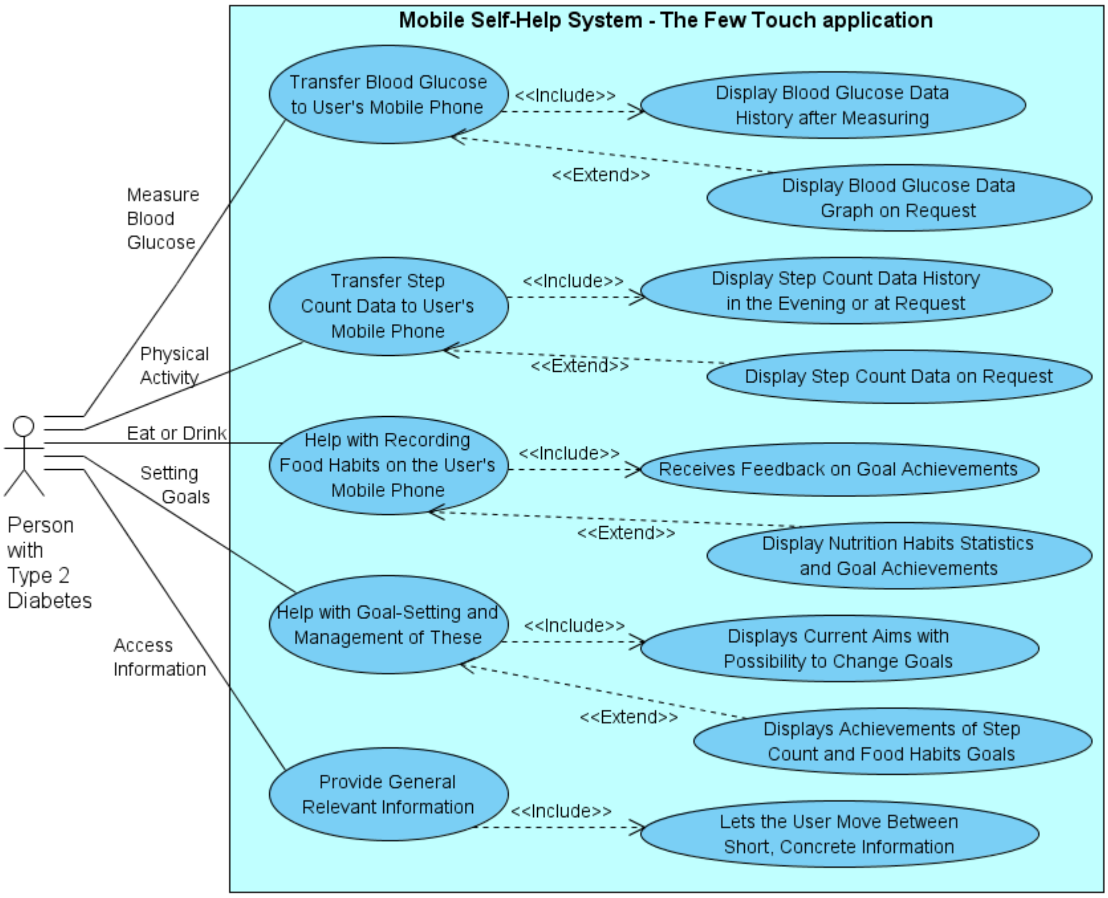

Fig. 9. Use case diagram of the Few Touch application for the Type 2 diabetes cohort.

4.1.2 The Type 1 Diabetes Cohort

Categories similar to those for the Type 2 diabetes case can be applied to Type 1 diabetes. However, for Type 1 diabetes, the age range is wider and has to be considered as an important parameter in the design of self-help solutions:

A) children;
B) adolescents;
C) adults;
D) elderly people;
E) relatives to any of the categories A-D;
F) any of the categories A-D with healthy diabetes management;
G) any of the categories A-D with unhealthy diabetes management;
H) health care personnel who want to help any of the categories A-D

Also for Type 1 diabetes, the degree of motivation has to be considered, but this group is usually more motivated since people with this kind of diabetes are totally dependent on some kind of self-management in order to stay alive (minimum insulin therapy and some form of blood glucose management). Whether the users are active/inactive, fit/overweight/obese, at kindergarten/school/work/retired, well educated/less educated, well-informed or less knowledgeable about diabetes, etc. are important elements, but it is of course difficult to take many of these into account when designing one type of tool.

The Type 1 cohort participating in the study presented in this dissertation represents category A, children. Since very many young people with diabetes have levels of HbA1c (long-term blood glucose) that are too high, one could also consider this group in terms of the category G, with unhealthy diabetes management. The main use cases for the Type 1 diabetes study are illustrated in Fig. 10 below.

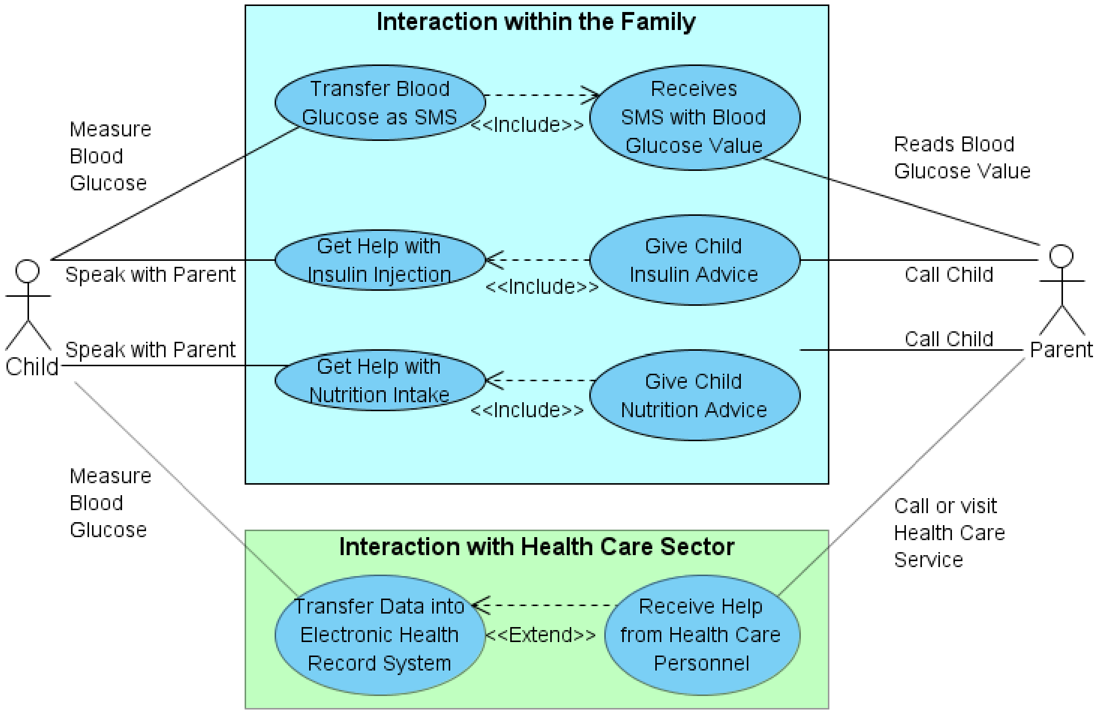

Fig. 10. Use case diagram of the Blood Glucose Sensor system for the Type 1 diabetes cohort.

The use case diagram presents two systems, of which the “Interaction within the Family” has been subjected to a clinical trial [384],[124], and the “Interaction with Health Care Sector” has been implemented only as a proof of concept [357],[397]. As Fig. 10 shows, there are two actors: the child with Type 1 diabetes and his/her relatives, who are the main helpers in the disease management. The main system automatically transfers blood glucose data from the sensor to one or two predefined mobile phones (usually the parents’). Since mobile phones constitute the patient terminal as well as the communication terminal for contacting the parents when the actors are apart, several use cases can be included in the system. The use cases for insulin and nutrition management are not supported directly by the system, but are implicit actions that often involve using mobile phones immediately after the system has delivered blood glucose values.

The other system, “Interaction with Health Care Sector”, has been implemented as a proof of concept. It sends blood glucose values to the electronic health record system Dips [357]. As indicated in Fig. 10, an option (<<Extend>> arrow) for improving the help that parents receive from health care personnel is to consult the database of automatically transferred blood glucose data.

4.1.3 Designing with Informants and Participators

The third cohort, the US cohort (six patients) that was used to inform Paper 5 [390], consisted of adults with either Type 1 or Type 2 diabetes. For my study, members of this cohort were used as informants only, in contrast to the members of the Type 2 diabetes cohort (12-15 patients) in particular, who were “active users” with extensive participation in the design process of the Few Touch application. One of the 15 members of the Type 1 diabetes cohort participated in the design process by using an early version of the No-Touch blood glucose sensor system prototype before the main intervention started and providing feedback on it.

4.2 The Data Capture Systems

As part of the design processes, user-involved design, focus groups, questionnaires, interviews, paper prototyping, thinking aloud, and scenarios have been used. The concrete designs have involved iterative processes with high-level and low-level programming as well as extensive testing of early concepts, functionalities and performance of the designs, until the prototypes were regarded as ready for user tests. The designs of the components, the main features, and the final Few Touch application are described below.

4.2.1 Sensors and Data Capturing

The Few Touch application involves use of one or more sensors during everyday activities. The aim is to design the application so that the use is as non-obtrusive as possible. The two concrete sensor units are a blood glucose monitor and a step counter, while the third data parameter, food habits, is captured by using the touchscreen-based user interface, described in Paper 5 [390]. Wireless sensor nodes generally consist of a sensing unit, a power unit, a processing unit and a communication unit, which also applies to the Few Touch physical sensors, described in Paper 3 [384] and Paper 4 [389]. The theory and approaches behind the design of the three data capture units and the other elements of the Few Touch application are presented below.

4.2.2 Wireless Communication

Wireless communication technology has made dramatic progress in recent years, with the emergence of standards such as Bluetooth, ZigBee, WiFi, and others. In spite of this, there are still only a few of the widely used sensor types such as blood glucose monitors (BGM) and step counters that are interfaced wirelessly to a health management system. Some BGMs enable data transfer using IR, but this requires aligning the monitor with the receiver to avoid disturbance of the communication signal, and the propagation distance is shorter. Bluetooth was therefore found superior and chosen as the wireless communication standard for the Few Touch application. Bluetooth is so far the only short-range communication standard that is widely implemented on mobile phones, and this was also one of the main reasons for the choice. Power consumption is an essential issue for increasing compliance in an application that is intended for use as a daily tool for people with a chronic disease. Fine-tuning of the communication modes of the units has made the implementations acceptable for approximately four to six months’ usage. Electronics were built for interfacing the Bluetooth units from connectBlue [67] to the RS232 port [384] on the chosen BGM, and a smaller version of the adapter was built into the step counter [389]. The Few Touch concept uses Bluetooth technology implemented in a way that fully automatically transfers sensor data into the patient terminal.

4.2.3 The Patient Terminal

Both the fact that very many new mobile phones are rapidly arriving on the market and the fact that people frequently change mobile phones make it challenging to foresee which terminal will be optimal as a basis for patient-operated health applications. The choice of the Windows Mobile 6.0 HTC phone "Touch Dual" [162], see Fig. 11, was based on the following main reasons:

Fig. 11. The HTC "Touch Dual", with both touchscreen and physical key interface.

a. The 14-patient Type 2 cohort preferred the possibility to both navigate and operate the phone using a touchscreen and physical buttons (as documented in Paper 1 [391]).

b. The patients found the phone and its features suitable and highlighted the advantage of having only one terminal to bring with them (feedback from user meeting April 2008).

c. The phone supported a large enough screen (41 x 54 mm) with a good resolution of 240 x 320 pixels, and simultaneously small enough (107x55x15.8 mm, 120g) to be perceived and used like an ordinary mobile phone.

d. Generally, the Windows Mobile Smartphones seem to perform better in multitasking than the iPhone and phones based on the other operating systems (currently, the Android OS phones might be an alternative), a quality especially important when the various elements of the Few Touch application are included.

e. The OS Windows Mobile was found to be the easiest system on which to program Bluetooth connectivity to the two external sensors: the blood glucose sensor and the step-counter sensor.

f. Models of smartphones similar to those that formed the foundation for the system design were found at an early stage (in 2005), and the current model "Touch Dual" was brand new in January 2008, i.e. it will stay in the market for a while (still in the market at July 2009). Also, HTC seems to bring fairly similar models to market, making it easier to transfer the concept to future phones and continue the development and testing in future.

The most important reasons, a, b and c, are congruent with other mobile technology design aims and guidelines, e.g. [314] and [24], regarding the need for ease of use and unobtrusiveness.

4.2.4 Design of the Blood Glucose Sensor System

The aim for the blood glucose sensor system as part of the Few Touch application was to enable unobtrusive wireless transfer and display of blood glucose data using the patient terminal (mobile phone). Unobtrusive, in this context, means without requiring any additional efforts from the user, other than measuring blood glucose in the usual way. For the Type 2 cohort, easy access to accumulated blood glucose values was regarded as leading to greater understanding and healthier values.

Requirements: Thus, the blood glucose monitor (BGM) used in such a system must have a communication interface and must be able to store blood glucose values measured previously, in case communication fails. Many of the commercially available BGMs do fulfil these requirements, but few monitors have open data communication protocols like some of the BGMs from LifeScan [219]. Another requirement, which is fulfilled much more rarely, is that it must be possible to use the monitor for measurements simultaneously with preparation of the communication interface for data transfer. In most cases this means that the RS-232 cable has to be plugged into the monitor while the measurement is performed. For most BGMs this is impossible, either because the RS232 port is the same as the measurement-strip port or because the monitor is physically switched into communication mode when the RS232 plug is inserted. The OneTouch Ultra and the OneTouch Ultra 2 meter from LifeScan Inc. [220] enable this. When we ran the first study, on the Type 1 diabetes cohort, there was no BGM Bluetooth adapter on the market that made it possible to transfer data fully automatically. Therefore, my colleagues and I designed and implemented such an adapter at that time; see Paper 3 [384], the master thesis of Andersson [13] for software design details, and Appendix 19 for hardware design details.

Design Choices: To achieve the aim of designing a system that did not need any additional actions from the user, we let the interface card power up the Bluetooth serial port adapter when it sensed a “power down signal” from the blood glucose meter. The meter is powered down either when the user removes the blood glucose test strip after a measurement or two minutes after a measurement is performed, due to an automatic power-down function in the BGM when the user forgets to remove the test strip. It was also taken into account that blood glucose testing might fail, requiring the user to repeat the test, so the interface card was set to keep power to the Bluetooth transceiver for a period of three minutes. The electronics were powered by a 3.6 volt lithium battery (size AA), with a 2250 mAh nominal capacity, enabling approximately four months of operation time, assuming that blood glucose is measured five times a day. All measurements stored in the memory of the BGM were transferred at each Bluetooth connection, to ensure that no measurements that had not been transferred were lost. With a baud rate of 9600, transferring all 150 measurements took only a few seconds. The software application running on the mobile phone kept track of the last measurement value sent and the time of transfer. If the system failed to send some earlier measurements, for example because the blood glucose monitor was too far from the mobile phone (> 10 meters), the application sent all the unsent measurements in batches of five SMS messages (due to the 160-character limit for each SMS). The current value measured was however given priority and was always sent first as a stand-alone SMS.

Integration with a Patient Terminal: As the long-range communication unit, the mobile phone Nokia 7650 was chosen for the Type 1 diabetes study. Using a mobile phone for this purpose enables sending the data as SMS messages, and if required, using the phone as a verbal communication channel at the same time. Patients could then use the same terminal for emergency calls and for disease support from relatives or health care personnel. The main requirements for the mobile phone were that it should be programmable and feature a short-range communication transceiver, Bluetooth in this case. To access both the Bluetooth and GSM/SMS protocols on the phone, it was necessary to program the unit using C++. The Nokia *7650* terminal runs the Symbian OS, Series 60 application framework, on which the application for blood glucose transfer is implemented. This involves handling incoming blood glucose values from the BGM via Bluetooth, checking which data has been transmitted earlier, and sending new data out to one or two recipients as SMS messages.

For the Type 2 diabetes study, the mobile phone HTC *Touch Dual* was used as the patient terminal. The self-designed Bluetooth adapter was replaced with the one from *Polymap Polytel* [234], which appeared on the market in 2007. Principally, the integration of the blood glucose sensor system and the patient terminal was implemented in the same way for both the Type 1 diabetes study and the Type 2 diabetes study. However, the Few Touch application was implemented on a phone running Windows Mobile, programming the application in C# using .NET Compact Framework. The code and details for this implementation have not been made publicly available.

4.2.5 Design of the Physical Activity Sensor System

The physical activity sensor system should be able to unobtrusively and wirelessly transfer and display data on the patient terminal, without any efforts from the user other than wearing the sensor and if desired, viewing the data on the mobile phone. The data should be easy to understand and interpret, and a one-axis movement sensor – a step counter – was therefore chosen instead of a three-axis movement sensor, or accelerometer. An accelerometer would have provided the user with information about physical activities other than walking, jogging and running, but would have been more complex to interpret; see the paper by Jatobá et al. [179] for details regarding pattern recognition of accelerometer data.

Requirements: The main requirement for the step counter was that it should be possible to wirelessly transfer daily step count data fully automatically, but also to transfer step count data to a mobile patient terminal at any time, by pressing only one button, once. Other requirements included convenient size and weight, a proper fastening method, robustness, the possibility to change the automatic transfer time, and several months of battery life.

Design Choices: No commercially available system was found that fulfilled these requirements, so I decided to go through the process of designing such a system based on the one-axis movement principle, described in Paper 4 [389], and in more detail in the master's thesis by Olsen [266]. The design of the physical activity sensor system has been based on the Type 2 cohort's feedback, the concept of fully automatic data transfer, state of the art within communication technology, microprocessors and electronics, in addition to the given timeframe and resources.

The design consisted primarily of five components: the mechanical sensor, a microcontroller, a Bluetooth adapter, a battery, and a button. It was decided to have no LCD on the step counter, since we wanted all interaction to be controlled from the patient terminal. To filter out random movements and noise, the application is programmed not to start counting before it has received six consecutive movements within a timeframe of 8 seconds. Then it counts normally until it has not been subject to any movements for 8 seconds. To optimize power saving, the embedded microcontroller is set to go to sleep between each step the user takes. Each new movement event will wake the microcontroller up for registering and storing the step. The 8-bit RISC microcontroller, the Atmel ATmega164P, can be programmed to transfer data depending on the patient's needs and health challenges. More extensive details around the hardware design (printboard layout, etc.) have intentionally not been included in this dissertation, to avoid affecting the prospects of a manufacturing process of the step counter application.

Integration with a Patient Terminal: A routine was implemented in software at the patient terminal to constantly listen for incoming data from the step counter. When data was sent, the routine stored data on the mobile phone in the application database, and automatically presented the current reading and a week of historical data as a bar chart diagram. The routine was implemented in C# using .NET Compact Framework.

4.2.6 Design of the Nutrition Habit Registration System

The nutrition part of the Few Touch application is a system that has been implemented in software, and runs on the patient terminal, i.e. the mobile phone. The purposes of this system are to make users aware of their eating habits, and to motivate them to change their eating habits towards three kinds of nutritional goals.

Requirements: The requirements for this system were briefly that the user should be able to use her fingers directly on the mobile phone's touch-sensitive screen, with as few touches as possible, to register eating habits. A consequence of this simplification is that the aim is to register nutrition *habits*, and not *nutritional contents* of the food intake. However, this consequence has been discussed with the 14-person cohort and found acceptable and also beneficial related to the likeliness of use [391], also confirmed by the 6-person US-cohort in Seattle [390].

Design Choices: In order to design the system for food habit recording for quick entry of approximate records of eating habits, many iterations and user interventions were performed. Firstly, an early concept was tested both on the cohort of 20 healthy people and on the US cohort, using an HTML demo.
Then, through a user-participatory design process with the Type 2 diabetes cohort, as described in the Chapter 5.2.3, an application with a user interface that facilitated the requirements was composed. The user launches the application via the Few Touch main menu, pressing the soft button "Food". The application then renders a graphical user interface displaying six categories of food or meal types as seen in Fig. 12. Records of food consumption are created and registered by touching the icon that best represents the food(s) consumed. Immediately following data entry the user is presented with a screen that shows their cumulative total registrations by category compared with their stated goals; see Fig. 15 – picture B. In an effort to motivate the users

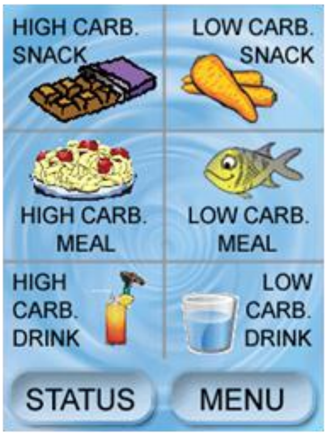

Fig. 12. The nutrition habit registration user interface.

of this system, achievements of the goals were indicated with smiley faces.

The nutrition habit registration is designed to allow users some degree of freedom. For example, users who would like to keep track of their fruits and vegetables – trying to reach 5-a-day – can press the "Low Carb. Snack" button, see Fig. 12, each time a fruit or vegetable is eaten. Users trying to replace high-carbohydrate snacks with low-carbohydrate snacks can press the "Low Carb. Snack" button each time they eat high-fibre crispbread, healthy biscuits, etc, and in this way monitor their progress. A third example might be a user with little need for energy at lunchtime, who wants to count an apple plus a banana as a meal, and presses the "Low Carb. Meal" button instead of the "Low Carb. Snack" button for this food intake.

4.3 The Few Touch Application

Putting the various systems together in one application was both a challenging and exciting exercise. The Few Touch application comprises five main elements, visible to the users, i.e. the blood glucose sensor system, the physical activity sensor system, the nutrition habit registration system, the personal goals functionality, and the general information functionality. Each element is accessible directly from the main menu, of which the two sensor systems' visual feedback on the mobile phone in addition is automatically launched after data transfer.

4.3.1 Stand-Alone Versus Healthcare Interaction Tool

The design of the Few Touch application has until now focused exclusively on use as a personalized patient-operated tool. This means that even though there are clearly good arguments both for transferring data to the health care system and for interacting with health care personnel, such features are omitted. Managing health challenges together with health care workers is very effective, e.g. a decrease in 1.3% (a considerable improvement) in HbA1c levels for 85% of the informants in the study by Sadur et al. [305], an effect seldom found in interventions using purely stand-alone applications. Health care interventions and services are however very time-consuming and costly; they cannot be offered to everyone with a chronic illness today, and this will definitely not become more likely in future, when the number of elderly people and the associated prevalence of chronic illness will be much higher than today. Implementing the concept of transferring the data directly into a electronic health record system, as demonstrated in one of our previous studies [357],[397] seems tempting. Medication recordings and advice could also be part of the tool, but there are several reasons that one should be careful about including this information. These functionalities have many potential implications and have therefore been omitted in the first version of the Few Touch concept. Among the more critical implications is the question of whether health care professionals could be held responsible for medical complications caused by unhealthy management of their diabetes, if blood glucose data and medication registrations were available at the hospital, and if the personnel did not react quickly enough to unhealthy conditions. Thus, my main reasons for starting out with a design for a stand-alone application were:

- little research has been done on optimization of patient-operated mobile self-management tools in order to increase compliancy;
- a prerequisite for optimal patient-healthcare services is sufficient compliancy in the patient tools for everyday disease progress monitoring;

- rapidly evolving mobile terminals, sensor system elements and wireless communication protocols trigger a need to research the potential of these technologies for mobile self-help tools;
- the time and economic framework did not support a health-care system implementation.

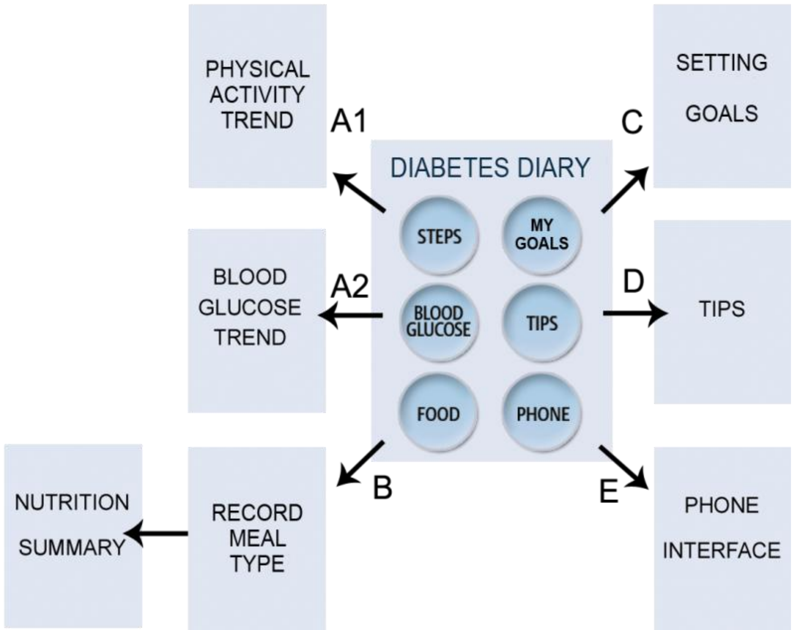

Fig. 13. Diagram of the self-help tool's user interface and main functionality (modified diagram from Paper 1).

4.3.2 Functionalities

The chosen functionalities of the Few Touch application are capture, transfer, display and simple analysis of the three cornerstones of diabetes management: nutrition, blood glucose, and physical activity. In addition, a concept for goal setting, feedback and follow-up regarding these parameters as well as concise general information related to Type 2 diabetes information has been developed. The application is based on a commercially available mobile phone as the patient terminal, and the user may switch between using the phone and the diabetes diary application by pressing one button. See Fig. 13 for the organization of the functionalities. As proposed by Petersen [275], we aim for "engaging facilities in the design" that hopefully will "motivate users to explore the technologies in new ways grounded in the needs of their everyday lives". Iacucci and Kuutti [168] also conclude that "the aim of design is to deliver systems that can be appropriated by people in real life", as do Sundström et al. [331] and Ballegaard et al. [22]. Emphasis is placed on making the functionalities visual and easy to perceive, aiming for systems that encourage users to reflect and learn while using them, analogous to the "reflection-in-action" notion used in [321]. A visual presentation to the diabetes patient, enabling the patient to "comprehend his diabetic condition and take action accordingly" was also the idea in [75]. The feedback from the Few Touch application generates overview reports of the collected data – overview reports were addressed by the 11 informants in [285]. The functionalities in the Few Touch application that were finally chosen were aimed to blend into the users' everyday or real life, and are presented below, and in Fig. 13.

Automatic Data Transfer (A1, A2):
To capture blood glucose data and exercise data, the blood glucose sensor system and the step counter sensor system presented in Paper 3 [384] and Paper 4 [389] are used. To optimize usability, data from these sensors are automatically transferred using a "no-touch" principle. Updated data will be available from the "Diabetes Diary" user interface of the Few Touch application at any time.

Entry of Nutrition Data (B): Users can record their food intake by two touches on the mobile phone's screen, from the main menu. This design has been chosen to make the data entry process as fast and effortless as possible. After each entry, users are presented with a summary of the current status of their nutrition habits, related to their personal goals.

Setting Personal Goals (C): Users can press the "My Goals" button to choose between viewing or editing their step goals and food habit goals, see Fig. 14; it is easy to change the goals by using finger movements. The food-related goals are the most advanced, divided into three categories emerging from the user meetings as described in Paper 5 [390] and in Chapter 5.2.3. The food habits that the 14-person cohort think are the most important to change are namely to increase the intake of fruits and vegetables, to eat often enough and to reduce the number of carbohydrate-rich meals. The system is thus designed so that it is easy to adjust these two goals using the fingers on the touch-sensitive screen, as presented in Fig. 14. The user's data is then measured against these goals and the user receives feedback as in the example B in Fig. 15. A smiley is presented for the user when the aim is achieved, and an expressionless symbol (head without a face) is presented until this aim is achieved. The cohort stated that a reasonably low average for blood glucose values was important, and this kind of goal is therefore exemplified in Fig. 15, yet not implemented. The goal is thus related to average accumulated blood glucose value; see example C where the user is 0.4 mmol/l higher in the average value than her goal. For physical activity, the users chose the bar graph presentation of the step counts as the best visual way of getting the overview, related to a vertical line indicating their daily goal; see the text and the red line in example D, Fig. 15.

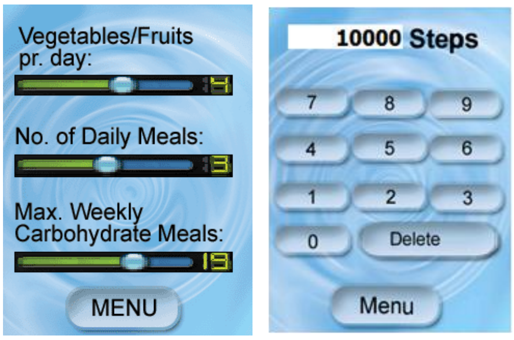

Fig. 14. Goal setting for food habits and physical activity.

General Information (D): Tips and information related to practical situations, i.e. information that is sufficiently "down to earth", are included to provide functionality that will motivate, educate and be appreciated by the user group. Ideally, the user should have been able to access <u>all</u> general information directly from the patient terminal. This assumes however that users generally understand and interpret the information correctly, which may be unrealistic. Therefore, we included information that is easy to understand, with examples and with short text, as illustrated in Fig. 16. The aim is to provide functionality that will both motivate and educate users by relating as much of the information as possible to practical situations. A future goal is to include an extensive diabetes dictionary in which the user can look up terms related to diabetes, tailored to the small screen of a mobile phone.

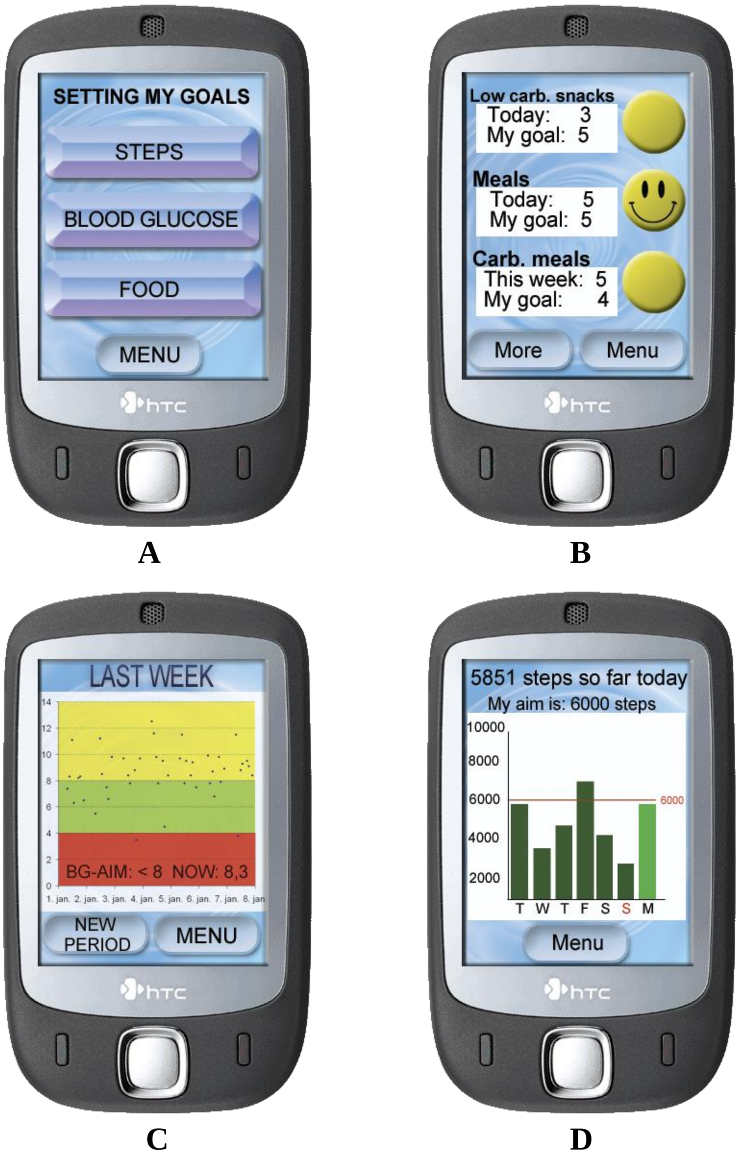

Fig. 15. Screen views of goal setting, food habits feedback, blood glucose level feedback, and step count feedback.

Integrated with the Mobile Phone (E): Since the Few Touch application runs on a mobile phone, the user does not need to carry an extra device. The idea is that the Few Touch application is as integrated with the mobile phone as possible. There is a soft button accessible from the main menu of the Few Touch application that brings the user directly to the phone application. Vice versa, one hard key button on the phone (the camera button) is assigned to activate the Few Touch application, enabling the users to switch between the two applications with only one touch. In practice this means that the user may choose to use the Few Touch application or the ordinary phone screen as the daily interface, depending on which is used the most.

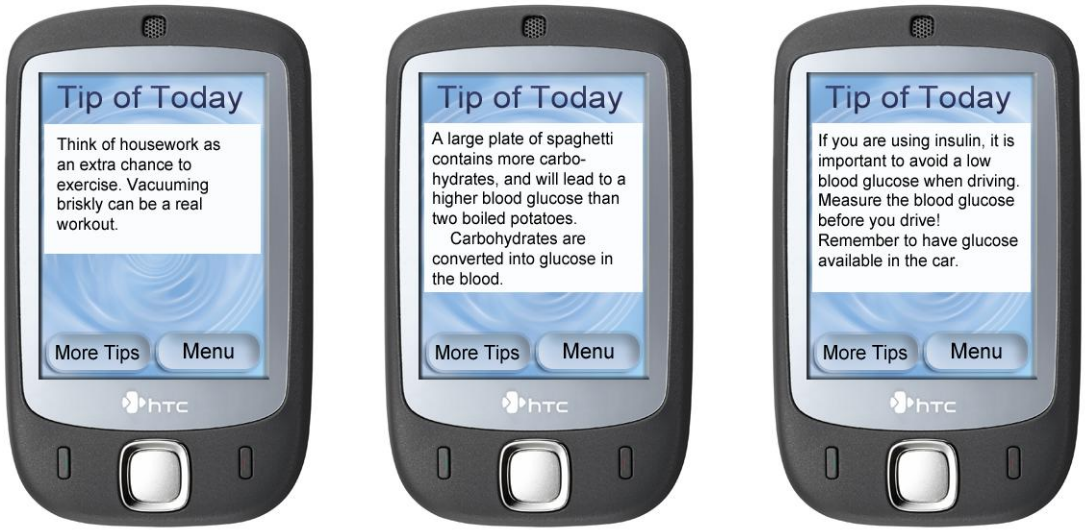

Fig. 16. Three examples of daily tips that are part of the Few Touch application.

A scenario of how the Few Touch application may be used is presented below.

Petra retired recently at the age of 63. She was diagnosed with Type 2 diabetes last year and recently received the Few Touch application from the NST. She uses the new mobile phone both as her ordinary phone and as an interface for improving her diabetes management. She tries to wear the step counter and to use the blood glucose monitor every day. Each morning she measures her blood glucose value. On Sunday morning it was rather high: 9.5 mmol/l. She wonders why. Then she remembers the features of the Few Touch application features, and fetches the phone. The phone's screen displays the last seven measured values, with her recent 9.5 mmol/l measurement highlighted at the top of the list. Now, she notices that she also had a high measurement at the bottom of the list. Since she measures once a day, she understands that this was last Saturday. Hmm, high during weekends, can this be a general pattern, she wonders. She presses the graph button, which shows her the last 50 measurements. Yes, as she suspected, the reading has generally been higher every weekend for the last seven weeks. She now decides to change her physical activity goal, to see if this can improve the blood glucose readings for the next weekend. She presses the menu button and then the set-goal button, and increases her recent aim of walking 6000 steps per day to 8000 steps per day. She also sets the step counter module to tell her the daily step status at 16:00, so that when she gets the automatic pop-up message about the daily steps, she can still work on improving this number in the afternoon.

4.3.3 Hierarchical Structure of the Few Touch application

The total graphical user interface and the hierarchical structure of the software (the Diabetes Diary) running on the mobile phone are presented in Fig. 17. The various screens are shown in the final, authentic Norwegian layout, but English translations of the screens are presented elsewhere in the dissertation.

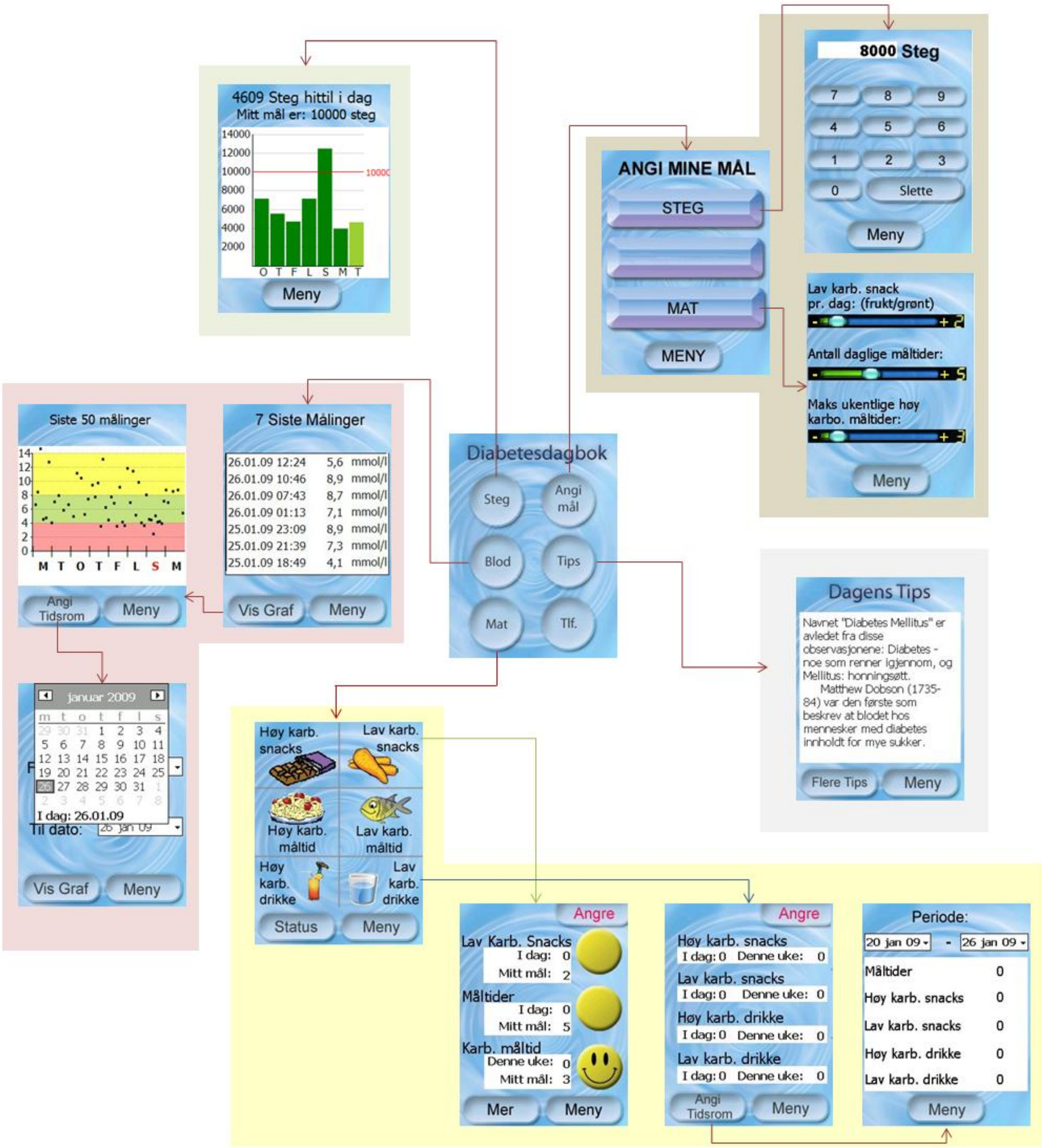

Fig. 17. Overview of the graphical interfaces and the hierarchy of screen elements of the Few Touch application.

5 Results

In the current version of the Few Touch application, users are receiving feedback on how they perform in relation to their own personal aims. The application also presents graphical views on all three parameters (food habits, blood glucose and physical activity). The main results from my PhD project are described in the papers from Paper 1 to Paper 7, as well as the results from the half-year user test of the Few Touch application which are described in Chapter "5.3 The Few Touch Application – Six-Month User Test". Below, I will try to give a structured overview of these results:

- Firstly, in Chapter 5.1, results regarding patient involvement that informed sub-problem 1: How can one involve real patients in a long-term design process, constructing mobile self-help tools based on real needs and preferences?
- Secondly, in Chapter 5.2, results regarding the design of the three data capture systems that informed sub-problem 2: How can data capture systems for tracking blood glucose, nutrition habits and physical activity be designed in a way that will encourage patients to use them and benefit from them on a daily basis?
- Thirdly, in Chapter 5.3, results regarding the total Few Touch application and the six-month user test that informed sub-problem 3: How can the three data capture systems be integrated into a mobile health diary, based on the new generation of mobile phones?
- Lastly, in Chapter 5.4, Chapter 5.5, and Chapter 5.6, Cross-Disciplinary Research is described, a Future Application – Epidemic Disease Indicator based on the proposed application is proposed, and Dissemination results other than the scientific ones are reported.

I argue that these results in total inform the main aim of this dissertation: *to generate new knowledge about how a mobile tool can be designed for supporting lifestyle changes among people with diabetes*.

5.1 Forming the Self-Help Tools

5.1.1 A Framework for User Involvement

Various methods have been used in the studies, many of these presented in Paper 2 [385] and Appendix 9 [380], i.e. standards (ISO and ETSI) for user-centred design, focus groups, paper prototyping/sketching, thinking aloud, scenarios, interviews, questionnaires, logging and other observation methods. A framework for user involvement in the design process was designed on the basis of the experience with the methods, and presented in Paper 2 [385] and Fig. 18. It is inspired by existing methods and standards within the field of human computer interaction, as well as by documented experience from relevant eHealth projects. The method paper, Paper 2 [385], analyses the Type 1 diabetes case study presented in Paper 6 [124] and the Type 2 diabetes case study presented in Paper 1 [391], as well as a US Smart Home study on older adults [79]. On the basis of the experience from these and other eHealth studies, we highlight the importance of patient involvement in the design process and suggest guidelines for patient-centred system design.

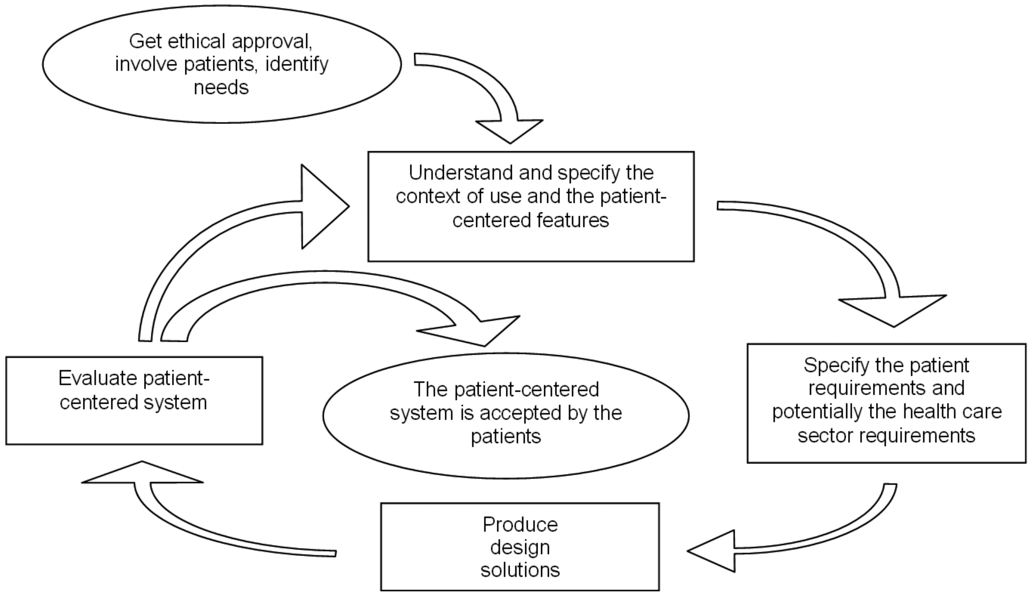

Fig. 18. Framework for user involvement in designing a self-help tool (adapted from Paper 2 [385]).

The suggested guidelines are as follows (from Paper 2, slightly modified):

1. Develop and test a prototype with real patients who have a need for the tools' functionalities.
2. Use scenarios as effective ways to explain how a technical solution works for the patients, and for caregivers to gain an understanding of the patient's experience, needs and expectations.
3. Allocate sufficient time for several meetings to allow users to understand the possibilities that the technology provides and to let their own creative ideas "bloom". The same is true for initiatives intended to enable users to contribute with paper prototypes, homework, or other concrete inputs.
4. Plan for extra iterations in the prototype design and testing with real users, which will ultimately improve the post-intervention data analysis process.
5. Automate the logging of the use of the prototype. Getting the users to do the logging themselves requires incentives, if it is possible at all.
6. Use post-intervention interviews when an in-depth understanding of the patient experiences is required. (Remember to plan for this in the application to the regional ethical committee.)
7. Consider using a reference group for preparation, comparison and quality assurance purposes. The challenge in this context is to explore ways to recruit such a group. (In many cases it might be suitable to recruit conference participants or members of the social network of the design team.)
8. Consider combining relevant HCI methods with other methods, both as a help in the design process and to document the effects of the systems. Use the triangulation approach in the process of designing good patient-operated tools.

Thus, the general conclusion from Paper 2 [385] is that the focus on HCI methods and standards within eHealth studies should be increased, and hopefully this paper can provide some help to researchers and designers in a user-centred design process.

Most of the methods, concepts and recommendations presented by the contributors to the book “Design at Work” [139] seem to be useful in design processes outside working life as well. Paper 2 [385] generally illustrates the use and outcomes of such theories in interactions with patients using ICT in everyday life. Ballegaard et al. [22] address “methods that take the daily life of the citizen as the starting point and support development processes that fit well into the daily life of all the participants” as a main challenge for participatory design. By following the plans and facilitator scripts (Appendix 11) that we used in the focus group meetings with the Type 2 cohort, we experienced a low drop-out rate during the two-year intervention. The meetings were arranged at a time that we found interfered the least with the participants’ other everyday activities (between 19:00 and 21:00), and they were given two alternative days for attendance, which the cohort described as satisfactory.

5.1.2 The Few Touch Concept

On the basis of the experience from the first study, the one on children with Type 1 diabetes presented in Paper 3 [384] and Paper 6 [124], it became clear to me that the functionality of patient-operated self-help tools has to be as automatic as possible, i.e. to require little time and effort. This is illustrated by the comments of users’ parents that fully automatic data transmission was “alpha and omega” and “extremely important”; “[I am] very thankful for it” (page 6 in Paper 6). The general underlying belief is that people with chronic diseases have more than enough additional disease-related issues to consider and manage on a daily basis, so that self-help tools must be as automatic and easy to use as possible. The patient terminal is based on a mobile phone so that patients do not need to carry, manage and charge an extra device; see Fig. 19. For the main study of my PhD project, with the Type 2 diabetes cohort, fully automatic data transfer has been achieved for the blood glucose system and the physical activity system. The nutrition habit registration system is based on a principle where one uses the fingers to tap a few times on the touch-sensitive mobile phone screen, to perform the data capture. The same applies to the case for setting personal goals, accessing blood glucose and physical activity data, accessing general information and accessing the ordinary phone functionalities from the main menu.

Fig. 19. Using the Few Touch application on the HTC Touch Dual mobile phone.

5.2 The Three Data Capture Systems

As mentioned earlier, the chosen data capture applications are based on the cornerstones of good diabetes management: healthy diet, blood glucose management, and exercise. More relevant sensors could have been included, e.g. medication counters, weight scales, blood pressure monitors, and heart beat sensors. I have however not included such sensors due to the complexity of designing the system with the chosen three sensors, and also in order to design an easy-to-use system. The three data capture systems that I have designed are presented below.

5.2.1 The Blood Glucose Sensor Systems

Paper 3 [384] presents the technology and concepts behind a system for fully automatic transfer of blood glucose data, designed by my colleagues and I in the period 2001-2003, and excerpts from this paper are presented below. This system was implemented in 17 clinically functioning units and tested on the Type 1 diabetes cohort as described in Paper 3 [384] and Paper 6 [124]. However, the system has now been refined and included as part of the Few Touch application. The refined system is based on a commercially available BGM from LifeScan Inc. [220], a commercially available Bluetooth serial port adapter from Polymap Wireless [282], utilizing the short-range communication standard Bluetooth [36], and the possibilities that mobile phones offer as a patient terminal. We have implemented 20 units for testing on the Type 2 diabetes cohort.

The Type 1 Diabetes Application: The psychologically and behaviourally oriented results from the Type 1 diabetes study are described in the sub-chapter "5.4 Cross-Disciplinary Research" and in Paper 6 [124]. The ideas and suggestions for incorporating the system in electronic health record systems are described in sub-chapter "5.5 Future Application – Epidemic Disease Indicator" and in Paper 7 [395], while the results from the technical implementation of the application are summed up in Paper 3 [384] and below. Fig. 20. presents an illustration of the total concept.

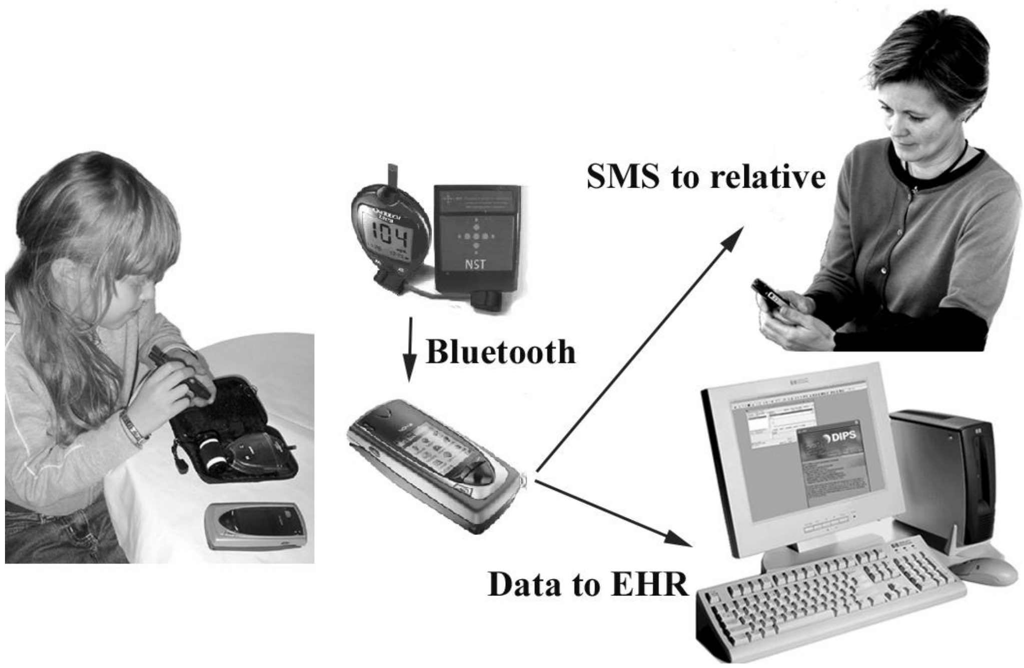

Fig. 20. Overall architecture of the no-touch wireless system for blood glucose transfer (Adapted from Paper 3 [384], Fig. 2).

The designed adapter had coverage with a radius of 10 meters. This means that the mobile phone could be placed in the child's rucksack at school or even further from the BGM system, and would still allow the system to work. For example, a child with diabetes can measure her blood glucose at school and transfer the reading to her parents, without operating or paying any attention to the phone lying in her rucksack. Prior to the four-month trial period, it was calculated that the Bluetooth adapter of the designed blood glucose sensor system would last 123 days. The experience from the four-month trial was that about half of the adapters' batteries lasted the whole period. For patients who only used the phone functionality a couple of times each day in addition to the wireless blood glucose data transfer function, the phone's battery lasted approximately three days. However, some patients used the phone a great deal, and one of these even turned off the Bluetooth transceiver via the phone's menus to extend the life of the battery. The result was of course no communication with the blood glucose Bluetooth adapter, but this "user error" was solved by a phone call to the project leader.

Of the 15 systems given to the children with Type 1 diabetes, 27% was reported to function perfectly during the whole trial, 60% had minor problems, and 13% had major problems. Examples of "minor problems" included users' unexpected exit from the Bluetooth transfer software on the phone, accidental unplugging of the RS232 jack from the blood glucose meter, a bug in the Bluetooth transfer software that required a restart of the phone for the system to work properly again, the battery on either the Bluetooth adapter or the blood glucose meter needed replacement, etc. Two examples of major problems were imperfect soldering of the jack, which caused communication problems between the Bluetooth adapter and the sensor; and a defect in the Bluetooth adapter caused by external shock or other influence. The major problems required users to hand in or mail the equipment for repair or replacement.

The Type 2 Diabetes Design: Due to the abovementioned problems, and the fact that the US-based company Polymap Wireless [283] made similar adapters commercially available in 2007, their FDA-approved adapters were used in the Type 2 study. The technical differences are that the current mobile phone model is the HTC Touch Dual, and that the successor BGM from LifeScan, the OneTouch Ultra 2 is used in the Type 2 study. The functional difference is that the blood glucose values are used for self-help purposes only, i.e. they are transferred to the user's own mobile phone and used by the patients themselves. This cohort was aged between 41 and 67, and assumed to be cognitively able to act upon their own blood glucose data, using the mobile phone as both their regular mobile phone and as their patient terminal for management of diabetes. The sensor feedback information is presented on the screen on their mobile phone after each measurement. Data and further information is also available whenever they want to access the various data-presentation screens for overviews and analysis, e.g. as illustrated in Fig. 21. Results from the half-year intervention, where the Type 2 cohort used the developed blood glucose sensor system for six months, are described in Chapter "5.3. The Few Touch Application – Six-Month User Test".

The blood glucose system described is the only no-touch transfer system for blood glucose data I have found documented and subjected to a clinical trial. Both the parents from the Type 1 intervention study [124] and the Type 2 cohort consider that such systems have to be fully automatic in order to be used as a daily tool, a quality that should also be shared by the sensor system for physical activity.

Fig. 21 The blood glucose module of the Few Touch application; the red circle indicates choices made and arrows point to subsequent screen feedback.

5.2.2 The Physical Activity Sensor System

In Paper 4 [389], the background, concepts and technologies behind the system, and initial tests and performance of the designed step counter, are presented in detail. Excerpts from this paper and further results from when it was included as part of the Few Touch application are presented below. Results from the half-year intervention, where the Type 2 cohort used the developed activity sensor system for two months, are described in Chapter "5.3. The Few Touch Application – Six-Month User Test".

The designed system is in principle a one-axis step counter, but with a tailored interface, and Bluetooth wireless communication with a mobile phone. Users of the system can attach the sensor to their belt or in other ways near their hip, and leave it unattended for the period of use. Data on their daily step counts will automatically be transferred each evening, and displayed to the users on their mobile phone, e.g. picture D in Fig. 15. The final choice for presentation of the step counts to the Type 2 cohort was made after focus group meetings with paper prototyping sessions. As shown in Fig. 7, three text-based screens for feedback on how physically active you have been during the day and the last five days or last week were proposed (A,E,F), three traditional graphical ways of data presentation were proposed (B,C,H), and two more untraditional and mostly visual ways of data presentation were suggested (D,G). All but D stated the biological health data in numbers and text ("5738 skritt", i.e. 5738 steps). Four of the suggestions (D,E,G,H) also presented a personal aim for the target number of steps each day, and how close the user is to fulfilling this aim. The cohort preferred alternatives A and B, and alternative B was chosen because it was the most visual.

Likeliness of Use: The likeliness of sustainable use of a monitoring system like this was checked by adding four questions to the survey "European citizens' use of E-health services"[14]. The results from asking 1001 informants these four questions in telephone interviews (CATI), surprised us. As many as 6.6% of people in general reported daily use of a step counter/pedometer, 7.4% reported weekly use, and 6.3% reported monthly use. We also asked about the use of other self-monitoring devices such as pulse, blood pressure, and blood glucose monitors. Less frequent use of these devices was reported, with cumulative monthly percentages of 11.3%, 7.7% and 5.7% respectively. The cumulative monthly percentages for all four devices are presented in Fig. 22.

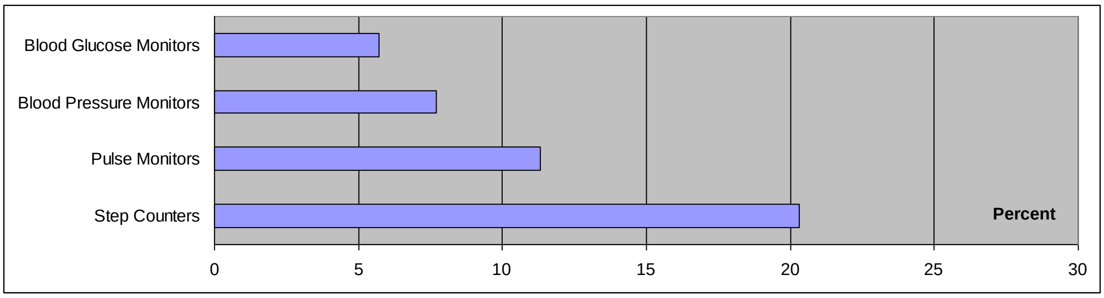

Fig. 22. Cumulative monthly percentages of use of four different monitoring devices, Norway 2007, by 1001 informants in the study by Andreassen et al.[14] using CATI.

The high numbers of informants who reported daily and weekly use of step counters/ pedometers foster the belief that the parameter "step counts" is both easy to understand and motivating for people in general to monitor. Our Type 2 diabetes cohort confirms this belief, and the participants expressed a positive attitude to the use of step counters. They wanted the functions of a step counter to be as automatic and easy to use as possible, and said that tools for self-help should be integrated with their daily tools and outfits.

Constructional Results: The physical activity sensor system is implemented on a printed circuit board containing the Bluetooth module, the microcontroller, the movement sensor and the battery. These components are embedded into a chase with a size of 6 x 4 x 1.5 cm, have no LCD-display, but one button; see Fig. 23.

Fig. 23 The final prototype; the electronics, front view, side view, and the feedback screen on the mobile phone.

Use of the button is optional, providing the users with the possibility to transfer the step count to the mobile phone's screen at any time. The step-counter application is so far equipped with a one-axis movement sensor only, but is designed for adding more sensors, or for exchanging the movement sensor with a three-axis accelerometer. On the basis of the feedback from the Type 2 diabetes cohort, the system is set up to automatically transfer the step count data once a day, around 10 o'clock in the evening. This can be changed to a more rapid transfer rate, e.g. each hour, every two hours, twice a day, or at other intervals. However, one of the user comments was that the application should last as long as possible before battery change, and the once-a-day data transfer rate gives the system a continuous operation time of approximately 4 months.

Fig. 24. How the step counter (enlarged) may be attached to the user.

Initial Tests and Performance: The functional tests were performed both on a treadmill and in natural environments, and showed that the step-counter application provides the user with sufficient accuracy compared with the "Omron Walking Style II HJ-113" step counter. Tests of walking at normal speed indoors and outdoors showed a difference of 2.5% after 2 hours, 1.2% after 7 hours and 0.9% after 12 hours between the two step counters. The treadmill test was performed at five different walking speeds. At 1 km/h the Omron step counter had problems in registering steps at all, while our application registered all steps. At 2 km/h the difference was 4%, at 3 km/h it was 3%, at 5 km/h it was 7%, and at 10 km/h there was no difference between the application and the Omron step counter. It was also demonstrated that the step-counter application sends data properly to the patient terminal, both automatically at preset intervals, and manually when the transfer button is pressed. Prior to the two-month test by the Type 2 diabetes cohort, my colleagues and I tested the step counters on a daily basis in the period October-December 2008. During this period, both hardware and software errors were discovered and fixed.

Pre-Test by the Type 2 Diabetes Cohort: Two of the participants of the Type 2 cohort received the step counter application as the final element of the Few Touch application in mid-December 2008. After wearing these for three weeks they did not report any problems with either the step counter or the corresponding software on the mobile phone. They gave the following responses to a question sent to them by SMS after three weeks, concerning how the application worked for them:

User A: "*Hi, the step counter works very well, good functionality and it gives me the function that I want*."

User B: "*It still works the way it should. I have on three occasions tested it against two other step counters, and it showed practically the same results on two of these occasions.*"

Step counters were then given to the rest of the 10 participants in the middle of January for a two-month trial until mid-March, when the official test period was concluded and focus groups were organized. The feedback and experience from this test are described in chapter "5.3.4 Testing the Physical Activity Sensor System".

5.2.3 The Nutrition Habit Registration System

These results presented below are related to the design of the nutrition habit registration system, and are mainly excerpts from Paper 5 [390] and feedback from the focus group sessions with the Type 2 diabetes cohort during spring 2007 (Appendix 11) and the thinking aloud sessions with the US cohort in December 2007 (Appendix 12). The results from the half-year intervention, where the Type 2 cohort used the nutrition habit registration system for six months, are described in Chapter "5.3.2 Testing the Nutrition Habit Registration System".

Fig. 25. The Few Touch food habit registration concept (adapted from Paper 5 [390]).

Findings from the Focus Group Sessions, February-May 2007: From the first of the 2-hour sessions where the informants (n=8) discussed food habits and food habit registrations, 7 expressions emerged as the most focused:

1. Healthy food is important for blood glucose.
2. More knowledge about food.
3. Follow-up is important.
4. Difficult/demanding to type on mobile phones.
5. Dieting is negative.
6. Eating healthy gives a great feeling.
7. Rewards are important.

From the second group (n=5), these 7 expressions were most focused:

1. Healthy food is important for blood glucose.
2. Eating regularly is important.
3. More knowledge about food.
4. Eating healthy gives a great feeling.
5. Using a manual diary is helpful.
6. Weight monitoring is inspiring.
7. Need for a simpler system than a manual diary.

Grouping these expressions from the two focus groups together and filtering for expressions that are related to design of a mobile phone-based food habit registration system gave us this three-element "things-to-register" list:

- Carbohydrate
- Eating regularly and often enough
- Healthy eating

In addition, it gave us this functional list:

- Follow-up and feedback
- Provide knowledge
- Easy input

I interpreted these findings along with the verbal discussions into a Smartphone-based few-touch registration system that provided setting food-habit related goals and easy food registration at the touch of a finger, with feedback; see Fig. 25.

Representative sayings that reflect a wish for these food-register categories:

"I notice a huge difference depending on what I eat – if I eat carbohydrate-rich food, I get high blood glucose."

"I try to eat fruit and vegetables, but I don't manage five each day."

"It's difficult when I am home and at weekends – then there may be few meals per day, unfortunately."

Sayings that represent the functional design decisions were:

"The amount of follow-up from doctors is limited, and therefore a mobile phone will perhaps work well."

"I would like to know more…I learn every day, something I find on web-pages – information is important."

"On the mobile phone it could be a simple system where you entered something, quite simply."

Findings from the Thinking Aloud Sessions December 2007:
A thinking aloud study was done in cooperation with my colleague researchers at the University of Washington School of Medicine, Division of Biomedical and Health Informatics, USA, and is presented in full in Paper 5 [390]. The function for recording nutrition habits in the Few Touch application was tested on a cohort of six patients (with both Type 1 and Type 2 diabetes), and compared with two other food registration systems: a desktop food pick-list based system [263] and a smartphone picture-capture system (prototype made by colleagues at UW).

This cohort expressed the following views:

- Regardless of the specific design approach, the act of recording and reviewing records of one's actual eating habits is inherently motivating, an important facet of diabetes management, and a mechanism to "*keep yourself honest about what you eat*" via self-monitoring of eating habits and behaviours.
- They also acknowledged that generating these records requires work, and to achieve sustained use of these tools they should be designed such that each act of registering a meal is coupled with some form of reward or "payoff" at the time of data entry. Specifically, the tools should either a) teach the user something about the nutritional content of the foods they are registering while they are registering them (e.g. carbohydrate content) or b) provide real-time feedback about their progress towards achieving their personal nutrition-related goals.
- Mobility is critical to sustained use of any of these nutrition diary tools, and is a highly desired feature in any of these systems – including the commercial Web application for PCs [263].

- Their desires to self-configure and tailor these applications to meet their own needs and to support their own unique goals.
- Varying opinions about the extent to which each application prototype would be useful in a pure self-care context vs. a healthcare provider (e.g. nutritionist) supported context, but all participants said that at least one of these tools would be useful in each of these two contexts.

Participants generally said that the Mobile Picture Capture design approach as instantiated in the Food Photo Moblog prototype would not be useful or practical for routine use, e.g.:

"You want me to take a picture of my plate before I eat? (laughter) That ain't gonna work out, dawg!"

However, most participants commented that it could potentially be useful for occasional ad hoc use to register meals or foods that are unfamiliar, assuming that the pictures would serve to enable a more robust discussion with their nutritionist. Nutritionist involvement was viewed as essential to using this system in any capacity.

The Food Pick-list design concept as instantiated in the commercial Web application for PCs was viewed as a useful and potentially powerful tool in both self-care and provider-supported care contexts. The most powerful feature associated with this approach was the automatic population and display of foods' nutritional content values at the time of data entry, e.g.:

"Four carbs? Wow! See that teaches me right there that I would have given too much insulin."

However, participants commented on several high-impact usability challenges associated with this particular implementation of the design concept that, if not addressed, would significantly reduce the likelihood that they would use it. Specifically, the food pick-list was too limited and should be expanded to include more items; re-ordered based on frequency of item selection; and allow for user entry of new food items. Also, the ability to edit meal and individual food item entries prior to submission should be made more flexible and robust, as should the functions for specifying portion and serving size parameters. Finally, participants also expressed the necessity to extend this system to a mobile (e.g., smartphone) platform to enable routine use.

The Smartphone Touchscreen concept as instantiated in the Few Touch prototype was generally well-received, e.g.:

"This is a good idea, this really is... I would actually use this."

All participants commented on its ease of use and simplicity. Five of the six participants stated that they would be very likely to use this tool on a routine basis if given the ability to specify and personalize the goals and registration categories, e.g.:

"I think those categories could be different. I think the goals could be different too."

Other desired enhancements included the ability to download the resulting data to a PC to enable more detailed analyses (including longitudinal analyses spanning more than one week); the ability to delete or edit entries after they are submitted (e.g., in the case of a touch screen error resulting in an unintended entry); and the addition of negative as well as positive reinforcement cues in the graphical user interface (e.g., "frowney faces" as well as the "smiley faces" as indicators of progress towards achieving goals). Participants commented that this would be a useful tool regardless of healthcare provider involvement, although some commented on the extent to which provider involvement might enhance the usefulness of this approach. Participants also viewed the tool's real-time goal progress reporting as the "payoff" associated with individual food registration sessions, in contrast to the other two design approaches in which this payoff took the form of learning about the nutritional content of the foods being registered.

Affective interfaces [167] like "frowney faces" and "smiley faces" received positive comments from some members of the Norwegian Type 2 cohort and some of the US cohort, but not all. Ideas put forward to the Type 2 cohort included rewarding goal achievement by presenting pictures of the user's grandchildren or by playing music that the user liked, but these ideas received only limited support, without the enthusiasm envisaged by the project group. The feedback screens were therefore designed with less personalization, such as presenting smileys, and blank faces instead of frowneys when the user's goals were not achieved; see Fig. 15 picture B.

5.3 The Few Touch Application – Six-Month User Test

The 12-patient cohort with Type 2 diabetes tested the Few Touch application for half a year starting in mid-September 2008, ending in mid-March 2009. The three functionalities of the application: the Blood Glucose Sensor System, the Nutrition Habit Registration System, and the Personal Goals functionality were introduced to the cohort in September 2008. The General Information functionality (daily tips) was introduced after seven weeks, at the end of October. The Physical Activity Sensor System was introduced in mid-January 2009. The user's interface on the mobile phone was software called the Diabetes Diary ("Diabetesdagboka" in Norwegian). The questionnaires C, D, E, and F, see Appendix 15, were the main instruments to inform the conclusions regarding the use of the Few Touch application. In addition, analysis of and quotations from the audio tapes from the focus groups, see Appendix 11, were used to illustrate the active users' experience with the Few Touch application, and analysis of each user's Few Touch application database. Since this Type 2 study is a typical feasibility study, the active users' statements in the interviews and focus groups were important sources of information.

5.3.1 Testing the Personal Goals Functionality

As earlier presented in Fig. 13 and Fig. 14, the patients were able to set, view and change their personal goals related to food habits and physical activity. For both parameters, the users receive immediate feedback after data capture from the system related to whether they had achieved their goals or not. Generally, many of the patients reported that they were motivated by the challenges of trying to reach the red line representing the aim for daily steps, and trying to achieve a smiley face representing attaining their food habit goals. Although they found it easy to change the goals (on average they rated the ease of use at 4.3 points on a scale from 1 to 5), few of them had changed the initial goals they set for themselves.

The following quotations from the last user meeting illustrate the general feedback related to the personal goal setting functionality:

> *"I have not changed my goals, but it is a nice option!"*
>
> *"When I set such goals for myself, few things change."*
>
> *"One has to think about whether one should set one's own goals or if one should go for the general recommendations."*
>
> *"A goal for the total achievements could have been a nice thing."*
>
> *"I have on several occasions experienced that after having changed the goal for daily steps, after a while, then it's changed back again, and then I have to change it again."*

Summary: As indicated by the last quotation above, a bug in the software made the program set the goal to its previous state. This happened seldom and did not create major problems for the users. The personal goal functionality was in general well received by the cohort, but little used throughout the half-year study. However, on average they used it indirectly 6.1 times a day: every time they looked at their physical activity achievements (once a day) since their daily steps goal is shown as a red target line, and also each time they registered food habits (the average was 5.1 times a day) since they were then presented with a smiling face or a blank face depending on whether they had achieved their food aims or not.

5.3.2 Testing the Nutrition Habit Registration System

This functionality was tested by the 12-patient cohort during the whole six-month intervention period. Unlike the two sensor systems (blood glucose and physical activity), this registration system required manual input of data. To record food category intake, the user touches the mobile phone's touch-sensitive screen twice to choose the corresponding food type; see Fig. 25. After each recording, the Few Touch application displays how the user is doing in achieving her three food habit aims; see Fig. 15, picture B.

Statistics: Among all participants, the food habit recording application was used to register food and drinks 5.1 times daily on average. The most frequent user had a usage of 11.7 daily inputs, while the least frequent user used it once a week. At the focus group meetings in the spring of 2007, we learned that the three nutrition elements that most patients would like to improve were: a) to eat more fruits and vegetables, b) to eat more meals a day, and c) to eat less carbohydrate-rich food. Thus, these three elements were addressed in the focus groups and questionnaires and were logged in the databases. The findings from the six-month Few Touch intervention were as follows:

a) **Fruits and vegetables:** Seven of the users (58%) reported through questionnaires that they had increased their daily intake of fruits and vegetables, three of the users (25%) said that there was no change, and two (17%) reported a decrease. Analysis of the database reflecting use of the Few Touch application, see Table 4, showed that for "Low carb. Snack" – representing fruits and vegetables – seven of the participants have registered a considerable amount of fruit and vegetables, i.e. more than 100 units over the half-year period. Thus, these seven have most likely focused on improving the intake of this type of food.

b) **Number of daily meals:** Four (33%) of the users reported through questionnaires that they had increased the number of daily meals, five (42%) of them reported no change, while three (25%) reported a decrease in the number of daily meals. When analysing the database for recorded meal intakes for the total period, we see from Table 5 that the patients registered data most frequently at the start of the study, but most of them did keep up the food habit recordings fairly intensively throughout the half-year period. An analysis restricted to daily meals, i.e. "high carb. meal" and "low carb. meal", shows that five of the users had most recordings at the start of the intervention (September or October), three of the users in November, two of the users in January and two in March. The average for the periods when the users were most active in recording food habits was 2.2 meals a day, ranging from 0.1 to 4.6 recorded meals among the 12 users.

c) **Number of weekly carbohydrate rich-meals:** Through the questionnaire, one user reported a decrease in the number of weekly carbohydrate-rich meals, while three users reported an increase. Eight (67%) of the users said there was no change. However, by analysing the log file of the Few Touch application, and comparing the first two weeks with the last two weeks, we find the following positive trend: The participants generally had a reduced intake of carbohydrate-rich food types toward the end of the study compared with the beginning of the study. More specifically, nine participants had a reduction, two had an increase, and one (User 9) had too few recordings in total to be included.

Table 4. Types and amount of food intake recorded by the individual 12 users, during the half-year study.

User	High carb. Snack	Low carb. Snack	High carb. Meal	Low carb. Meal	High carb. Drink	Low carb. Drink	Total recordings
User 1	0	106	14	206	21	166	513
User 2	8	29	10	36	7	31	121
User 3	41	417	15	623	35	738	1869
User 4	0	4	4	10	2	20	40
User 5	73	216	37	229	72	424	1051
User 6	34	404	26	440	20	578	1502
User 7	37	75	73	199	19	168	571
User 8	431	154	551	98	474	433	2141
User 9	1	5	2	1	1	4	14
User 10	8	21	20	143	1	159	352
User 11	28	221	96	349	2	4	700
User 12	25	338	15	457	7	436	1278

General perceptions: To the general question of whether the patients thought they knew enough regarding which kind of food they could eat, nine of the 12 (75%) answered positively before the intervention with the Few Touch application. Interestingly, only seven of the users (58%) answered the same after the half-year intervention. This might illustrate the saying that the more you know, the more you discover that you do not know, also stated by one user in the last user meeting: "*The more one learns – the more stupid one becomes – because one doctor [GP] asserts one thing, and another – the opposite thing. So, one becomes confused.*" Most of the users (11 out of 12) thought they already had a good overview of their eating habits before the intervention, and all 12 claimed this after the intervention.

Table 5. Amount of recorded food intake distributed by users and months.

User	Sep. 08 (per day)	Oct. 08 (per day)	Nov. 08 (per day)	Dec. 08 (per day)	Jan. 09 (per day)	Feb. 09 (per day)	Mar. 09 (per day)	Total
User 1	70 (5)	163 (5.3)	127 (4.2)	40 (1,3)	67 (2.2)	13 (0.5)	33 (1.7)	513
User 2	20 (1.5)	7 (0.2)	54 (1.7)	12 (0.4)	12 (0.4)	6 (0.2)	10 (0.3)	121
User 3	133 (9.5)	288 (9.3)	232 (7.7)	322 (10.4)	452 (14.6)	308 (11)	134 (7.9)	1869
User 4	24 (2)	15 (0.5)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	40
User 5	96 (8)	170 (5.5)	164 (5.5)	151 (4.9)	178 (5.7)	175 (6.3)	117 (6.9)	1051
User 6	128 (10.7)	282 (9.1)	293 (9.8)	206 (6.6)	219 (7.1)	219 (7.8)	155 (9.1)	1502
User 7	not started	108 (4.5)	109 (3.6)	110 (3.5)	166 (5.4)	21 (0.8)	57 (3.4)	571
User 8	164 (11.7)	339 (10.9)	339 (11.3)	291 (9.4)	413 (13.3)	337 (12)	258 (13.6)	2141
User 9	-	-	7 (0.2)	3 (0.1)	0 (0)	2 (0.1)	2 (0.1)	14
User 10	102 (8.5)	54 (1.7)	65 (2.2)	71 (2.3)	30 (1)	48 (1.7)	36 (1.9)	352
User 11	not started	174 (5.6)	165 (5.5)	119 (3.8)	102 (3.3)	88 (3.1)	52 (3.1)	700
User 12	135 (11.3)	302 (9.7)	219 (7.3)	202 (6.5)	232 (7.4)	95 (3.3)	93 (4.9)	1278
Average	**7.5**	**5.7**	**4.9**	**4.1**	**5**	**3.9**	**4,6**	**5.1**

Focus group quotations: Quotations from the last focus group illustrate that not all people with Type 2 diabetes found this kind of nutrition habit registration system useful, that there were several wishes for changes to the system, and that the tested version was helpful to many of the patients:

> *"I don't use the nutrition habit registration system, since I have a very balanced diet with few carbohydrates."*
>
> *"This is a tool that can help you to learn more about yourself, but sometimes I become tired of recording what I eat each day."*
>
> *"The categorization of the food types is perhaps a bit rough."*
>
> *"It is only when I travel that I use the nutrition habit registration system, because I am quite a systematic person regarding what I eat."*
>
> *"I have now got better control over what I eat."*
>
> *"Now I eat correctly – and the best of all is that the family eats less sugar, eats in a more healthy way, more vegetables, the kids are starting to be interested – we talk about what we should eat, and the kids have begun to eat broccoli!"*
>
> *"When I record the food, I am sometimes unsure about which food is HIGH carbohydrate food and which is LOW."*
>
> *"It is also feedback, or confirmation, that the things I eat on a daily basis are what I have found healthy."*
>
> *"We are also becoming certain about whether the food we eat is right or not, you get to know what you may eat and not, and then you know more."*

Brief discussion and conclusion: The food habit recording part of the Few Touch application seems to be most useful as a tool for working with fruit and vegetable habits. This supports the idea that simple things are the easiest to work on, and potentially improve. An improved intake of fruit may also explain why most of the patients recorded fewer main meals at the end than at the beginning of the study. Furthermore, even though we found a positive trend reflecting a reduced intake of carbohydrate-rich meals at the end of the study, this might be caused by the participants' reduced use of the nutrition habit system (as presented in Table 5). The importance of analysing the actual use of the application was illustrated by the discrepancy between the users' self-reported increase in daily carbohydrate-rich meals, and the considerable reduction that was logged by the system. A general weakness associated with presenting statistics like this is the lack of a control group, and that the patients only used the system for half a year, so that seasonal fluctuations (autumn, Christmas, summer) influenced only parts of the data.

5.3.3 Testing the Blood Glucose Sensor System

This functionality was provided to the 12-patient cohort during the whole six-month intervention period. The system functions without needing any extra efforts from the users, compared with a traditional procedure for blood glucose measurement. After each measurement, the Few Touch application on the mobile phone automatically displays a list of the last seven BG values, with the current measurement at the top of this list. With one touch on this pop-up list on the mobile phone's screen, users can also display a graph of the 50 last measurements; see Fig. 21.

Frequency of use: The frequency of use varied from one user who measured BG 564 times during the half-year intervention period to another user who measured BG only 23 times in the same period. The average individual usage among all 12 patients was 202 measurements in this period. Even though the system was available for the cohort over a half-year period, the average period of actual use, i.e. the period when BG data was stored in the Few Touch application's database, was 167 days. Reasons for this were that two participants started 1-2 weeks later, one had a data loss, and some participants did not measure the last weeks of the period. Some BG-related statistical data from the intervention are presented in Table 6.

Table 6. Statistical data from the 12-patient cohort's use of the Blood Glucose Sensor System.

	Average BG value	Minimum BG value	Maximum BG value	Self-reported HbA1c Sep.08	Self-reported HbA1c Mar.08
Average for "n" users	7.9 mmol/l (n=12)	4.8 mmol/l (n=12)	13.8 mmol/l (n=12)	6.5 % (n=9)	7.0 % (n=8)
Lowest	5.8 mmol/l	3.7 mmol/l	9.3 mmol/l	5.5 %	6.3 %
Highest	12.6 mmol/l	6.6 mmol/l	19.3 mmol/l	7.8 %	8.1 %

HbA1c: The patients reported their HbA1c values before and after the study, by questionnaires. As shown in Table 6, generally the group did not experience a positive change in HbA1c during the period they used the Few Touch application. Some reasons for this might be that many of the HbA1c "before" values were from May and June – summertime is a more "active and healthy" period than the autumn, as noted by Bellazzi et al. [28], and that some values were reported as approximate values. Furthermore, the given values were reported from the users' memory, i.e. not measured; only nine of the users remembered their value in the beginning of the study, and eight at the end.

BG values: Analysing the users' databases, comparing the BG values from the first two weeks with the last two weeks, we find a slight improvement. Average BG values for the whole 12-patient cohort are 7.9 mmol/l for the first two weeks and 7.8 mmol/l for the last two weeks. More specifically, six patients had improved their average value, two were unchanged, and four had an average BG value that was worse. However, the data is not good enough to base conclusions on, since individual events, e.g. data loss, sparse data in periods, illnesses, etc. had a considerable impact on this small sample of patients. Visual presentations of the BG graphs from two participants with an average number of BG readings are shown in Fig. 26 and Fig. 27. As an example of effects external factors might have on the patients' blood glucose, the participant for whom the BG graph is presented in Fig. 27 reported that the high BG values for February and March were caused by influenza.

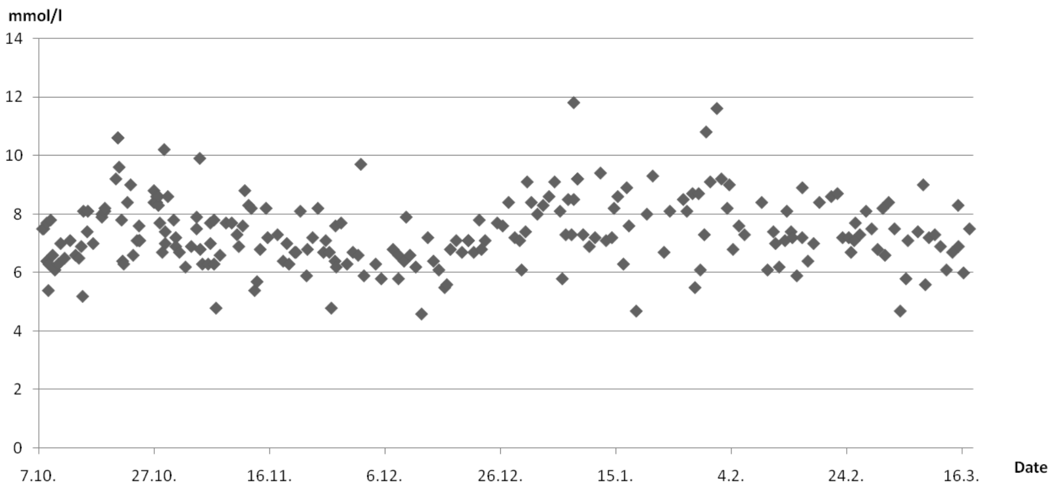

Fig. 26. Blood glucose measurements (229) for one of the patients in the half-year test period.

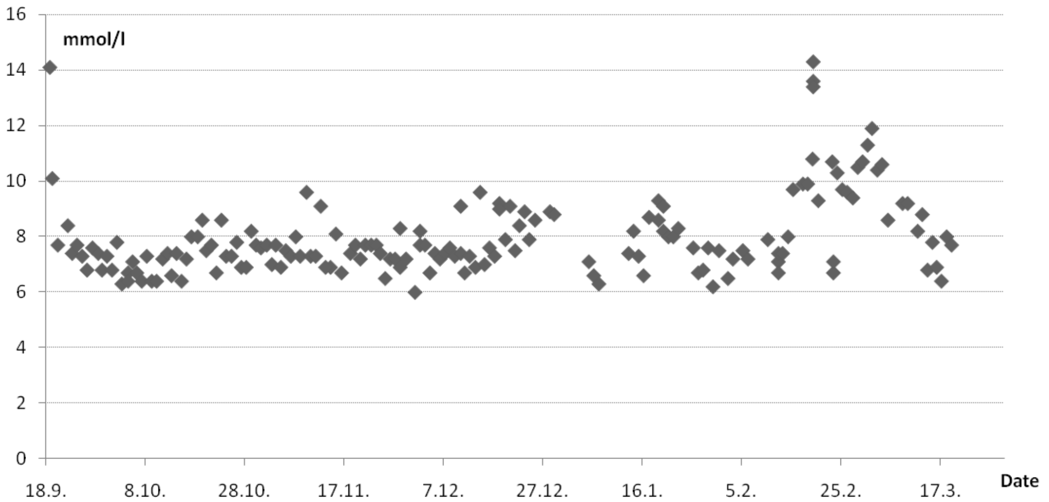

Fig. 27. Blood glucose measurements (166) for another patient in the half-year test period.

Questionnaire data versus data from the patients' database: The answers to the questionnaires are generally more positive than the actual figures from the patients' databases indicate. An example of this is that they report more frequent BG measurements than their Few Touch application's database reveal. Before the intervention they report on average that they measured 8.3 times a week. After the study they report that they measured 9.3 times a week, while statistics from their databases show a frequency of 8.1 times a week as an average for the whole period.

Importance of the BG system: To the question of how important it is to measure their blood glucose in order to manage their diabetes, eight users answered “7” and four answered “6” on a scale from 1 to 7, after the intervention. To the question about what had been the most useful aspect of the Few Touch application, four in the cohort mentioned the blood glucose functionality exclusively and five others mentioned the blood glucose in connection with other functions.
Examples of these statements are:

> *“It is nice to have an overview of the blood glucose.”*
> *“That one can gather the measurements.”*
> *“That I can manage the blood glucose.”*
> *”The system for blood glucose measurements and recording of food.”*

Focus group quotations: From the last focus group meetings, the following quotations are illustrative for the variety of personal experience and perceptions of the blood glucose sensor system:

> *”It happens some time that it takes some time before the measurement arrives at the phone, but it finally shows up.”*

> *”I can clearly see that the blood glucose graph is moving downwards when I manage to hold the focus.”*

> *”But then I think – how perfect should this become? Well, shall we be controlled in such a way that we forget to allow ourselves a kick?”*

> *”Even though I admit that the blood glucose measurement system made me stressed, I also see that when using it, I reduced my medication by one tablet a day.*

> *”I am afraid to lose the blood glucose system, since it is the best I have ever had.”*

> *”I think it is nice to get this blood glucose graph and see how I am doing, and then I can think back on what I ate.”*

> *”I am satisfied with most of it, especially the blood glucose system – now I do not have to write down the measurements manually, as I did before.”*

> *”One sees that one is within the graph one shall be, and if one jumps over the green area I ask myself what did I do then – aha, it was the cake I ate. And then it’s OK – one does not feel bewildered, there is always a reason why.”*

> *”But it is clear that after having started with this kind of measurements, I have become much more conscious, one lives in a healthier way I would say. Yes, to a great extent actually, in all ways.”*

Brief discussion and conclusion: The blood glucose sensor system is the subsystem of the Few Touch application that the patients appreciated the most, as reported in interviews and focus groups. In spite of this, the effect over the half-year period of use was limited, and the self-reported HbA1c, reflecting the average blood glucose level over the past three months, increased slightly during the period. Possible reasons for this might be that the HbA1c values were merely based on values that the patients remembered being measured at their last visit at their health care centre. The preferred method would have been to exclusively measure HbA1c values right before and right after the study, which would be recommended if the study were to be repeated with a larger cohort. As seen from the quotations above, few new suggestions for the blood glucose sensor systems were proposed, and the users were generally satisfied with the system. This is also confirmed by the relatively high usage of the system, with an individual average among the 12-user cohort of 202 measurements for the half-year period.

5.3.4 Testing the Physical Activity Sensor System

This sensor system was tested by 10 of the 12 patients for two months, and by two of the 12 patients for three months. The specially designed step counter, which is the main part of the physical activity sensor system, automatically transfers and displays the number of steps to the user's mobile phone each evening at around 10 pm. In addition, the users may transfer the number of steps to their mobile phone at any time of the day by pressing the step counter's only button.

Frequency of use: The average period of use was 58 days for each patient in the cohort. On average, the users manually transferred the data (pressed the button) 0.88 times a day, where the most eager user transferred data 3.6 times a day, and the least eager, none. Using the mobile phone, the 12 participants checked the physical activity graph once per day (7.25 times a week) using the Diabetes Diary software installed on the phone. For the two patients who used the physical activity sensor system for three months, it worked without errors and with no need for battery replacements. Six of the other 12 users experienced malfunctions with the step counter during the test period, usually lack of battery capacity or an internal "hang-up" in the device that needed a hard re-start (disconnection of the battery). One of these had major problems, which led to little use of this application. Members of the Type 2 cohort were encouraged to call the project team when a problem occurred, and they were then helped and given a new step counter within few days.

Table 7. Physical activity data for the Type 2 cohort – changes in the addressed parameters during the whole six-month intervention.

Type of change	Minutes of daily physical activity	Frequency of exercise	Intensity of exercise	Satisfied with phys. act. level	Satisfied with step counter	Motivation (step counter)
Positive	7 users	3 users	5 users	5 users	8 users	9 users
Negative	4 users			2 users		3 users
None	1 user	9 users	7 users	5 users	4 users (neutral)	

Physical activity data: Results from some of the items addressed in the questionnaires (see Appendix 15) are presented in Table 7. Generally, the users were satisfied with the step counter application. Five of them answered "very satisfied", three answered "fairly satisfied", and three answered "neither satisfied nor dissatisfied". Furthermore, they reported that they did increase their physical activity from the start of the intervention in September 2008 to the end of the intervention in March 2009. The tendency toward increased activity is confirmed by the results from the two-month use of the step counter application. In this period, there was an increase in the number of steps from the first week they used the sensor system to the last week; see Table 8. As shown, nine of the participants increased their number of steps, while three experienced a decrease in their number of steps. Among all 12 users, there was an increase of 20 % during the two-month trial. The maximum individual daily step counts varied between 4376 (user 10) and 20222 steps (user 11).

Table 8 also shows how often the users manually transferred the number of steps to the Few Touch application, i.e. the “No. of readings” minus “Days of use”, since one reading each day was automatically transferred to the application.

Table 8. Statistics for use of the physical activity sensor system, and average steps.

User	Days of use	No. of readings	Avg. first week (*)	Avg. last week(*)	Max. steps
User 1	48	220	10222	9489	19063
User 2	63	59	5574	6208	10843
User 3	54	54	1760	2515	5144
User 4	56	58	7163	11284	15193
User 5	89	103	7094	10000	16860
User 6	60	226	3839	3038	7170
User 7	32	51	3717	5588	6581
User 8	50	93	4118	5988	11028
User 9	60	89	4813	5317	16363
User 10	40	62	2927	2763	4376
User 11	55	134	9508	10301	20222
User 12	91	98	3522	5013	7796
Average	**58**	**104**	**5355**	**6459**	**11720**

(*) The first and last week averages are calculated on the basis of the nearest 7 days with valid recordings. This is because there are generally some days in a full week where data is not transferred.

Motivational effects: The patients’ written comments in the questionnaire (Appendix 15) regarding why they were motivated by the step counter system to be more active were:

“It shows the length of the exercise sessions.”
“Exciting to check how much one moves during the day.”
“I get fitter.”
“I get motivated to walk more.”

The written comments regarding why they were **NOT** motivated by the step counter system to be more active were:

“It has been motivating, but not led to increased activity.”
“I think I am as active as I should be already.”
“Since the step counter mostly did not work.”

Focus group quotations: The patients’ statements from the last focus group meetings illustrate both negative and positive elements of using the physical activity sensor system, e.g.:

“I think that the step counter is too big and it is stupid that I have to wear it attached to a belt.”

“The motivation increased again when we got the step counter. I have tried not to take the bus, but instead walked back and forth to my work.”

“The step counter works badly when I ski.”

“It should have had round edges; I got a blister on my gut from using it!”

“I think it is very nice viewing the steps as bar charts – then you can see them visually and not only as numbers.”

“Of course I like this step counter.”

“I walk more when this step counter works.”

"I think it is a very OK system, especially after we got the step counter – very motivating, exciting to see how much I have walked today. It has worked."

"I think this one is very nice, I am eager to see what the next functionality is."

"The step counter has had the result that – I have a rather routine job – when I drive to a meeting, I park as far as possible from the door, and even make a detour. Before – I parked as close as possible."

"The step counter we had initially, I did not like very much, but this one – since you get a historical graph from it – is much more motivating."

"But it should have been smaller, and had some memory, because it does not always transfer the daily activity if I am too far away from the mobile phone."

Brief discussion and conclusion: Most of the users expressed enthusiasm for the physical activity sensor system when they met in the last focus group meetings, despite a relatively high error rate for the hardware (the step counter). Fifteen episodes of malfunction among six users were registered during the two-month test. In addition to the malfunctions, the large size and the fact that the sensor unit only recorded steps (not skiing, cycling, swimming, etc.) were mentioned as the biggest disadvantages. The concept of visually having an overview of the number of steps on their mobile phone was highly appreciated. Among all the 12 patients, there was an increase of 20 % in the number of steps, when comparing the first week of use with the last week of use.

5.3.5 Testing the General Information Functionality

This functionality was introduced to the 12-patient cohort two months out in the study, thus it was tested for four months. The functionality is labelled "Tips" in the main menu, and consists of 80 short texts related to Type 2 diabetes that the participants are able to navigate through. The source of the tips was databases developed as part of two of our previous projects providing general diabetes-related information to people with diabetes [378],[360].

User satisfaction: There were no reported malfunctions of this functionality, and the users were especially satisfied with it in the beginning of the test. Many members of the cohort requested new texts with information at the subsequent user meetings. Eight of the users were "fairly satisfied" (rated as 4 on a scale to 5) with the functionality, 3 were "very satisfied" (score 5 of 5) and one ranked it "neither satisfied nor dissatisfied" (score 3 of 5). The users reported at the end of the study that they used the functionality on average 1.7 times a week, and all 12 users appreciated the food-related texts as the most useful. Three of the users mentioned the exercise-related texts as the most useful as well.

Some of the patients' feedback regarding desired future improvements is illustrated by these suggestions entered into the last main questionnaire (Appendix 15, Questionnaire F):

> *"Include pictures of the food, fruits."*
>
> *"Include links [www] for those who are interested in more details."*
>
> *"More tips about food habits and contents of sugar."*
>
> *"A more active service, tips about food and exercise, to help change lifestyle – possibilities to receive SMSs about food, exercise, and to build up own profiles."*

The statements from the last focus group meetings also show that the nutrition-related texts are the most focused:

> *"I think it is nice to be able to show others which kinds of food I shouldn't eat."*
>
> *"Regarding this Tips-bank – there could have been more help with the food part."*
>
> *"I am still a bit unsure about the nutrition thing, you should be able to make food that you like. That is important."*

Brief discussion and conclusion: The general information functionality was especially appreciated in the beginning of the study, but more content was soon wanted by the users in the subsequent focus groups. All participants found the food-related information most useful, and some of them would like to have more advanced functionality with pictures, profiling and links to more information.

5.3.6 Usability of the Few Touch Application

As one of the issues addressed in this dissertation is research on how data capture systems for tracking blood glucose, nutrition habits and physical activity can be designed in a way that will encourage patients to use them and benefit from them on a daily basis (sub-problem 2), focusing on usability specifically was relevant. Both a standard usability questionnaire (the SUS) and a tailored questionnaire were used to access the users' feedback on the specific elements of the Few Touch application.

The System Usability Scale (SUS): After the six-month intervention, the participants were asked to fill in the SUS questionnaire (Appendix 15, Questionnaire G). The results from this were positive regarding the users' subjective reactions to the usability of the Few Touch application. The average score for all users was 84.0 out of the maximum of 100. The individual users' results ranged from 67.5 to 100, with a standard deviation (SD) of 13.7.

Tailored usability scale: Generally, the 12-patient cohort gave the specific items listed in Table 9 high scores. The original table can be found in Appendix 15, Questionnaire H. Table 9 lists the items ranked by score, and has been translated into English. The maximum score for each item can be achieved if all users give the item a score corresponding to "very satisfied"; thus 12 users multiplied by score "5" equals a maximum score of 60 points. As seen from the ranking, the food feedback screens, battery capacity, ease of recording food habit data, and the mobile phone size are the four items with the lowest scores.

Table 9. Ratings of specific usability items for the Few Touch application.

No.	Item / Rating (weight) ↓ →	Very satisfied (5)	Fairly satisfied (4)	Neutral (3)	Fairly dissatisfied (2)	Very dissatisfied (1)	Score
6	The colours used in the Few Touch application	9 users	3 users				57
13	How easy it is to get to the different screens in the Few Touch application	9 users	3 users				57
7	How clearly the text is presented in the Few Touch application	8 users	4 users				56
8	How easy it is to understand the BLOOD GLUCOSE graph	9 users	2 users	1 user			56
2	The screen-size of the mobile phone	8 users	3 users	1 user			55
5	The size of the buttons for the Few Touch application	9 users	1 user	2 users			55
9	How easy it is to understand the STEP graph	8 users	3 users	1 user			55
12	How easy it is to change the GOALS	5 users	6 users	1 user			52
4	Response time (from pressing to action) for the Few Touch application	5 users	5 users	2 users			51
1	The size of the mobile phone	4 users	7 users		1 user		50
10	How easy it is to add a food habit record	5 users	4 users	3 users			50
3	The capacity of the mobile phone's battery	4 users	5 users	3 users			49
11	How easy it is to understand the food feedback presented in the Few Touch application	5 users	3 users	4 users			49

Focus group quotations: User satisfaction is considered an important aspect of usability [72]. Some usability quotations are already included in the quotations relevant for the previous sub-chapters, but the following quotations may enrich the perception of how the cohort found the usability of the Few Touch application:

"That one gets it visually – the combination of all the efforts you do – it's incredibly important for further motivation."

"It's difficult to use the finger – then I have to push hard, but now I have begun to use the finger."

"I probably use the finger the most."

"I have been very satisfied with this – not only with the diary but with the mobile phone as well."

"To get the table with the step count data visible is a bit difficult."

"I do agree that it [the step counter] should have been smaller."

"Very OK to measure and then get it straight into the phone."

"No, I have got so used to it [the Few Touch application] that in my case I think it has become very easy to use."

"No, it's easy to relate to, it's after all just three buttons usually: steps, blood and food. Tips I just visit now and then. When you are into the food function, you know that you are dealing with food things – nothing else that may confuse you. So I think it's nicely constructed."

Brief discussion and conclusion: Checking Nielsen's "Ten Usability Heuristics" [249], I find that the Few Touch application supports most of these ten general principles, though his guidelines are not intended specifically for mobile units. Comparing the scores from the SUS test with other similar studies where it is concluded that usability is satisfactory or high, e.g. [227], [30],[137], where the scores were respectively 68.9, 72.5, and 78.1, our cohort's score of 84.0 can be considered high. The tailor-made questionnaire with the 12 items listed in Table 9 also received high scores. However, since the Type 2 diabetes cohort has been involved in the design process of the Few Touch application, the scores would most likely be lower if the system were tested on a new cohort. From the user meetings there were many quotations reflecting very positive responses to the application, but there are also several issues that should be improved in further versions, e.g. the touch sensitivity, the size of the step counter, and the bug in the step count goal setting, and the access to the step count table. This table showing the date, time and number of steps transferred was actually a hidden function described to the users only once, and appeared when the screen to the right of the bar-chart was touched.

5.3.7 Suggestions for Future Functionalities

The cohort both judged a predefined list of possible future functionalities for the Few Touch application, and came up with many of their own suggestions.

At the last focus group meetings the patients were asked to rate the ten suggestions for future improvements; see Appendix 15, Questionnaire H, or the ranked result in Table 10. When the answers were weighted by assigning 5 points for "Totally agree", 4 points for "Agree", etc., the suggestions were prioritized in this order: No. 3, no. 4, no. 9 and 10, no. 1 and 7, no. 2 and 6, no. 8, no. 5. Thus, suggestion no. 3 related to a smaller and easier-to-wear step counter was the most wanted, followed by no. 4 involving automatic pop-up tips on the mobile phone. Frequent transfer of data to the general practitioner (GP) was the least wanted future functionality, followed by no. 8, communication with peers with the same disease. The suggestions are sorted by score and presented in Table 10.

Table 10. The Type 2 diabetes cohort's ratings of predefined suggestions for future functionalities.

No	Suggestion **(score)**	Totally agree	Agree	Neutral	Dis-agree	Totally disagree
3	A smaller and easier-to-wear step counter **(52)**	7 users	2 users	3 users		
4	Automatic pop-up tips on the phone **(50)**	5 users	5 users	1 user	1 user	
9	Automatic feedback from the system, based on my measurements/data **(49)**	3 users	7 users	2 users		
10	Be able to use my own mobile phone **(49)**	5 users	4 users	2 users	1 user	
1	A reminder for measuring BG **(48)**	4 users	4 users	4 users		
7	Feedback from the health care sector related to my disease on my mobile phone **(48)**	5 users	4 users	1 user	2 users	
2	A reminder for recording food habits **(47)**	3 users	5 users	4 users		
6	Transfer of data to my GP when my values necessitate it **(47)**	4 users	5 users	2 users		1 user
8	Use of the system for communication with others with the same disease, about data, goals, tips, etc. **(44)**	4 users	3 users	2 users	3 users	
5	Frequent transfer of data to my GP **(43)**	2 users	5 users	4 users		1 user

Focus group quotations: Additionally, the following 17 suggestions were proposed by the patients themselves in the two focus group meetings at the end of the study:

1. *"I would have liked to have more tips with food types stating their glycaemic index (GI). This would have helped me to eat more fruit."*
2. *"I would like to have a display on the step counter as well, so that I do not have to check the mobile phone for the number of steps taken."*
3. *"My GP proposed having an easy way of presenting only the fasting blood glucose."*
4. *"There should have been a way of viewing the relationship between the three parameters (blood glucose, physical activity and food), a sort of conclusion from these all together."*
5. *"Regarding the relationship between the three parameters, give me for instance a number that I should stay below."*
6. *"The only thing I could wish was that there was a way to go directly to the food category of interest, e.g. to headings, so that I don't have to go through all the preceding tips."*
7. *"I have thought about having functionality enabling me to calculate the glycaemic load of the food."*
8. *"I would like to have a function that gives me an overview of how many calories I have eaten and how many I have spent."*
9. *"I wish that it was possible to view the step graph more than one week back in time."*
10. *"It could have been an idea to get a message like: Ugh! Now you have eaten too much!"*
11. *"What about using this system for children with Type 1 diabetes – the ones that I have showed it to were very impressed."*
12. *"Have you thought about using the system for prevention of diabetes as well?*
13. *"I would like more tips related to exercise, about what is exercise and such things. I could have got one SMS each day about food habits and exercise."*
14. *"The maximum value for the blood glucose graph should have been higher than 14 mmol/l."*
15. *"There could have been a calculator helping you to find out which foods are healthy, when you are shopping."*
16. *"There could have been more levels and more food to choose from, when recording food habits."*
17. *"I wish I could register more meals at the same time, without returning to the main menu between each registration."*

Brief discussion and conclusion: The patients' own suggestions for future functionalities confirm the view that food is the area of most interest for the cohort. This is also in line with the findings from Mamykina et al. [229]. Nine of the listed suggestions are food related, three are related to exercise or the step counter, and two are related to blood glucose measurements. Exciting functionalities like designing a system for feedback that sums up all three parameters (BG, steps and food) into one number, and suggestions for various calculators, came up. The importance of improving the step counter unit was confirmed from the scores of the predefined suggestions, and perhaps surprisingly for health care actors – the proposal for data transfer to patients' GPs received the lowest rating.

5.4 Cross-Disciplinary Research

The technical solution for an aid for families' self-management of diabetes as described in Paper 3 [384], was the basis for the cross-disciplinary study described in Paper 6 [124]. This study used questionnaires both before and after the intervention, directed at both young people with Type 1 diabetes and their relatives (Appendix 14), and using interviews with the relatives to elicit experiences and ideas regarding the blood glucose sensor system (Appendix 16). Two psychologists and authors of Paper 6 [124] independently read the transcripts of the interviews, noting emerging themes and corresponding quotes that recurred across interviews. The emerging themes were then condensed into these nine themes:

1. *Sense of security and reassurance:* The parents almost without exception expressed appreciation for the security of knowing whether or not their children had measured their blood glucose and that they could intervene immediately.
2. *Nagging and scolding:* Some parents reported that their nagging increased, while others reported a decrease, depending upon whether children monitored their blood glucose regularly or not.
3. *Control, responsibility, and independence:* Parents struggled to find a balance between the control they felt necessary to ensure the health of their child, while at the same time allowing for the child to develop their own sense of responsibility and independence.
4. *Surveillance and opposition:* An identified concern was that the system may create a negative sense of surveillance and thus fuel oppositional behaviour.
5. *Learning and age-phased appropriateness:* Parents indicated that the potential of the system to facilitate knowledge and skills about BGM and regulation was greatest at the onset of disease.
6. *Focus upon illness:* The parents who explicitly commented on this tended to think that their focus on illness was the same or less, but that this depended on the way it was used.
7. *If it's not automatic, forget it:* Parents were adamant about the measures needing to be transferred automatically, and had no faith in a concept requiring efforts from their children to trigger the transfer of measures.
8. *System type and functionality:* Suggestions for improving functionality included automatically generated dietary and insulin dosage advice. None of the parents thought the system would be useful in interaction with their health care provider, except if automatically generated historical graphics could be transferred to their provider in preparation for their ordinary checkups.
9. *It depends on how you use it:* Parents indicated that it was more the way they used the system than the system itself that was important.

The excerpts listed from the findings in the Type 1 study [124] clearly demonstrate the enrichment gained when one combines medical/psychological research with technically oriented feasibility studies like the one presented. For example, the involvement of the psychologists in this study revealed the necessity for total automation of the data transfer, and led to suggestions for improved functionalities.

5.5 Future Application – Epidemic Disease Indicator

The future use of the blood glucose sensor system described in Paper 7 [395] is based on the technological solution for transferring BGM data into the electronic health record (EHR) system “DIPS” (from DIPS ASA Norway [88]), as presented in [357]. The medical background for the future application described is that the blood glucose value increases when a person develops an infection. Furthermore, let us make the assumption that the blood glucose data from a large number of patients with diabetes, annotated with geographic location information, are collected in a central database. Advanced data analysis on this data may then detect higher than normal numbers of incidences, indicating a possible epidemic disease outbreak. This may enable health authorities to take actions to limit the outbreak and its consequences for all the inhabitants in an affected area. An example of a single incident that may be detected by an implementation of the “Epidemic Disease Detection using blood Glucose (EDDG) system” presented in Paper 7 [395] is presented in Fig. 28. The black dots represent the single measurements of a real Type 1 diabetes patient, the red line represents his average BGM, and the red, green and yellow areas respectively indicate critically low, healthy, and unhealthy high blood glucose value intervals defined for this patient.

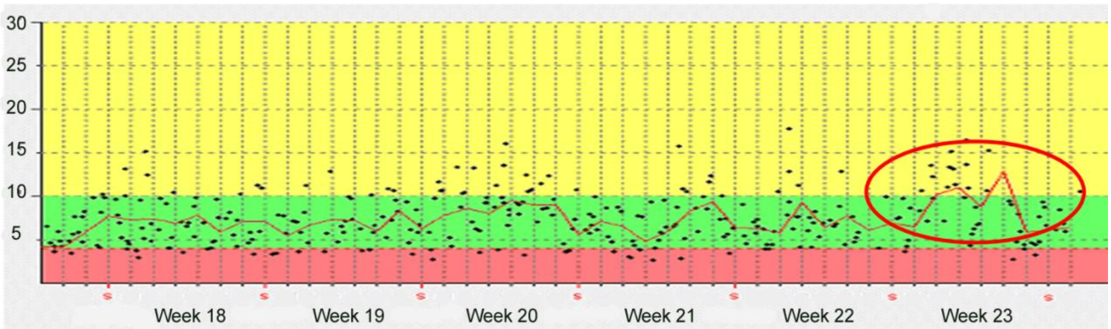

Fig. 28. Patient BG profile, with a potential infection in week 23, indicated by the red circle.

Many of the prerequisites of the EDDG system are in preparation and two research projects are ongoing as collaborative projects between the NST and the University of Tromsø. The work presented in Paper 7 [395] shows that it is possible to construct a fully automated and patient-operated system for transfer of blood glucose data into an EHR system, where the EDDG system is schematically outlined. The remaining technical issues to solve are mainly at the server side of the system, but also relate to the prerequisites for this concept to enable it to be implemented as a functional system. This involves merging all elements together in a functioning system, which includes an analysis of the aggregated data, executed in decision support management modules to provide the national or international health care surveillance authorities with justified information related to epidemic disease outbreaks. One should be aware that the EDDG system is a futuristic solution, and that the main aim of Paper 7 [395] was to increase awareness of the possibilities: technically, health-related and economically. Since the proposal in our paper, this concept has been elaborated on, presented in several other scientific papers, e.g. [138], [148], [41] and described further in a recent paper together with colleagues [149].

5.6 Dissemination

The efforts involved in designing, testing and presenting the self-help tools, especially the blood glucose adapter and the step counter elements, have been acknowledged by several organizations. The Bluetooth SIG exhibited the blood glucose sensor system as a Business Case Study on their web page [35], and as a reference eHealth application during a marketing tour in Asia during the autumn of 2004 and Europe in the spring of 2005. The Bluetooth adapter was designated as a "reference application" for the Bluetooth serial port vendor connectBlue AB [68]. Microsoft Norway presented the Few Touch application as one of their six customer applications within Health on their web page in March 2009 [237]. Both the blood glucose sensor system and the physical activity sensor system were recently also presented in Bluetooth SIG's magazine SIGnature[12] [215]. The Norwegian Diabetes Association has presented the self-help tool in their member magazine several times, e.g. [216],[382],[383]. The response to the concept from my colleagues at the University of Washington, USA, during my research stay, resulted in the common research study: "Using Interoperable Mobile Phone Applications for Managing Daily Events in Diabetes Care" as part of the Project Health Design [297], and subsequent video presentation of the blood glucose system of the Few Touch application at the *Project HealthDesign's* showcase event [298], now available at YouTube [117].

[12] The magazine is also available online: http://www.nxtbook.com/nxtbooks/bluetooth/signatureq208/ (see page 32-35).

6 Discussion

The overall aim of this PhD project was to generate knowledge about how a mobile tool can be designed for supporting lifestyle changes among people with diabetes. Cooperation with three different groups of patients with diabetes over several years and various methods and theories founded in computer science, medical informatics, and telemedicine have been combined in design and research on patient-oriented aids. The blood glucose Bluetooth adapter, the step counter, and the nutrition habit registration system that have been developed were all, to my knowledge, novel and unique designs at the time they were first tested. The achievements, the addressed problems, reservations, self-help versus health care support, and the future plans and prospects are discussed below.

6.1 Achievements

6.1.1 Premises and Conclusions

Given the underlying premises described in the Design chapter, I briefly discuss the emphasized issues and the achievements related to these:

Mobility: From the feedback from the half-year intervention, the Few Touch application seems to fulfil the attributes of mobility, except for the step counter application, which was perceived as too big and not ideal to wear.

Pervasiveness: The feedback from the active users does not indicate that the use of the application added any additional burdens for them, other than when technical problems arose. There were some episodes where the patient terminal, i.e. the HTC "Touch Dual" mobile phone, created extra strain in the form of malfunctions or difficulties in use, and a few episodes involving malfunctions of the blood glucose sensor system, but mostly it was the step counter that malfunctioned. Despite these problems, the users emphasized the usefulness of the application, and many of them found that the total experience of using the system was pervasive.

Blood Glucose functions: The 12-patient Type 2 cohort liked the blood glucose sensor system the best of the five different functionalities of the Few Touch application, and highly appreciated being able to see their glucose values as a historical trend graph. Few negative issues were expressed regarding this function.

Physical Activity functions: This sensor system was also appreciated by the cohort, but due to many malfunctioning units, only about half of the users referred to it as a very useful or motivating system. Users seemed to like the concept of accumulating the step count history on the mobile phone, but the sensor size and form need further work. Some individuals expressed a need for a way of measuring activities other than steps as well, e.g. by using a 3-axis sensor.

Nutrition Habit Registration functions: Of the three data capture systems, this seems to be the system that was regarded as least useful. However, analysing the database as presented in the Results chapter, we find that this is the system that most clearly indicated an improvement in its parameters. The system was fully used by a little less than half of the cohort, even though no malfunctions were reported. The effort involved in the manual data capture and the perception that the feedback from the system was not very useful were most likely the main reasons for the low level of use. Individuals in the Type 2 cohort expressed a wish to do more detailed recording of food data, which ideally should be an option.

Effortless and Fast to Use: This is a concrete premise to take into account regarding the data capture systems themselves, but is more a matter of subjective consideration when it comes to the feedback interfaces on the patient terminal. The blood glucose sensor system and the physical activity sensor system themselves do not add any extra tasks or efforts. The nutrition habit registration function needs two presses on the mobile phone's screen to perform a recording, but starting the application requires the user to find her mobile phone, turn it on, open the phone/keyboard lock if necessary, and potentially press the camera button to go to the main menu, thus requiring considerable effort and time in total. Using the other applications on the phone requires the same procedure, except for the two sensor applications – where the feedback screens on the phone are automatically activated.

Feedback: The nutrition habit registration system gives feedback in the form of smiley faces if the user has achieved her goals, and a blank face if not. This had been considered perhaps too simple, but some of the users really appreciated it. The data from the sensor systems are presented as either a bar graph or a scatter plot graph, which is a more visual way to present the user's achievement historically. Thus, in future, elaborating on concepts and implementations of nutritional feedback should be given priority.

Lifestyle Related Status: When using the data capture systems of the Few Touch application, one certainly gets an overview of blood glucose values, daily steps taken and food habits. Food habits are however the most difficult parameter of these to provide a status for, and the current version of this system is not optimal. On the basis of the feedback from the users in the half-year intervention, such a system should be configurable to each user's individual preferences and needs. Also, the status for blood glucose and step counts can be elaborated on, and individually tailored in future versions of the application.

Sustainability: The half-year intervention with the Type 2 cohort demonstrated that the Few Touch application and its elements were in fact used over long periods. Analysis of the patients' databases confirmed this. The experience from the four-month intervention with the Type 1 cohort also demonstrated sustainable use of the No-Touch blood glucose system. Again, the nutrition element, in addition to the personal goal element and the general information element, were the functions that were least used in the Type 2 study. It is perhaps obvious, but this emphasizes the importance of tuning the usability and the functionalities to fit the users.

Responsibility to Learn: The Type 2 cohort was generally knowledgeable regarding the main elements of managing their disease. However, several examples of misconceptions and lack of knowledge became evident during the focus group meetings. Some of these examples arose in connection with use of the Few Touch application, indicating that it may encourage learning in settings other than self-help. For instance, the Few Touch application, or elements of it, may be used in "motivational groups" such as those arranged by the Norwegian Diabetes Association.

Access to Information: Using the Few Touch application, the users actually had access to information about their blood glucose history, their daily steps during the last week, their food habits measured against their goals, and a limited amount of general information – at all time and everywhere, as long as they brought their mobile phone. Individuals told us that they actually accessed this information in situations where they would not have done this without the application, e.g. during physician visits, in meetings with friends and family, when waiting for appointments, at work, on the bus, etc.

6.1.2 General Outcomes

As a general outcome of the work with the Few Touch application, I would assert that applying technologies and methods from the informatics field has contributed to improved insight into how mobile tools can be designed for supporting lifestyle changes among people with diabetes. This was also the overall aim of the dissertation. Conversely, by addressing concrete use cases for people with diabetes, sound and innovative ICT designs have been achieved. The use of the focus group method throughout the whole design process proved to work well for the Type 2 cohort, but efforts should be made to check whether the designed prototypes work for unbiased user groups as well. As a whole, the work thus addresses the three sub-problems specified:

1. How can one involve real users in the design process and construct mobile self-help tools based on patients' real needs and preferences?
2. How can data capture systems for tracking blood glucose, nutrition habits and physical activity be designed in a way that will encourage patients to use them and benefit from them on a daily basis?
3. How can the three data capture systems be integrated into a mobile health diary, based on the new generation of mobile phones?

In total, the work done and the results achieved, address the main problem of the dissertation as well:

How can mobile devices for supporting lifestyle changes among people with diabetes be designed to be perceived as motivating and helpful by the users?

Generally, the work done has generated novel concepts based on the cohorts' needs and thoughts regarding what could be useful and user-friendly tools. The Few Touch application motivated and was perceived as useful for many members of the Type 2 cohort. Thus, the presented studies served both as a way of determining how the end-users would like the specific elements and the application as a whole, and how they thought it could work in everyday life. A summarized review of how the sub-problems have been addressed is presented below.

6.1.3 Sub-Problem 1 – User Involvement

The question "How can one involve real users in the design process and construct mobile self-help tools based on patients' real needs and preferences?" has been addressed in three of the papers included in my dissertation (Paper 1 [391], Paper 2 [385], and Paper 6 [124]). Frequently used methods from both medicine and computer science are used in the studies, with a focus on the best way to combine the use of methods from the two fields. There has been a special emphasis on including real users. Paper 6 demonstrates that developing technological solutions for patients benefits from being combined with thorough evaluations of the perceived usefulness and implications obtained by doing research in the medical/psychological field. For the main study, 12-15 active users were involved in the design throughout the design period. By including people who have the disease themselves in this case, we were able to obtain first-hand insight into the challenges they meet in their everyday lives. It would actually not have been possible to use people other than real end-users, when the aim was to design and test the blood glucose sensor system, or to see the correlation between food habits, physical activity and blood glucose values. The extensive user involvement made it feasible to test most of the elements of the Few Touch application over a half-year period, and all of the 12 active users have agreed to test the system for a full year. A prerequisite for testing whether the proposed ICT tools will lead to a better patient outcome is that the tools are designed in a way that enables patients to test them over a long period – which was achieved for the Type 2 cohort involved, entailing a high degree of user involvement.

The most widely used method – the focus group method – combined with other methods as part of the user meetings, provided the project team with sufficient feedback to inform the designs. By following the framework for user involvement as suggested in Paper 2 [385], we also achieved a high degree of user satisfaction as referred in Chapter "5. Results". Comparing the specific methods used, I would single out the focus group method, and frequent gathering of real patients in meetings of approximate seven active users, as the most important. An iterative prototyping process was indeed important as well, where available software and hardware competence was a necessity in order to implement the various designs presented. The thinking aloud method was informative, and would have been used more if we could have arranged the studies once more. I find questionnaires, interviews, data logging procedures and usability assessment essential in studies like the ones I have presented.

The main cohort (the Type 2 cohort) was a culturally homogenous group of people, all living in northern Norway. The fact that the designers, i.e. both the active users and the members of the project teams, come from the same culture excludes many of the culture-related relevancy issues described by Grimes and Grinter [140]. A weakness of the automatic functioning of the designed systems might be that the automation results in less *reflective thinking* by users. Reflective thinking is generally rare in applications, according to Mamykina et al. [229]. Examining the Few Touch application in comparison to the MAHI application [229], we find that our application has no explicit procedure that encourages reflective thinking by users. One might argue that after the automatic step counts or blood glucose data transfers, or after food habit recording – when the feedback screen is automatically activated on the users' mobile phone – reflective thinking is encouraged. Also, the "Personal Goals" functionality may stimulate reflective thinking, but this function was little used by the cohort. Looking at the quotes from the Type 2 cohort in the Results chapter, we see that they include many reflections during the focus group meeting. Whether the Few Touch application promotes reflective thinking in everyday life or not is yet to be determined in future research using other methods, presumably through field studies.

6.1.4 Sub-Problem 2 – Data Capture Systems

The question "How can data capture systems for tracking blood glucose, nutrition habits and physical activity be designed in a way that will encourage patients to use them and benefit from them on a daily basis?" has been addressed in three of my dissertation papers (Paper 3 [384], Paper 4 [389], and Paper 5 [390]). At least in Norway, my colleagues and I have experienced that people with diabetes do not generally keep written or computer logs of their blood glucose and other relevant parameters, i.e. the opposite of what Smith et al. [321] claim. Consequently, one of this dissertation's main areas of focus has been on designing systems that support generating logs, and it has been demonstrated that it is possible to design a sensor system for fully automatic transfer of blood glucose values [384], and a sensor system for fully automatic gathering and transfer of step count data [389]. At the time they were designed, both of the two sensor systems were novel in the way they captured data, transferred data in a fully automated process, and presented the data on the mobile phone-based diabetes diary system.

Novelty of the Blood Glucose Sensor System: At the time (2001-2003) that my research group and I identified and worked with the need for an easier way to transfer blood glucose data from children and adolescents to their parents, we could not identify any solutions that worked wirelessly and fully automatically – qualities which we considered to be innovative and desired by patients and their relatives. Confirmation that there were no similar patented solutions was received after the Norwegian Industrial Property Office[13] was requested in May 2003 to check the possibilities for patenting our solution. They performed a search in the *Derwent World Patent Index* for possible conflicting inventions. Three relevant patents were found, one of which [202] was characterized as conflicting with our concept. However, none of these three addressed the same aim or had the same design as our prototype had. Further efforts towards a patent application from us (the Norwegian Centre for Telemedicine) were discontinued for financial and political reasons.

Novelty of the Physical Activity Sensor System: No process was undertaken with a view to patenting the presented physical activity sensor system as we did for the blood glucose sensor system. Searches in the US Patentstorm [272] and the European esp@cenet patent databases June 2009 gave some relevant results, but none was identical to the presented system. Using the search term "step counter and automatic and wireless transfer and diary" in the "Full text" field in the Patentstorm database yielded 39 results. However, these patents and patent applications were far richer in function and in general reflected aims other than measuring physical activity. A search using the term "step counter" in the 'Title' field and "wireless transfer" in the 'Full text' field gave no hits. Replacing "wireless transfer" with "data transfer" returned two hits, but none was relevant. Searching for "step counter" in the Title field alone yielded 14 results, of which the most relevant was a patent held by Hahn [143], describing a pencil-like step counter communicating with a pocket paging receiver.

Searching the European Patent Office's Worldwide database with the keywords "step counter" in the 'Title' field returned 94 results. Refining the search to include the search term "wireless transfer" in the 'Title or abstract field' as well yielded no results. Using "wireless" alone in the last-mentioned field yielded a fairly relevant result, the patent application described by Hong et al. [159]. This system called "Wireless communication device embedding step counter function, method and system for health management using the same" facilitates transfer of food intake data to a server, which returns the exercise amount necessary to compensate for the food intake. The calorie balance is then monitored on the local device. Further details of this patent application were difficult to obtain, since the full patent document is presented in Korean only. Performing the brief patent searches described thus

[13] http://www.patentstyret.no/en/english/

identified no concepts similar to the one-button step counter that is part of the Few Touch application.

Novelty of the Food Habit Registration System: The system for recording food habits that has been designed was based on a mobile phone and requires only two touches on the phone's touch-sensitive screen, from the application's main menu, to perform registration. Nor has there been a process with a view to patenting the suggested concept for food habit registration. Like the total mobile diabetes self-help tool, a mobile phone-based nutrition habit registration system might be regarded as too comprehensive or complex to allow filing of a patent. To check this, some patent searches were done. Searches in the US Patentstorm and the European esp@cenet patent databases June 2009 yielded a few results, but none was identical to the proposed system. Searching the Patentstorm database's 'Full text' field for the search term "diabetes and nutrition and diary" returned 131 results. Refining the search term to "diabetes and nutrition and diary and mobile and touch sensitive" returned 11 hits, none of which was relevant. Changing the search term to "mobile and touch and finger" in the 'Full text' field and "nutrition" in the 'Title' field, returned one patent application, but this was not relevant. Replacing "nutrition" with "food" yielded 11 results, none of which was relevant. A search with "diary" in the 'Title' field and "food" in the 'Full text' field yielded 10 results, of which the patent by Darrow et al. [76] was the most relevant, but was for registration of more acute health conditions. Searching for "diary log", or "nutrition log", or "nutrition day book", or "food day book" in the 'Title' field yielded no results.

Searching the European Patent Office's Worldwide database for the above-mentioned keywords in the 'Title' field returned a few results, none relevant. Searching for "diary" in the 'Title' field, and "food" or "nutrition" in the 'Title or abstract' field, returned 13 results, none of which was relevant. Neither were the six results of searching only for the term "food diary" in the 'Title' field. Searching for "phone" in the 'Title' field and "food" in the 'Title or abstract' field returned 11 results, none relevant. Searching for "recording food" or "register food" or "recording nutrition" or "register nutrition" in the 'Title' field in combination with "phone" in the 'Title or abstract' field did not return any results either.

Thus, the nature of the food habit registration system probably makes it difficult to fulfil the requirements of patent regulations. As summarized by Hunt [165]: "To qualify for patent protection, an invention must satisfy the requirements of *utility, novelty,* and *nonobviousness.*" The proposed food habit registration system would probably fail the requirement of *nonobviousness*. Hunt explains this further: "Patent law asks, would the invention have been obvious, at the time it was made, to a person with ordinary skill in the field and with knowledge of the relevant prior art? If the answer is yes, the invention is obvious and a patent will not be granted."

Many relevant issues and theories are discussed by Grimes and Grinter [140] in relation to nutrition, culture and health technology. One major issue they stress is to consider social psychological persuasion research. In this regard I recognize that the Few Touch application's nutrition-related tips are typically "gain-framed", which is effective in promoting preventive behaviours. Thus, ideally, the nutrition-related tips should maybe be linked to the users' actual eating habits. Most likely this means that we need to include psychological expertise in such a design, which could be a research task for the future in the evolution of the Few Touch application.

Sub-Problem 2 Summary: The sensor system for fully automatic transfer of blood glucose values has been subjected to a clinical trial, which revealed that the automatic functionalities are crucial for the use of the system [124]. The sensor system for physical activity was therefore designed with a similar degree of automation for the data transfer, and even performs the data recording without needing attention from the user as long as the sensor is attached to the user [389]. The application for recording food habits requires only two touches from the user's finger to accomplish basic registration [390]. All three data capture systems were generally found easy to use and appreciated by the 12-person cohort.

6.1.5 Sub-Problem 3 – A Mobile Health Diary

The question "How can the three data capture systems be integrated into a mobile health diary, based on the new generation of mobile phones?" has been addressed in two of my papers Paper 1 [391], and Appendix 1 [387]. A thorough process has been conducted to determine the components of the Few Touch application so that it would be possible to integrate them in a holistic tool for the target group. The patient terminal constitutes the most important element of the tool, and the process of choosing which kind of device to use is partly described in Paper 1, and in Appendix 11. How the sensor systems should connect to the patient terminal is also important, and a description of alternatives and which wireless communication standard was chosen is described in Paper 3 [384]. The Type 2 cohort's preferences for the tool as a whole are described in Paper 1, while the patients' preferences for the data capture system components are described in, Paper 3 [384], Paper 4 [389], Paper 5 [390] and Paper 6 [124]. Thus, all of the described components of the Few Touch applications work together, configured for the same patient terminal, the HTC *Touch Dual* mobile phone. Furthermore, the work presented in Paper 7 [395] and Appendix 7 [357] shows that it is possible to construct a fully automated system for transfer of sensor data, exemplified by blood glucose data, directly from the patient and into an EHR system.

Comparison with Relevant Systems: How the Few touch application differs from other mobile ICT self-help systems within diabetes is shown in Table 11 below. The main criteria for including the systems in this comparison were that the systems were mobile (usually based on a mobile phone or PDA) and had at least the functionality to monitor blood glucose values. The systems included are mainly publicly available systems from Table 2, but there are also some relevant and promising prototypes from Table 1, indicated by "prototype" in the first column. Patents are not included in this comparison since they are more general and less concrete, contain no reference to clinical evaluations, and have restricted or no availability. The general characteristics of the patents identified in Chapter "2.1.1 Mobile Diabetes-Specific Tools" are that they were filed during the last 2-3 years, have not been accepted as patents but have been published as patent applications, and present relatively similar common concepts, but not so relevant to the Few Touch application. The likelihood that they will become patents may be small, but there is certainly a great deal to learn from the patent applications, and they should be examined further in subsequent design and research. The patent application by Henry [155] would however be of interest in a continuation of the Few Touch concepts, since it proposes an interesting system for utilizing a large amount of blood glucose data gathered in a common repository – a system in which the Few Touch application might be a contribution as a sensor element.

Table 11. Functionalities included in the Few Touch application and other relevant mobile ICT self-help systems within diabetes.

Systems / Functions ↓ →	BGM	Physical activity	Nutrition	Goal setting	General information	Usability issues
Few Touch application (presented prototype)	X	X	X	X	X	
MDoctor for DM [188] (prototype)	X	X	X	n/a	X	"Full automatic recording of blood-glucose and exercise data".
The Diabetes Interactive Diary (DID) [302] (prototype)	X	X	X	-	-	"Automatic storage of blood glucose measurements", manual physical activity registration.
LogbookFX Diabetic Diary [238]	X	-	X	X	X	Wireless transmission of BG data.
SiDiary [320]	X	-	X	n/a	X	Automatic wireless transmission of BG data to phone and desktop.
DiabetesManager (WellDoc) [363]	X	-	X	-	X	Automatic wireless transmission of BG data to health care web site.
smartLAB genie [156]	X	X	X	-	-	Automatic wireless transmission of BG data to mobile phone or computer.
OneTouch UltraSmart [217]	X	X	X	-	-	A BGM with options for recording food and exercise data by using predefined choices using its keypad.
SymCare, the In-Touch Diabetes system [333]	X	-	-	X	X	Automatic wireless transmission of BG data to health care web site.
The Polytel System [283]	X	-	-	-	-	Automatic wireless transmission of BG data to phone and server.
Alive Diabetes Management System [6]	X	-	-	-	-	Automatic wireless transmission of BG data to health care web site or others.
GlucoMON [83]	X	-	-	-	-	Automatic wireless trans-mission of BG data to remote caregivers (manually initiated).
GlucoPhone [152]	X	-	-	-	-	Automatic wireless transmission of BG data to health care web site or others.
myglucohealth [96]	X	-	-	-	-	Automatic wireless transmission of BG data to mobile phone or computer.
t+ Diabetes [335]	X	X	X	-	-	Wirelessly transferred BG data, but manually initiated. Manual entry of other data.
Personal Assistant [125] (prototype)	X	-	X	-	-	Wirelessly transferred BG data, but manually initiated.
CONFIDANT Diabetes Solution [66]	X	-	-	X	-	Wirelessly transferred BG data, but manually initiated, to mobile phone and remote server.
OmniPod with Personal Diabetes Manager [171]	X	-	X	-	-	Blood glucose (CGM), food planning and insulin delivery in one unit.
Glucose Buddy [245]	X	X	X	n/a	n/a	Manually initiated data transfer from phone to desktop.
Elardo DiabetesProfiler [246]	X	X	X	-	-	Manual entry of data, manually initiated data transfer from PDA to desktop.
Personal GlucoseTracker (Palm/Handspring companion program) [123]	X	-	-	-	-	Manually initiated data transfer from desktop to phone.
SugarStats Mobile Edition [329]	X	X	X	n/a	n/a	Manual entry of data.

DiabGo [4]	X	X	X	-	X	Manual entry of data.
Diabetes Pilot [86]	X	-	X	-	X	Manual entry of data
Glucose-Charter Pro [131]	X	-	X	-	X	Manual entry of data.
GlucoControl [49]	X	-	-	-	-	Manual entry of data.
GlucoTools [133]	X	-	X	-	-	Manual entry of data.
UTS Diabetes [170]	X	-	X	-	-	Manual entry of data.
GlucoseOne Palm Application [132]	X	-	X	-	-	Manual entry of data.
HealthEngage [151]	X	-	-	n/a	n/a	Access to data from iPhone or other mobile device.

Note: "X" means included, "n/a" means that information was not found, "-" means that the functionality is not provided.

As Table 11 shows, I found no systems comprising all elements included in the Few Touch application that are publicly available. The "MDoctor" [188] system is very similar to the Few Touch application in functionality, but little information about this system was found. Furthermore, there is no evidence that it has been subjected to clinical testing, and no detailed descriptions of the three data capture systems were found. The "Diabetes Interactive Diary" [302] also looks promising in terms of functionality, but regarding usability it seems to be based on manual data input for most parameters. The "LogbookFX Diabetic Diary" [238], the "SiDiary" [320], the "WellDoc DiabetesManager" [363], and the "smartLAB genie" [156] were the publicly available systems that were closest in functionality, with automatic wireless transmission of blood glucose data. The blood glucose monitor "OneTouch UltraSmart" [217] has predefined choices for recording food, exercise, medication and other health data, using the BGM's keypad and menus. However, the operation of this system requires much manual entry using the keypad and it does not seem to be widely used, at least in Norway. The Personal Assistant prototype [125] is rich in functions including insulin recording, and physical activity can be recorded as a general parameter, but its mobile terminal needs charging each 12 hours.

Usability Scores: The usability of the Few Touch application has been measured qualitatively through discussions in the focus groups, through interviews and through the SUS questionnaire and the self-designed questionnaire. Feedback from the focus groups and the individual interviews generally indicates good usability of the tested systems. The creator of the SUS questionnaire [47] specifically notes that the scores for the 10 individual items/questions are not meaningful on their own, and unlike other studies, e.g. [227], [377] and [122], individual item scores are therefore not presented. The study by DeWitt and Kuljis [80], where the score was 44.2, states that most users indicated that the software was cumbersome to use. The study by Lutes et al. [227], where the average SUS questionnaire score by their 11 users was 68.9, concludes that their system is usable. The study by Bernhaupt et al. [30], where the score was 72.5, describes the usability as reasonable with some room for improvements. For the study by Grammenos et al. [137], with a score of 78.1, the system usability was considered high. Thus the average score of 84.0 (SD=13.7) for the 12-patient cohort evaluating the Few Touch application can be considered high as well, i.e. the application is reported easy to use. The specific items addressed in the self-designed questionnaire (see Appendix 15) also received high scores from the users. The thorough involvement of the Type 2 cohort in the design process might be the main reason for these high scores.

Sub-Problem 3 Summary: Although the chosen smartphone – the "HTC Touch Dual" – is advanced and rather small, in general few users expressed problems during the half-year intervention, contrary to what was reported for e.g. the Nokia N80 in the MAHI study [229]. We might assume that the choice of a mobile phone with both a touch-sensitive screen and a physical keypad contributes a great deal to the generally very positive usability evaluations of the mobile health diary system presented. Whether the concept of the Few Touch application presented is the ultimate solution for designing a self-help system that is as automatic and easy to use as possible, is obviously debatable. As discussed by Smith et al. [321], automatic recordings might hinder the useful critique and reflection that often occurs during manual registration of events, i.e. the "reflection-in-action". A more systematic *task analysis* as described by Kwok and Burns [198] might further improve the usability of our application.

6.2 Reservations

The Type 2 cohort is a very engaged user group and a self-selection bias in our sampling and recruitment strategy may have yielded participants with relatively high knowledge of their disease. Most of the users also stated that one important reason for them to participate in focus groups and in the other interventions was that they believed that they could learn more about their health. These patients also perhaps have higher expectations of the tested ICTs than other people with diabetes, who may be comparatively less motivated or less committed to managing their health. Also, the Type 1 diabetes cohort was based on a recruitment process that involved searching for volunteers among local hospital patients, and this study had no control group. These conditions must be taken into account when the results presented are used.

A future issue for the Few Touch application and its elements to address is whether to use incentives or not. In order to maintain the adherence to the systems, which has so far been high, incentives should be considered in future designs and studies. Furthermore, even though the visualizations of the collected data seem to be appreciated by the Type 2 cohort, they have not been tested for how well they encourage reflection by the users, or whether they may lead to wrong conclusions or not. Another future task that has to be solved if the Few Touch application is to become commonly available is the sensor for physical activity. The current version only exists as a prototype in 20 samples, and as the Type 2 cohort has stated, it is too large in size.

Qualitative design research such as this provides rich insights into design concepts, but is not intended to support formal hypothesis testing or generalizable claims of causality. The tested application is a pure self-help application, with no interaction with health care personnel. However, several statements from patients expressed the benefits of being able to communicate either with health care personnel or with peers. Future studies should address whether and how tools like the Few Touch application could form part of the health care system, and how the application can be designed to offer peer-feedback functionalities. There may also be a vast medical research potential if these data are made available in databases for data mining and refined analysis.

None of the elements of the Few Touch application devices, technologies or studies has been commercially sponsored, other than the supply of free BGMs from LifeScan Norge [221].

6.3 Self-Help versus Health Care Support

The issue regarding whether blood glucose data should be transferred to the health care system or not has previously been discussed in Paper 3 [384], and is the basis for the more generalized discussion below.

6.3.1 Transfer of Data into EHR Systems

Transferring data directly into an EHR system seems tempting, but also has many implications. A situation in which health care personnel have such an amount of data available prior to or during patient consultations will clearly be beneficial if the data are used in the right way. A more critical consideration is the question of whether health care professionals could be held responsible for the medical complications that patients themselves cause due to unhealthy management, especially of their blood glucose level. Given this situation, health care professionals would have detailed information throughout the often long-term progression of the medical complications, and might be criticized for not taking action in time. Another issue is that acting on this vast amount of data might become an unmanageable burden for health care personnel in any case, due to the prevalence of diabetes in the population (typically at least 5%).

A future concept is a two-way disease management system between the patient and health care personnel. A typical feature might be to let health care personnel interact with the patient, suggesting changes in factors essential for diabetes management such as medication, nutrition, and physical activity. Possibly the strongest argument against this is that it would require considerable effort from a number of medical personnel. A counter-argument could be the possibility to design systems that only transfer necessary data when the patient's health situation requires it. Another consideration is that patients who have lived for many years with diabetes often know more about how to handle difficult disease-related situations than physicians and nurses. It might also be tempting to suggest a two-way system that provides feedback on the basis of algorithms and routines implemented in software, but there is a risk that providing clinical advice in this way could have harmful or even fatal consequences.

6.3.2 Data Ownership

Ownership of personalized health data is also a relevant issue to debate, especially since in this case it is the patients themselves who both acquire the data and transfer it into a database. A fear sometimes expressed by patients with chronic diseases is that insurance companies may refuse to insure them or may increase their premiums, if the companies get hold of detailed medical data. For example, insurers could increase premiums if patients' blood glucose control is not optimal. Similarly, there are concerns that medical personnel may refuse to support renewal of the patient's driving licence or other licences if they misinterpret (or correctly interpret) the patient's blood glucose data. Not least, there are many other psychological implications related to patients' awareness that they are constantly being monitored by health care personnel.

6.4 Future Plans and Prospects

Even though the Few Touch application is designed to be used for secondary prevention, i.e. on people who have already been diagnosed with the disease, research shows that lifestyle intervention can also prevent Type 2 diabetes in high-risk subjects [351]. In future plans, it is therefore natural to consider use of the tool for primary prevention as well as secondary prevention, i.e. it may be used on heart disease patients, for obese patients, for fitness purposes, and even on children with various chronic diseases. People with a high risk of developing diseases such as diabetes or various kinds of heart diseases could for example use only the physical activity module and the nutrition habit registration module of the Few Touch application, in order to change these lifestyle factors. For people with asthma one could interface the peak expiratory meter to communicate with the Few Touch application in a similar way to the blood glucose meter and the step counter. For some people with migraine and allergies, food intake has a major impact on their health problem, and the food habit element of the Few Touch application could be adapted to their needs. To conclude, the sensor interface, the content and interface of the digital diabetes diary could be changed to serve as a tool for other diseases or as a preventive aid.

There is an obvious need to coordinate efforts with others who are working with personal health, and a promising initiative is the Continua Health Alliance[14]. This consortium's aim, enabling interoperability between various products and services, is an important task for the future. Many further properties may be built into the Few Touch application, e.g. context awareness as we suggested in [63], real-time reprogrammable hardware as we suggested in [386], an EDDG system as we presented in Paper 7 [395], more *reflective thinking* as described by Mamykina et al. [229], or even *affective computing* – i.e. detecting and reacting to the user's emotions as Höök describes in [167].

6.4.1 Future Qualities of Self-Help Tools

Sainfort et al. [307] stress four specific qualities that human-computer interfaces must possess to be optimal both for the medical personnel and the patient, namely they need to be personalized, context aware, adaptive, and multimodal. One future improvement that will make the Few Touch application personalized and context aware may be the introduction of a start-up module. This module could classify patients into different profiles on the basis of questions asked by the system. An additional module may use the calendar (if synchronized with, for example, Microsoft Outlook), the time of day, the season, and other relevant factors for making the system context sensitive. Innovative use of mobile phones for capturing and using context information is described by e.g. Froehlich et al. [121], and concepts for use of context information for the Few Touch application, described briefly in [63], and in detail in [62].

Making the system adaptive or self-configurable may be implemented by letting it analyse and process the user's level of physical activity and nutrition habits as well as logging the frequency of use of the system and other relevant parameters for adapting the system during its use. In practice, this means that the Few Touch application would function quite differently during a week when the user is ill and inactive

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[14] http://www.continuaalliance.org/

compared with a normal week. Multimodality of such tools will provide users with several ways of interacting with it, other than the touch-sensitive screen and the physical numeric keypad. This may be via voice (speech recognition for input and speech synthesis for output) or haptics (e.g. vibrations and motions input/output), but also alternative ways of using the touch-sensitive screen, as with the iPhone [17].

Generally, tools like the Few Touch application should tailor feedback and encouragement for the achievement of good blood glucose patterns, good physical activity patterns and good nutrition habit patterns by the individual user, and vice versa the application should learn which interactions which are effective when unfavourable patterns need to be improved. "Interactive behaviour change technology" as advocated by John D. Piette [279], for example, holds promising potential for improvements for systems like the Few Touch application, and should be considered as well. As a final consideration, storage of the patient data in a secure and backed-up repository might be a good future solution. The security solution chosen for the Type 2 diabetes cohort was to inform the participants about the risk of having their data on their phone and explain how to use password protection for the phone. There was no backup routine for securing the data, other than quarterly at the focus group meetings.

6.4.2 Future Use of Self-Help Tools

The prevalence of Type 2 diabetes has increased strongly, including in adolescents, due to the recent negative trends in physical inactivity and change in food intake. Thus, adolescents and even children may be future users of a configurable version of the Few Touch application. A stand-alone self-help tool like the Few Touch application will enable people with diabetes to provide their health care helpers (diabetes nurse, nutritionists and doctors) better and more objective information about the three main parameters, at the regular consultations. The data may be a source for fruitful discussions between the patient and health care workers, and form a basis for the health care workers to give advice and proper treatment.

The Few Touch application may even be applied for the general population, for people who want to work with their health – who can choose parts of the tool for this, e.g. the nutrition habit registration part and the physical activity part. The possibility of comparing one's own measurements and habits with other people in the same situation, which may be motivating, is also a feature that remains untried, and is a candidate for future work. Presenting patients with more advanced collocations such as standard deviations, challenging times in the day, challenging days of the week, challenging times of the year, etc. for all health data, would also be sound candidates.

Continuous blood glucose monitor (CGM) systems have gained momentum in recent years, but are not yet well enough developed to provide the same accuracy as the conventional BGMs, and are also too expensive to be available for patients in general. Given that CGM systems will be commonplace within a few years, a relevant task may be to interface the Few Touch application with such sensor systems. The same of course applies to the other relevant sensor systems, when improvements appear, and a near-future scenario is that accelerometers, i.e. physical activity sensors, will be embedded in many of our electronic devices with standard wireless communication interfaces like the Bluetooth Medical Device Profile [34]. Even though these are highly promising possibilities and suggestions for improvements, user involvement and clinical tests have to be focused in future too, in order to achieve sound functionalities for improving disease management. Until implantable and continuous sensor systems are generally available, it makes sense to use existing sensors to prepare for future optimized implementations and self-help concepts like the Few Touch application.

I have described one of my concrete plans for utilizing the data and functionalities that the Few Touch application provides as a Post. Doc. project[15] called “Collocated Personal Diabetes Data (CPDD) – A System for Combining and Processing Data from Sensors and Other Relevant Data to Improve the Health of People with Diabetes”. This project will address the problem “Can the health of people with diabetes be improved by providing patients and health care personnel information based on collocated data from personal sensors and other relevant data?” It will involve cooperation with several partners, including two medical doctors and a nutritionist/physical activity educator. This project and another of our projects address how the Few Touch concept can be used in helping health care personnel to improve support and advice to the patient with a view to achieving better health.

[15] The Post.Doc. proposal was submitted to the Research Programme for Telemedicine (TFP) Helse Nord RHF on September 1 2008, and received confirmation for funding December 2008, for a four-year period starting February 2009.

7 Concluding Remarks

The concepts developed in this project may be even more valuable when implantable sensors become more common, accurate, and safe to use. The sensor systems will then be even easier to use, making it more likely that patients will accept the total concept, using a mobile phone as their patient terminal. Sound algorithms for processing and presentation of data gathered by data capture systems, such as useful trends in blood glucose values, physical activity data, and nutrition habits, will need to be developed and tested in the near future. The positive feedback from the active users of the Few Touch application is in line with the conclusion of Ballegaard et al. [22] in that healthcare technology is much more than informing clinicians; it is also about supporting the collaboration between the patients and the clinicians. In addition to support the Type 2 cohort being a mobile self-help aid, some of the Type 2 cohort members showed the system to their medical doctor, suggesting the potential for a common benefit from its functionalities.

The current version of the Few Touch application is designed for the case of motivated, healthy patients who want to improve their condition, but its various sensor elements will hopefully be useful for other cases as well. If the concept of enabling patients to gather, view and analyse their own health data becomes widespread, the result will be a kind of diabetes management that is quite different from today's. The benefits and consequences for the patient are discussed elsewhere in this dissertation, but the concept also has many practical consequences. It would mean that the patient needs to obtain and use a fairly advanced mobile phone with the Few Touch (or similar) software installed, and use specific blood glucose monitors with Bluetooth or other wireless communication interfaces as well as a physical activity sensor with a wireless communication interface. Financially, for the current version of the Few Touch application, and with the component prices applicable in 2008, this will result in a cost of approximately EUR 650, or NOK 6000. Whether this is a reasonable cost that society should spend on each diabetes patient is open to discussion. However, if one considers the vast amount of money – an annual sum of NOK 7 billion [254] – that is spent on diabetes complications in Norway alone, the expense of a self-help tool could be a worthwhile investment, given that the tool improves health. In addition, considerable weight should be attached to the potential effect of improved quality of life for patients.

The integration of the various components of the Few Touch application is now finalized, the system has been through a half-year test, and the 12-patient cohort is still using the system, aiming to conclude the intervention as a full-year test in September 2009. The findings will be reported as subsequent publications in the cooperating projects [277], [297], [278]. Larger clinical RCT studies of the system will hopefully also be funded in coming projects, where it will be rational to involve the health care actors and perform medical measures like HbA1c, which is the single most important factor predicting improvement in glycaemic control.

The Diabetes/Lifestyle Team that I am part of at the NST is currently involved in extensive activity within this area, regarding both ongoing projects and project proposals. I therefore end this PhD dissertation by expressing my optimism that patients in general will soon have access to self-help systems that are relevant and useful in their everyday lives, and that will increase their quality of life.

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Part II – Collection of Papers

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The papers [391],[385],[384],[389],[390],[124],[395] included in the dissertation are listed below. These may be categorized into five main themes: A) Requirements, designs and early tests, B) Methods, C) Data Capture Systems and System Design, D) User evaluation and cross-disciplinarity, and E) Future applications. Together, they present my main focus and contributions during the design and research related to the Few Touch concept. In addition, Part III contains 10 more of my recent scientific works that are relevant and complementary to the theme of the dissertation with regard to the Few Touch application.

Thus, the seven main papers for my dissertation are:

Requirements, Designs and Early Tests

Paper 1: Usability of a Mobile Self-Help Tool for People with Diabetes: the Easy Health Diary, by Årsand E, Varmedal R, and Hartvigsen G. Published in The third annual IEEE Conference on Automation Science and Engineering (IEEE CASE 2007), Scottsdale, Arizona, USA, September 22-25. IEEE Press, pp. 863-868 (ISBN 978-1-4244-1154-2) [391].

Methods

Paper 2: User-centered methods for designing patient-centric self-help tools, by Årsand E, and Demiris G. Published as an original article in the journal: "Informatics for Health & Social Care", September 2008, Vol. 33, No. 3, pp. 158-169 [385].

Data Capture Systems and System Design

Paper 3: No-Touch Wireless Transfer of Blood Glucose Sensor Data, by Årsand E, Andersson N, and Hartvigsen G. Published in the proceedings of COGnitive systems with Interactive Sensors 2007 (COGIS '07), Stanford University, USA, November 26-27, Paris: S.E.E. (Société de l'Electricité, de l'Electronique et des Technologies de l'Information et de la Communication) [384].

Paper 4: A System for Monitoring Physical Activity Data Among People with Type 2 Diabetes, by Årsand E, Olsen OA, Varmedal R, Mortensen W, and Hartvigsen G. Published as proceedings of The 21st International Congress of the European Federation for Medical Informatics 2008. Göteborg, Sweden, in the journal Studies in Health Technology and Informatics, Amsterdam: IOS Press, Vol. 136, pp. 113-118 [389].

Paper 5: Designing Mobile Dietary Management Support Technologies for People with Diabetes, by Årsand E, Tufano JT, Ralston J, and Hjortdahl P. Published in the Journal of Telemedicine and Telecare, London: Royal Society of Medicine Press, Vol. 14, No. 7, pp. 329-332 [390].

User Evaluation and Cross-Disciplinarity

Paper 6: Parent-Child Interaction Using a Mobile and Wireless System for Blood Glucose Monitoring, by Gammon D, Årsand E, Walseth OA, Andersson N, Jenssen M, and Taylor T. Published in the online journal Journal of Medical Internet Research, 2005, Vol. 7, No.5, pp.e57: 1-9 [124].

Future Applications

Paper 7: Using Blood Glucose Data as an Indicator for Epidemic Disease Outbreaks, by Årsand E, Walseth OA, Andersson N, Fernando R, Granberg O, Bellika JG and Hartvigsen G. Published as proceedings of The Medical Informatics Europe (MIE) congress 2005, Geneva, Switzerland, in the journal Studies in Health Technology and Informatics, Vol. 116, pp. 217-222 [395].

Paper 1: Requirements, Designs and Early Tests

Usability of a Mobile Self-Help Tool for People with Diabetes: the Easy Health Diary

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Published in The third annual IEEE Conference on Automation Science and Engineering (IEEE CASE 2007), Scottsdale, Arizona, USA, September 22-25. IEEE Press, pp. 863-868 (ISBN 978-1-4244-1154-2).

Paper 1: Årsand E, Varmedal R, and Hartvigsen G. Usability of a Mobile Self-Help Tool for People with Diabetes: the Easy Health Diary, The third annual IEEE Conference on Automation Science and Engineering, Arizona, USA, 2007.

Paper 2: Methods

User-Centered Methods for Designing Patient-Centric Self-Help Tools

by Årsand E, and Demiris G.

Published as an original article in the journal: Informatics for Health & Social Care, Informa Healthcare, September 2008, Vol. 33, No. 3, pp. 158-169.

Paper 2: Årsand E, and Demiris G. User-Centered Methods for Designing Patient-Centric Self-Help Tools. Informatics for Health and Social Care, Informa Healthcare, September 2008.

Paper 3: Data Capture System 1

No-Touch Wireless Transfer of Blood Glucose Sensor Data

by Årsand E, Andersson N, and Hartvigsen G.

Published in the proceedings of COGnitive systems with Interactive Sensors 2007 (COGIS '07), Stanford University, USA, November 26-27, Paris: S.E.E. (Société de l'Electricité, de l'Electronique et des Technologies de l'Information et de la Communication). pp. 1-8 (S6.3). (ISBN 2-91-2-328-470).

Paper 3: Årsand E, Andersson N, and Hartvigsen G. No-Touch Wireless Transfer of Blood Glucose Sensor Data. Proceedings of Cognitive systems with Interactive Sensors 2007, Stanford University, USA, 2007.

Paper 4: Data Capture System 2

A System for Monitoring Physical Activity Data Among People with Type 2 Diabetes

by Årsand E, Olsen OA, Varmedal R, Mortensen W, and Hartvigsen G.

Published as proceedings of The 21st International Congress of the European Federation for Medical Informatics 2008. Göteborg, Sweden, in the journal: Studies in Health Technology and Informatics, IOS Press, Vol. 136, pp. 113-118.

Paper 4: Årsand E, Olsen OA, Varmedal R, Mortensen W, and Hartvigsen G. A System for Monitoring Physical Activity Data Among People with Type 2 Diabetes. Studies in Health Technology and Informatics, IOS Press, 2008.

Paper 5: Data Capture System 3

Designing Mobile Dietary Management Support Technologies for People with Diabetes

by Årsand E, Tufano JT, Ralston J, and Hjortdahl P.

Published in the Journal of Telemedicine and Telecare, London: Royal Society of Medicine Press, 2008, Vol. 14, No. 7, pp. 329-332.

Paper 5: Årsand E, Tufano JT, Ralston J, and Hjortdahl P. Designing Mobile Dietary Management Support Technologies for People with Diabetes. Journal of Telemedicine and Telecare, London: Royal Society of Medicine Press, 2008.

Paper 6: User Evaluation and Cross-Disciplinarity

Parent-Child Interaction Using a Mobile and Wireless System for Blood Glucose Monitoring

by Gammon D, Årsand E, Walseth OA, Andersson N, Jenssen M, and Taylor T.

Published in the online journal: Journal of Medical Internet Research, November 2005, 7(5):57 doi:10.2196/jmir.7.5.e57.

Paper 6: Gammon D, Årsand E, Walseth OA, Andersson N, Jenssen M, and Taylor T. Parent-Child Interaction Using a Mobile and Wireless System for Blood Glucose Monitoring. Journal of Medical Internet Research, 2005.

Paper 7: Future Applications

Using Blood Glucose Data as an Indicator for Epidemic Disease Outbreaks

by Årsand E, Walseth OA, Andersson N, Fernando R, Granberg O, Bellika JG, and Hartvigsen G.

Published as proceedings of The Medical Informatics Europe (MIE) congress 2005, Geneve, Switzerland, in the journal: Studies in Health Technology and Informatics, IOS Press, Vol 116, pp. 217 – 222.

Paper 7: Årsand E, Walseth OA, Andersson N, Fernando R, Granberg O, Bellika JG, and Hartvigsen G. Using Blood Glucose Data as an Indicator for Epidemic Disease Outbreaks. Studies in Health Technology and Informatics, 2005.

Part III – Appendices

Part III – Appendices

As appendices to this dissertation, I have included a collection of 10 other scientific works [387],[388],[394],[359],[393],[386],[357],[397],[380],[392] that I have worked on, and that are relevant and complementary to the theme of my dissertation with regard to the Few Touch application. Also included are the thinking aloud session protocol, questionnaires, interview guides, Bluetooth adapter specification, and the requirement specification for the Few Touch application. Most of the session protocols, questionnaires, and interview guides are attached in their original language, Norwegian. As argued by Erkut et al. [97], translation of measures into another language is not straightforward, and extensive efforts should be dedicated to this. Due to this, and the considerable work it would have entailed, the Norwegian measures, protocols and guides are introduced by an English summary instead of a total translation.

The appendices are:

Appendix 1: A wearable eHealth system for people with Type 2 diabetes, by Årsand E, and Hartvigsen G. Published in the proceedings of the Scandinavian conference on Health Informatics 2005. Aalborg, Denmark, August 25-26, pp. 82 – 85. (ISBN: 87-986264-5-0) [387].

Appendix 2: Construction of a self-help system for automatic capture of physical activity data among people with Type 2 diabetes, by Årsand E, Olsen OA, Mortensen W, Varmedal R, Østengen G, and Hartvigsen G. Abstract and electronic poster presentation at the Tromsø Telemedicine and eHealth Conference 2007, Tromsø, Norway [388].

Appendix 3: Lessons learned from interacting with users 40-70 years old in designing an eHealth self-help tool, by Årsand E, Varmedal R, Østengen G, Gammon D, and Hartvigsen G. Abstract and oral presentation at the Tromsø Telemedicine and eHealth Conference 2007, Tromsø, Norway [394].

Appendix 4: Exploring different electronic media to support diabetes self-management, by Wangberg SC, and Årsand E. Poster presentation at the 19th World Diabetes Congress, Cape Town, South Africa, December 3-7, 2006 [359].

Appendix 5: Capturing and presenting patient-data through a smartphone; designing a self-help tool, by Årsand E, Varmedal R, Wangberg SC, and Hartvigsen G. Abstract and poster presentation at the Tromsø Telemedicine and eHealth Conference 2006, Tromsø, Norway [393].

Appendix 6: Reprogrammable hardware used in future patient-centric eHealth tools, by Årsand E, and Hartvigsen G. Abstract and oral presentation at the Tromsø Telemedicine and eHealth Conference 2006, Tromsø, Norway [386].

Appendix 7: Wireless transfer of sensor data into Electronic Health Records, by Walseth OA, Årsand E, Sund T, and Skipenes E. Published as proceedings of The Medical Informatics Europe (MIE) congress, August 2005, Geneva, Switzerland, in the journal Studies in Health Technology and Informatics: pp. 334 – 339 [357].

Appendix 8: Blood glucose data into Electronic Health Care Records for diabetes management, by Årsand E, Walseth OA, and Skipenes E. Published in the proceedings of the second HelsIT Conference at the Healthcare Informatics Week in Trondheim, Norway, 2004, pp. 19-23 [397].

Appendix 9: Design and Evaluation Methods; HCI, eHealth and Patient-Centric Self-Help Tools, by E. Årsand, 2006 [380]. Unpublished paper written as part of the doctoral HCI course at NTNU: "Advanced Topics in Human-Computer Interaction" (IT-8002). Note**,** the presented paper is slightly updated compared to its original version, due to progress in the referred projects.

Appendix 10: The Few Touch Application - Experience with a Diabetes Diary based on a Mobile Phone, by E. Årsand, R. Varmedal, H. Nilsen, G. Østengen, G. Hartvigsen. Poster presentation at the 2nd International ATTD Conference on Advanced Technologies & Treatments for Diabetes, Athens, Greece, February 2009 [392].

Appendix 11: Focus Group Sessions: Plans and Facilitators' Scripts
Ten focus group sessions were arranged in the period February 2007 until March 2009. It was the main methods for involving the Type 2 cohort in the design and research on the Few Touch application. Each of the arranged sessions lasted for two hours, and the number of users varied between five and eight. The full and original descriptions of the sessions are in Norwegian, and introduced with an English summary.

Appendix 12: Thinking aloud Sessions Round 2: Test Plan & Facilitator Script
The script used in December 2007, Seattle, USA, when presenting the nutrition system of the Few Touch application to the 6-patient US cohort. Included with the permission from Jim Tufano, UW, Seattle, USA.

Appendix 13: Paper Prototyping Session
The paper prototype schemes used to ask for the active users' view and suggestions for feedback screens for physical activity, presented for the Type 2 diabetes cohort spring 2007. The two pages of the original Norwegian version are listed first, then an English translated version.

Appendix 14: Questionnaires used as part of the Type 1 Diabetes study
The following questionnaires are in Norwegian, but each questionnaire is introduced with a brief description of the content in English:

Questionnaire 1, general questions (Spørreskjema 1)

Questionnaire 2a, children, before intervention (Spørreskjema 2a)

Questionnaire 2b, parents, before intervention (Spørreskjema 2b)

Questionnaire 3a, children, after intervention (Spørreskjema 3a)

Questionnaire 3b, parents, after intervention Spørreskjema (3b)

Appendix 15: Questionnaires used as part of the Type 2 Diabetes study
The following questionnaires are in Norwegian, but each questionnaire is introduced with a brief description of the content in English:

Questionnaire A – Early Feedback on the HTML demo

Questionnaires B – Mobile Phone Use, in Focus Group Meetings Spring 2007

Questionnaire C – Before Introduction of the Few Touch Application, Sept. 2008

Questionnaire D – 7 weeks after the introduction of the Few Touch application, prior to test of the tips and step counter applications, Oct. 2008

Questionnaire E – 4 months after the introduction of the Few Touch application, prior to test of the step counter application, Jan. 2009

Questionnaire F – 6 months after the introduction of the Few Touch application, March 2009

Questionnaire G – The System Usability Scale, 6 months after the introduction of the Few Touch application, March 2009

Questionnaire H – Usability Issues, 6 months after, March 2009

Appendix 16: Interview guide used as part of the Type 1 Diabetes study
The interview guide is in Norwegian, but is introduced with a description of the content in English.

Appendix 17: Interview guides used as part of the Type 2 Diabetes study
The interview guides are in Norwegian, but are introduced with a description of the content in English.

Interview Guide 1 – Individual talks 4 months after the introduction of the Few Touch application, prior to test of the step counter application, Jan. 2009

Interview Guide 2 – Added question to the 2007 survey on eHealth trends

Appendix 18: Requirements specification - for the Few Touch diabetes diary system 2008 - Type 2 diabetes

Appendix 19: Specifications for the Bluetooth adapter for the blood glucose sensors system

Appendix 1: A Wearable eHealth System for People with Type 2 Diabetes

by Årsand E, and Hartvigsen G.

Published in the proceedings of the Scandinavian conference on Health Informatics 2005. Aalborg, Denmark, August 25-26,
pp. 82 – 85. (ISBN 87-986264-5-0)

Appendix 1: Årsand E, Hartvigsen G. A wearable eHealth system for people with Type 2 diabetes. Scandinavian conference on Health Informatics 2005. Aalborg, Denmark.

A Wearable eHealth System for People With Type 2 Diabetes

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Abstract

Prevention of complications related to the disease Diabetes Mellitus requires appropriate changes in blood glucose levels, eating habits and physical activity. Many find that making and maintaining such changes are difficult. Thus, an important challenge to address is how to motivate and maintain positive changes in lifestyle over time. At the Norwegian Centre for Telemedicine we investigate how information and communication technology may support self-help and lifestyle changes. One aim among others is to gain knowledge about designing a wearable self-help tool for people with Type 2 diabetes. It has been proven that wireless transfer of blood-glucose data from sensor to a personal terminal (Smartphone) is possible and can be done non-obtrusively. A system which collects, processes and presents blood glucose, physical activity and nutrition data is being constructed. This system will provide the patients with important personal and general information and motivational advices, aiming to be a help in their disease management.

Keywords:

Diabetes Mellitus, Medical Informatics, Patient Monitoring, Self-Help Devices, Blood Glucose Self-Monitoring, Motivation, Sensors, Wireless Transfer.

Introduction

Improved blood glucose levels among people with diabetes are important in reducing long-term diabetes complications [1,2]. Long-term effects of diabetes include progressive development of retinopathy with potential blindness, nephropathy that may lead to renal failure and/or neuropathy with risk of foot ulcers, amputations, sexual dysfunction and substantial increased risk of cardiovascular diseases [3]. These types of complications account for huge annual expenses, and for Norway it sums up to NOK 3.5-4 billions per year [4]. Prevention of these types of complications requires appropriate changes in eating habits and physical activity. Many find making and maintaining such changes difficult. Thus, an important challenge to address is how to motivate the target group and maintain positive changes in lifestyle over time.

Fuelled by the epidemic proportions of lifestyle related diseases, many are seeking to design low-cost and tailored ICT-based systems for supporting lifestyle changes [5,6]. These ICT-based tools for changing lifestyle behaviour are typically based on existing stationary platforms tools (e.g. personal computers (PCs) accessing the Internet or CD-ROM) and then later adapted for specific needs (health, elderly, disabilities) within the limits of the existing technology. Park and Daly [7] identified 33 Windows based software systems and 14 Web based systems targeting diabetes. Based on controlled evidence from multiple sources, Balas, Boren and Griffing [8] indicated that computer-patient interactions lead to improved outcomes in the areas of diabetes management.

Thus, personal ICT tools for lifestyle change and disease prevention are mainly based on PC platforms using CD-ROM/DVD or web-based sources. Despite the fact that 46 % of users of different Internet health sites in the US report altering exercise/eating habits due to this use [9], research also shows that PC-based tools often are experienced as too complex or demanding. Future tools ought to allow integration onto peoples daily lives, being as simple and mobile as possible, preferably wearable. Mobile phones are approaching PC functionality with larger displays, and represent an appropriate platform for the project.

Social disparities in media access and literacy are contingent upon low-cost support tools. The future of interactive tools for health promotion and education will entail other platforms than ordinary PCs connected to the Internet. Today, almost every Norwegian citizen regardless of socioeconomic status owns a mobile phone [10]. Mobile phones are rapidly evolving into so called "Smartphones" with near-PC functionality. A potential benefit of these mobile platforms compared to a personal computer is their size, increasing simplicity and cheapness. Further, mobile phones can both be configured to be user-tailored and context sensitive in ways that are characterized as non-obtrusive, demonstrated in several projects, e.g. [14,16].

This paper gives and overview of the initial work in the process of constructing a system which collects, processes and presents blood glucose, physical activity and nutrition data to the patients.

Materials and Methods

Proof of concept

In experimental computer science, "proof of concept", i.e. to demonstrate that a particular configuration of ideas or an approach achieves it's objectives, is regarded as an intellectual contribution to a specific field. An engineering approach will be used for implementing the necessary prototype to be tested in user studies. This iterative approach is based on multiple development cycles of analysis, design, implementation and testing, and actively involves potential users of the system (i.e. people with Type 2 diabetes for this project).

Qualitative user studies

Proof of concept will be combined with qualitative user studies. Five users will be recruited through the local group of the Norwegian Diabetes Association with whom NST is currently collaborating. The prototype will be designed in collaboration with these persons, who have Type 2 diabetes. User-input will be facilitated throughout the development process. This input will be documented and included as part of the findings and methodological triangulation.

Quantitative user studies

Informants will be recruited through the University Hospital of North Norway (UNN), and if necessary also through other hospitals, advertisement in newspapers and the Norwegian Diabetes Association. Informants for the focus group will be selected in order to achieve dispersion with respect to age, sex and disease severity. As it is not possible to include as many participants in the intervention group within the scope of this study, as would be desired from the apriori power analysis, it will be run 30 participants through the intervention in three consecutive sequences and include twice as many in the control group. This will result in an estimated power of 0.65 for detecting differences of medium (0.25) effect size between the two groups with ANOVA at an alpha level of 0.05.

Measures

The participants will receive a questionnaire asking for demographic information, previous experience with relevant ICT tools, and current health status and blood glucose control. Improvements in health status will be measured by the three surveys/schemes described under the heading "Instruments" below. During the test-phase, blood glucose data, data of physical activity and nutrition data are continuously gathered by the wearable tool. Once the test-phase has ended, health status will again be assessed. In order to generate additional factors for evaluation of ICT tools, the focus group method will be applied. A questionnaire for assessing user-interface issues, e.g. particular problems, obstacles for use, safety, efficacy, and versatility will be developed based on previous studies. A guide for carrying out focus-groups will be designed as well. The main theme for the focus groups will be pros and cons of the wearable tool.

Instruments

Changes in health status, nutrition and exercise will be assessed by a questionnaire consisting of selected items from the Norwegian version of the widely used and validated questionnaire SF-36 Health Survey [11], the main questionnaire from the Romsås og Furuset Health Study 2003 (MoRo) [12] and the Diabetes questionnaire "Hunt-diabetes" from the Nord-Trøndelag Health Study (HUNT2) [13].

Results

Project results

The project "Automatic transfer of blood glucose data" [14] showed that it is possible to design a system for transfer of blood glucose data without any user-interaction. The same principles, using short range communication standards (e.g. Bluetooth) from sensors to a personal terminal (e.g. Smartphone) will be used in this project. The mentioned project was object of a clinical test (n=15) for a period of four months, and the current project will build on the results from this intervention [14], as well as from other NST-projects targeting people with diabetes [15,16,17].

Figure 1 – A wearable eHealth system for people with Type 2 diabetes.

As illustrated in Figure 1, the current system contains equipment for measuring, transferring and storing blood glucose data. The data is stored in an electronic health record and/or sent to relatives as an SMS. In addition, the patient can both access relevant data from a quality assured database via the Smartphone (data pull) or being sent relevant data to, as SMS (data push). Based on the patient's progress in her measured values, the patient is guided through recommendations regarded lifestyle changes. The final system will be equipped with one or more sensors for registration of physical activity and a simple user-interface for registration of nutrition data.

Thus, most of the system has been developed and tested on the reported patients. What remain to be implemented are the remaining sensors and software for personal motivational feedback, as well as clinical testing of the system.

Integration with EHR

Through the project "Wireless Health and Care" [17], it has been shown that transfer of sensor data, exemplified with blood glucose data, from the patient and directly into an EHR system, is possible. By using the API of one of the three main EHR systems for hospitals in Norway; *DIPS*, a prototype was developed and can be object for a larger clinical trial. This project is aiming to gain knowledge on how a future wearable self-help tool can be implemented, but also considering that a successful future implementation has to take into account the needs and aspects from the health care systems. To quality assure this, the project is supervised by expertise from the Norwegian Centre for Electronic

Patient Records (NSEP) as well as medical personnel. While NSEP aims to conduct research and development at the forefront of Electronic Health Record (EHR) system applications in the health services, this project aims to build knowledge on patient oriented health diaries/records. Many expect these two types of systems to merge in the future [18].

Prospective results

We will analyze the possibilities of using either Smartphones/PDAs or a custom-designed unit (FPGA/PLD/hybrid-based) as the basis building block for a patient terminal: "motivational self-help eHealth tool." Detailed analysis of suitable sensors for registration of blood glucose and physical activity will be documented and published. Similar analysis of the need to personalize the self-help tool and tailoring the patient information on the wearable terminal will be performed. In addition, articles on "systems for gathering lifestyle data", "capturing of nutrition data", "design of the self-help tool" and "the intervention group's change in diabetes control" will be submitted to international peer reviewed journals.

Discussion

The obesity epidemic has become a big problem on both a personal and public level today, leading to an increased risk of e.g. cardiovascular diseases, Type 2 diabetes and many different forms of cancer. Innovative actions are needed to stop this trend, that has lead to for example the fact that 65,7 % of American adults are either overweight or obese [19].

This project will contribute to Norway's ability to respond to the strategies outlines by EU's health ministers at the June 2004 meeting [20]. Member states are encouraged to develop and implement eHealth in the context of national strategies and of Community programmes in the field of public health. Diabetes is estimated to cost the Norwegian society NOK 10 billion each year [21], in addition to the impaired quality of life among those with the disease. Even if the knowledge and tools generated through projects of this type ultimately succeed in preventing *a mere fraction* of these costs, the impact may still be substantial.

Even though there is a significant increasing interest on using sensors for health monitoring devices, there are few examples of systems which enhance the use of the sensor-data in a useful and composed way. There are even fewer examples on systems that are wearable, providing the patient with motivational feedback based on actual habitual data (e.g. step counts per hour) and biological data (e.g. blood-glucose values). Some attempts are made, such as the "Diabetes Phone" [22] and the "Sweet Talk" [23], whereof both are aimed at young people with Type 1 diabetes. This gives rise to the need for more research on how to design the future generation of such tools, especially important due to the epidemic increase in the lifestyle disease Type 2 diabetes.

Recent advances in information and communication technologies support the belief in that such self-help tools are realistic to develop in near future, e.g. short distant communication standards and miniaturizations of microchips and sensors. Small size and "always-on" sensors will contribute to make the system more non-obtrusive, and to form an integrated element of the patient's daily life. Implementing a non-obtrusive way of measuring blood glucose data is more difficult than physical activity. The reason is that no non-obtrusively, reliably and continuously way of measuring the content of blood glucose in the blood is available yet.

Conclusion

Among other factors, Type 2 diabetes is related to an imbalance between energy intake and expenditure. For most of us, this imbalance is difficult to detect on a daily basis, something this research aim to address. With a simple and reliable way of keeping track on blood glucose, physical activity and food intake, and a tool that express improvements or remaining actions for exhibiting an improvement, people may be encourage to act more healthy. This research aims to contribute to this through design of a wearable, motivational self-help eHealth tool for people with lifestyle diseases, exemplified by the disease Type 2 diabetes.

Acknowledgments

Diabetes has been the theme of several projects initiated by the Norwegian Centre for Telemedicine in the period 2001-2005. We wish to thank all our cooperating colleagues and partners in these projects.

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Appendix 2: Construction of a Self-Help System for Automatic Capture of Physical Activity Data Among People with Type 2 Diabetes

by Årsand E, Olsen OA, Mortensen W, Varmedal R, Østengen G, and Hartvigsen G.

Abstract and electronic poster presentation at the Tromsø Telemedicine and eHealth Conference 2007, June 11-13, Tromsø, Norway.

Presenter: Årsand, Eirik

CONSTRUCTION OF A SELF-HELP SYSTEM FOR AUTOMATIC CAPTURE OF PHYSICAL ACTIVITY DATA AMONG PEOPLE WITH TYPE 2 DIABETES

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Abstract

We are developing a self-help system based on a specially designed step counter that captures data on the user's physical activity. The system displays the number of steps on the user's mobile phone automatically, or at the user's request. The system is designed for use by people with Type 2 diabetes, but may be beneficial for other groups who need to monitor their physical activity.

Growing awareness of the increase in obesity and Type 2 diabetes as well as a general concern with health and fitness have resulted in a strong focus on the use of step counters for self-monitoring of physical activity. This mainly involves wearing a sensor on the belt and reading the number of steps from its built-in LCD display. Some step counters come with built-in MP3 players and/or FM radios, enabling more functionality in the same device. Another trend is to include step counters in mobile phones.

Our step counter system is different from all of the above in its simplicity and the easy graphical overviews that are automatically generated. The system consists of two devices: a small sensor to attach to the belt or similar, and the patient terminal which at the same time is the user's mobile phone. The sensor sends data wirelessly once a day to the user's mobile phone, which in turn presents the daily result in a historical perspective (daily, weekly and/or monthly). The user thus needs only to deal with her mobile phone, but can also press the single button on the step counter if she needs more than one step-count reading per day. The step counter system is under development and the ePoster will present its appearance, functionality and potential.

Appendix 3: Lessons Learned from Interacting with Users 40-70 Years Old in Designing an eHealth Self-Help Tool

by Årsand E, Varmedal R, Østengen G, Gammon D, and Hartvigsen G.

Abstract and oral presentation at the Tromsø Telemedicine and eHealth Conference 2007, June 11-13, Tromsø, Norway.

Presenter: Årsand, Eirik

LESSONS LEARNED FROM INTERACTING WITH USERS 40-70 YEARS OLD IN DESIGNING AN EHEALTH SELF-HELP TOOL

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Abstract

Our research group is working toward useful self-help tools for people with chronic diseases. A group of 15 people with Type 2 diabetes has been included in a participatory design, over a period of four months. The overall aim of our current research is to design a self-help tool based on a mobile phone. This tool will capture data about the user's physical activity, nutrition habits and blood glucose levels, present these data to the user, and encourage the user to achieve a healthy lifestyle. In this presentation we will focus on the practical lessons learned while interacting with the informants, aged 40-70. More specifically, we will describe the user-centred methods applied in the participatory design phase and present our experience.

The motivation for the efforts in arranging user-centred design is to obtain as much valid feedback as possible, prior to the main prototype implementation phase. People with Type 2 diabetes are a highly heterogeneous group, with a typical onset at the age of 55 years. The trend is however that the onset age is getting lower. By including people from 40 to 70, we expected to obtain very different views on how a mobile self-help tool must be designed in order to be useful and sustainable.

Traditional telemedicine methods are typically questionnaires, workshops, interviews, focus groups and field studies. In our interaction we were applying human computer interaction methods to the participatory design phase. We required information on the users' real and practical needs in everyday life and their view on early prototypes, and thus decided to use prototyping and sketching exercises. The latter method is a variant of paper prototyping, in which users sketch the system design that would be ideal for them. Documentation methods were video, audio, schemes and notes.

The results from the participatory design phase gave us insight in which kind of user interface the different types of users preferred, their willingness to use wearable sensors for measuring physical activity, their willingness to measure blood glucose and factors that influenced the understanding of this parameter, the frequency of user interaction with a mobile tool in order for the device to be regarded as helpful rather than inconvenient, and many more aspects to be taken into account when designing such an eHealth self-help tool.

Appendix 4: Exploring Different Electronic Media to Support Diabetes Self-Management

by Wangberg SC, and Årsand E.

Poster presentation at the 19th World Diabetes Congress, Cape Town, South Africa, December 3-7, 2006.

Appendix 4: Wangberg SC, Årsand E. Exploring different electronic media to support diabetes self-management. The 19th World Diabetes Congress, 2006. (Poster).

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Authors:
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Exploring different electronic media to support diabetes self-management

Three studies aimed to assess how well suited mobile phones, DVD and Internet respectively, are to support diabetes self-management.

Together they support the idea that there is a potential for supporting self-management through information and communication technology (ICT).

Background

Managing diabetes is a complex task of balancing diet, physical activity and for many, medication, with the aid of blood glucose monitoring. Besides the educational needs this entails, maintaining such lifestyle changes over time is challenging. Therefore, there is a need for tools that can support and encourage long-term changes. ICT tools could facilitate information retrieval and interaction with peers and health care personnel.

Methods

11 parents of children with diabetes received diabetes information through mobile phone text messages (SMS) for 11 weeks and were interviewed at the end of the trial. 20 people with diabetes received an educational DVD and completed questionnaires before and one month after. 64 participants received a one-month multi-component Internet-based intervention and completed questionnaires before and after. Information was gathered on general perceptions, as well as specific features, of the media.

Results

Perceived usefulness ranged from medium to high for all media. The flexibility of electronic information retrieval was appreciated by users in all three studies. Time spent with material seems to be higher when education is "pushed". SMS seems well suited for delivering reminders in a pop-up fashion in busy everyday life. DVD seems to be a good medium for those familiar with TV, but not familiar with using the Internet. Improvements in self-care were found in the Internet study but not in the DVD study.

Currently we are combining tailored education with feedback based on sensor data in mobile life-style tools.

Figure 1: Main menu. Clicking on the "Steps" button will bring you to the screen below.

Figure 2: Steps screen.

Acknowledgements

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For more details see

Wangberg, S. C. (2006). An Internet-based diabetes self-care intervention tailored to self-efficacy. Manuscript submitted for publication.
Wangberg, S. C., Arsand, E., & Andersson, N. (2006). Diabetes education via mobile text messaging. Journal of Telemedicine and Telecare, 12(S1), 55-56.

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Appendix 4: Wangberg SC, Årsand E. Exploring different electronic media to support diabetes self-management. The 19th World Diabetes Congress, 2006. (Poster).

Appendix 5: Capturing and Presenting Patient-Data through a Smartphone; Designing a Self-Help Tool

by Årsand E, Varmedal R, Wangberg SC, and Hartvigsen G.

Abstract and poster presentation at the Tromsø Telemedicine and eHealth Conference 2006, June 12-14, Tromsø, Norway.

Presenter: Årsand, Eirik

CAPTURING AND PRESENTING PATIENT-DATA THROUGH A SMARTPHONE; DESIGNING A SELF-HELP TOOL

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Abstract (poster)

Self-management of diabetes is a complex task comprising keeping healthy blood glucose levels through balancing diet, physical activity, and for some, medicine. To succeed, extensive monitoring of these parameters is needed. We aim to design an interactive mobile tool that can aid people with Type 2 diabetes in managing their health. Blood glucose and physical activity data will be captured wirelessly from sensors, while nutrition data will be registered through a simple user-interface. These data will be integrated and fed back to the user.

The chosen self-help terminals for this scenario are Smartphones, i.e. mobile phones with near PC functionality. Smartphones can be configured to be both user-tailored and context sensitive. Typical screen size of such phones is 240 x 320 pixels, which is small compared to a PC-screen of 1024 x 768 pixels or better. This constraint presents a challenge in what we include as elements in our screen-designs, in order to present the health data to the user in a way that allows the individual to fully take advantage of the monitored parameters.

Various examples of such designs and reasons for our design-choices will be presented in this poster. The presented concept is part of an ongoing project, involving interdisciplinary research competence within informatics, psychology and medicine. The self-help tool will be designed and tested on real patients in two phases, whereof this poster presents phase 1.

Appendix 5: Årsand E, Varmedal R, Wangberg SC, and Hartvigsen G. Capturing and presenting patient-data through a smartphone; designing a self-help tool. Tromsø Telemedicine and eHealth Conference. Norway, 2006. (Poster).

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Designing a self-help tool

Capturing and presenting patient data through a smartphone

Authors: Årsand E, Varmedal R, Wangberg SC, Hartvigsen G.

Self-management of diabetes is a complex task which involves maintaining healthy blood glucose levels through a balanced diet, physical activity, and for many, medicine. Success depends on extensive monitoring of these parameters. We aim to design an interactive mobile tool that can help people with Type 2 diabetes to manage their health. Blood glucose and physical activity data will be captured wirelessly from sensors, while nutrition data will be registered through a simple user interface. These data will be processed and fed back to the user.

Intervention:

The presented concept is part of the ongoing PhD project "Self-help through a mobile ICT tool - Supporting lifestyle changes for preventing secondary diseases for people with Type 2 diabetes using a digital diabetes diary". This involves interdisciplinary research competence within informatics, psychology and medicine. The self-help tool will be designed and tested in two phases on users with Type 2 diabetes. This poster presents Phase 1.

We would like YOU to try the application on the mobile smartphones on the poster: both the mobile phone with a touch-sensitive screen, and the phone with a navigation button. Please give us your feedback on the self-help application, and on your experience of using these two different smartphones for this purpose.

Functionality:

For optimizing usability, both the number of steps and blood glucose data are automatically transferred using a "no-touch" principle. Users may record the kind of meal (breakfast, lunch, etc.) alone or add what kind of food they ate (bread, pasta, etc.). Pushing the help button presents the most vital health information for the user, and automatically sets up a call to the ICE relative (ICE – In Case of Emergency). Tips and information are related to practical situations, aiming to offer the users a tool that is sufficiently "down to earth" to be appreciated. The user may choose to use the "Easy Health Diary" application as the main interface or the ordinary phone interface, with access to all functions in both cases.

Please touch the screen or use the navigation button!

Sensor input:
The number of steps the user walks per day and each blood glucose measurement are automatically and wirelessly transferred to the smartphone diary using Bluetooth communication.

Reasons for our design choices:

The self-help terminals chosen for this scenario are smartphones, i.e. mobile phones with near-PC functionality. Smartphones allow both customized and context-sensitive configuration. The typical screen size on such phones is 240 x 320 pixels, which is small compared to a PC screen of 1024 x 768 pixels or more. The challenge is to restrict the elements in our screen designs, while still presenting health data to the user in a way that allows the individual to take full advantage of the monitored parameters. The current design strives to limit user actions to the minimum, both for data entry and for users to view their status and progress towards better health parameters.

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Appendix 5: Årsand E, Varmedal R, Wangberg SC, and Hartvigsen G. Capturing and presenting patient-data through a smartphone; designing a self-help tool. Tromsø Telemedicine and eHealth Conference. Norway, 2006. (Poster).

Appendix 6: Reprogrammable Hardware Used in Future Patient-centric eHealth Tools

by Årsand E, and Hartvigsen G.

Abstract and oral presentation at the Tromsø Telemedicine and eHealth Conference 2006, June 12-14, Tromsø, Norway.

Presenter: Årsand, Eirik

REPROGRAMMABLE HARDWARE USED IN FUTURE PATIENT-CENTRIC eHEALTH TOOLS

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Abstract (session)

We would like to address a technology area, when applied on patient-centric eHealth tools, is expected to give new and useful services for people with chronic diseases. This area comprises programmable logic devices (PLDs) where implemented functionality may be changed at real-time by re-implementing the hardware itself. Examples of such a tool may be a wearable ”buddy” for people with diabetes, giving the patient health advises based on exact input from the patient’s own sensors. This “buddy” will adjust and configure itself listening to proper sensors, giving advices at the right form, time and frequency, i.e. context aware. Such wearable terminals will be based on reconfigurable, small sized, computational components such as programmable System on Chips (pSOCs), Field Programmable Gate Arrays (FPGAs), hybrids with CPUs, and Application Specific Integrated Circuits (ASICs). Useful patient tools have to be optimized regarding size and power, where power issues still forms the biggest challenge.

Our work and focus so far has been on designing eHealth tools for people with the chronic disease diabetes, using off-the-shelf components like Smartphones and commercial available sensors. We now turn our focus on contemporary and comparable designs using reprogrammable hardware offering the same functionalities, achieving even more flexible and tailored patient tools.

Appendix 7: Wireless transfer of sensor data into Electronic Health Records

by Walseth OA, Årsand E, Sund T, and Skipenes E.

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Wireless transfer of sensor data into Electronic Health Records

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Abstract

The purpose of this study is to explore how wireless transfer of sensor data can be implemented in existing Electronic Health Record (EHR) systems. Blood glucose data from people with diabetes Type 1 has been selected as the case.

As proof of concept, a prototype for sending blood glucose measurements into an EHR system was developed for the DIPS EHR system. For the prototype to be transferable to a general setting, care was taken not to introduce any additional workload for the diabetes nurses or the diabetes Type 1 patients. In the prototype, the transfer of blood glucose data is automatic and invisible to the user, and the data is presented to the nurses within the existing DIPS laboratory module.

To determine whether deployment of such a system would present any risks or hazards to patients (medical or financial), a risk analysis was performed. The analysis indicates that storing blood glucose values in the patient's EHR does not represent any significantly increased risks for the diabetes patient.

The study shows that existing EHR systems are well suited to receive sensor data. The three main EHR systems in Norwegian hospitals are all supported with application programming interfaces (APIs), enabling external vendors to add modules. These APIs are sufficient to implement modules for receiving sensor data. However, none of the systems currently have commercially available modules for receiving such data.

Keywords:

Blood glucose sensor, diabetes, diabetes nurse, diabetes management system, EHR, electronic health record, risk analysis

1. Introduction

In the case of a chronic disease such as diabetes, much of the responsibility for managing the disease falls on the patient. When diagnosed, the patient is given a certain amount of initial training and information, but throughout the lifelong course of the illness it is primarily up to the patient to maintain the discipline required to keep blood glucose levels within recommended levels.

Monitoring and control of blood glucose levels are critical in the management of diabetes Type 1 to minimize long-term complications, and people with diabetes Type 1 may need to measure their blood glucose level several times a day [1,2]. Blood glucose measurements are performed by applying a single drop of blood to a measurement strip in a blood glucose monitor.

Norwegian health services put together diabetes teams, combining the skills of different professionals, to help and support patients with diabetes. A diabetes team may include doctors, diabetes nurses, secretaries, dieticians and paediatricians. If patients have poorly controlled diabetes they may require extensive, often continuous, follow-up, while well-regulated patients may require as little as one visit every six to twelve months.

The routines and strategies for storing and maintaining patient information vary between different diabetes teams and health services. The information may be stored on paper health records, in Electronic Health Record (EHR) systems or both. Some hospitals even use special software for storing diabetes health record information. The trend, however, is for health-related information to be collected in fewer and larger systems.

Electronic Health Care Records in Norwegian hospitals

During the last years there has been a considerable increase in the use of EHR systems in Norwegian hospitals. While only 36 % of Norwegian hospitals had implemented EHR systems in 1999, this percentage had reached 84% in 2003 [3].

The National Centre for Health Informatics (KITH) is responsible for the Norwegian EHR standard. The standard is not mandatory, but the various health sectors may require EHR vendors to comply with certain parts of the standard. The standard is technology independent.

The three main providers of EHR systems for Norwegian hospitals are Siemens (Doculive), DIPS ASA (DIPS) and Tieto Enator (Infomedix). In 2001 the KVALIS project [4] conducted a survey on how Norwegian hospitals use these systems in clinical tasks. This study concludes that "doctors use electronic medical record systems for far fewer tasks than the systems supported" but for the task of "following results of a test or investigation over time" most doctors use the EHR system or other computer software if available.

Hospitals with an EHR system licence often tailor the EHR system to fit the individual hospital's needs. Since smaller hospitals tend to have fewer or less complex needs, such hospitals are often pioneers in taking full advantage of EHR use [4].

This study investigates the feasibility of wireless input and long-term storage in Norwegian EHR systems of routinely collected diabetes data by the patients themselves.

2. Materials and methods

The three main EHR vendors in Norway were asked about the possibility for their systems to receive and use wireless sensor data, and we visited the software division of two of these vendors. We also had contact with external vendors making add-on modules for the EHR systems. Diabetes nurses at four different hospitals were interviewed to provide information on current diabetes practice and how they would prefer diabetes data presented in the EHR system.

The DIPS EHR system was selected to develop and test a prototype for wireless transfer of blood glucose values from patients.

Through collaboration with NR (the Norwegian Computing Centre), we performed a risk analysis. The purpose of this analysis was to investigate whether wireless transfer of blood glucose data from diabetes Type 1 patients into EHR systems is feasible and whether such a system presents any risks or hazards to the patients (medical or financial).

3. Results

The diabetes nurses who were interviewed said they would prefer to have the blood glucose values presented as a list. They said that it was easier to see the actual values when they were presented this way, and that it was faster for them to read a list than to interpret graphs or pie charts since they were used to traditional paper-based lists. However, data presented as pie charts and graphs were also found to be useful [5].

Wireless transfer of sensor data into Electronic Health Records

The three main EHR systems in Norwegian hospitals are all supported with application programming interfaces (APIs), enabling external vendors to add modules. This makes it possible for smaller or specialised companies to make software that extends or communicates with the EHR. The APIs are openly available for the Infomedix and the DocuLive EHR systems and licensed for the DIPS EHR system. All three EHR APIs contain sufficient functionality to receive and manage the sensor data applied in our prototype.

Chosen EHR system

To develop a prototype for wireless transfer of blood glucose data from diabetes Type 1 patients into an EHR system, we collaborated with DIPS ASA. The company provided access to a DIPS EHR server, complete with a set of fictitious patients, DIPS client software as well as support and technical help. The program for storing blood glucose measurements in DIPS was developed using the DIPS API, which is a COM+ interface. The DIPS API provides functions for creating and updating patient information, lab results, lab requisitions and documents. The interface also includes various search functions.

The prototype

The prototype for wireless transfer of blood glucose data into the DIPS EHR system is a further development of an NST prototype where an in-house developed Bluetooth unit automatically transfers blood glucose values from a OneTouch Ultra blood glucose monitor to a Nokia 7650 mobile phone using a Bluetooth connection [6], and where these data are sent from the mobile phone as an SMS to a preset phone number.

The only part of this process visible to the user is when the diabetes patient measures his/her blood glucose level using the blood glucose monitor.

When the blood glucose monitor is switched off after the measurement, the NST Bluetooth unit is automatically switched on and stays active for 3 minutes. If the Nokia 7650 mobile phone is within Bluetooth range (10 meter) a connection will automatically be established, and the last blood glucose measurement will be transferred. If the Nokia 7650 is not within range (or turned off), the blood glucose measurements taken will be sent the next time the Bluetooth unit is turned on and the phone is within range.

When the Nokia 7650 receives the blood glucose value from the patient, the phone will automatically send the measurement as a SMS to a preset phone number. In this study we have configured the Nokia 7650 to send the measurement data to a PC equipped with a Nokia D211 phone card. The measurement data received at the D211 server contains the blood glucose values together with the date and time of the measurement.

The D211 server runs a small application that accesses an external DIPS server using the DIPS COM+ API over an Internet connection (the Norwegian Health Network in a real setting). The values are stored as lab results in the DIPS EHR laboratory module. Once a measurement is stored in the DIPS server, any DIPS client connected to the server can present it.

Figure 1 – Transfer of blood glucose measurements into the DIPS EHR system

The DIPS EHR client laboratory module is used to display lab results, and the blood glucose values can be displayed as a list of data or as a time graph.

Figure 2 – The DIPS lab module displaying blood glucose values

Risk analysis

In Norway, diabetes patients are not highly stigmatised, and in the case of Type 1 diabetes, the disease is typically not something the patient would hide from his/her surroundings. It is even considered as an extra safety if the surroundings know that a person has Type 1 diabetes, due to the characteristics and consequences of potential low blood glucose values. The OneTouch Ultra blood glucose monitor used in the prototype stores the last 150 values (without any security measures), and the other parts of the prototype are not considered to make the data more accessible for the surroundings. The security for the data once they are stored in the EHR is ensured through the security of the EHR system.

In this context our findings suggest that blood glucose values are not highly sensitive. For the data to be of interest to somebody other than the patient and the hospital, the attacker probably needs to collect data for a certain period of time. The probability of such an attack is small, as would be the consequences.

Blood glucose data as described in the prototype are typically used as a tool for communication between diabetes nurses and patients. Today, the patient brings a handwritten diabetes diary or a computer printout of these values to discuss diabetes management with the diabetes nurse. It is also common for many patients to give an approximate of the values based on memory. Storing the measurements automatically will simplify this process, and should not introduce any new security issues. Loss of data or incorrect measurements may still occur (through hardware or software failure or through intentional manipulation by the user). The average blood glucose level of a patient is also measured through the HBA1c, and this serves as a security mechanism. The measurements provided by the prototype are not by themselves sufficient for providing medical advice.

The Norwegian jurisdiction on confidentiality of personal data is very strict. There are several laws and security requirements that must be followed, addressing issues such as documentation requirements, professional secrecy, privacy protection, disclosure requirements and information requirements. Applicable laws include the Personal Data Act, the Health Personnel Act and the Personal Health Data Filing System Act.

It seems likely that no extra safeguards need to be applied for blood glucose data compared with those necessary for other types of personal data, and security should be satisfied with any solution that complies with Norwegian legislation. Security safeguards include:

- The receiver of the information (blood glucose data) should be able to verify the identity of the sender.
- Sensitive personal data that are transferred electronically via a medium that is beyond the physical control of the responsible institution should be encrypted. SMS messages are encrypted over the radio link from the mobile phone to the GSM base station. The messages are transferred in plain text from the GSM base station through the telecommunication network or the Norwegian Health Network, but tracing these messages in the network is very difficult.
- The data received should be handled in a sufficiently secure manner with respect to confidentiality, integrity, availability and quality.
- In order to be able to make demands with regard to security of the equipment used by the patients, the health care institution should consider whether they should own the equipment.
- Communications (transfer of data) to or from the hospital should be fully controlled by the hospital.
- The blood glucose data should be protected against unauthorised access on the patient's side.

4. Discussion

Norway is approaching complete EHR coverage, and several hospitals are aiming to become totally paperless within the next few years. In order to gain the full benefits of this development, it is important that the EHR systems are not just electronic versions of the old paper-based health records, but take full advantage of the possibilities the new medium presents. EHR systems provide the possibility for automation of data retrieval, data structuring and data presentation. Transfer of sensor data from patients with chronic diseases is one such possibility [7].

In the case of diabetes Type 1, blood glucose data gathered automatically could support health personnel in helping and advising their patients in managing their disease. This function would also spare patients the trouble of keeping handwritten diabetes diaries. For an actual deployment of the system, SMS is probably too expensive. GPRS/3G should therefore be considered as an alternative for data transmission.

The concept can be applied to other settings, such as monitoring patient data at the patient's home and in some cases shortening hospital stays or eliminating the need for hospitalisation.

5. Conclusion

Our study suggests that transfer of sensor data into EHR systems is feasible with the current Norwegian EHR systems. A prototype has been implemented as proof of concept. The risk analysis suggests that the implemented prototype is sufficient for testing in an empirical trial. This is a possible continuation of the project and would help to further understand the usefulness of the concept in diabetes management.

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Appendix 8: Blood glucose data into Electronic Health Care Records for diabetes management

by Årsand E, Walseth OA, and Skipenes E.

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Appendix 8: Årsand E, Walseth OA, and Skipenes E. Blood glucose data into Electronic Health Care Records for diabetes management. The second HelsIT Conference at the Healtcare Informatics Week in Trondheim 2004, NSEP report no. 1. (Paper).

Blood glucose data into Electronic Health Care Records for diabetes management

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Abstract

A central issue in the future management of chronic diseases is transfer of vital sensor data from patients into the public health care system. Diabetes is selected as the case in this study.

The study analyses diabetology practice at four different hospitals, including the existing systems and protocols, practice and the professionals' view on future possibilities for using patient data more actively. A system has been developed which enables the automatic transfer of blood glucose measurements from the patient to a central database server, and we evaluate how these data can be transferred into Electronic Health Care Records (EHCR) at hospitals. The main objective of this study is to evaluate how wireless transfer of sensor data can be used by diabetes nurses to better assist and advise their patients.

Keywords:

Blood glucose sensor, diabetes team, diabetes nurse, diabetes management system, EHCR, Electronic Health Care Record

Introduction

The International Diabetes Federation estimates that there are currently some 194 million people around the world with diabetes, and that their number will exceed 333 million by year 2025 [1]. The increasing trend in the prevalence of diabetes is also manifest in Norway [2]. An intervention study from Romsås in Oslo discovered a diabetes prevalence of 9.0% for men and 5.1% for women [3]. The Norwegian Institute of Public Health estimates that more than 200,000 Norwegians have diabetes in 2004.

Monitoring and control of blood glucose levels is critical in the management of type 1 diabetes to minimize the long-term complications [4], [5]. Long-term effects include progressive development of retinopathy with potential blindness, nephropathy that may lead to renal failure and/or neuropathy with risk of foot ulcers, amputations, sexual dysfunction and substantially increased risk of cardiovascular diseases [6].

In the case of a chronic disease such as diabetes, much of the responsibility for managing the disease falls on the patient. When diagnosed, the patient is given a certain amount of initial training and information. During the lifelong course of the illness, it is up to the patient to maintain the discipline required to keep blood glucose levels within recommended levels.

Two parameters are especially important for diabetes management. The hemoglobin A1c test (HBA1c) indicates the average blood glucose level over the last 3 months. In addition, a person with diabetes may need to measure their blood glucose level several times a day. This is done by applying a single drop of blood to a measurement strip in a blood glucose monitor. The National Insurance Administration (Rikstrydeverket) records that in 2003 reimbursement was given for 36 million blood glucose measurement strips, with a total value of NOK 303 million (EUR 36 million) [7].

Norwegian health services provide *diabetes teams* combining the skills of different professionals to help and support patients with diabetes. A diabetes team may include doctors, diabetes nurses, secretaries, dietitians, and pediatricians. Patients with poorly controlled diabetes may require extensive, often continuous, follow-up, while well-regulated patients may require as little as one visit every six to twelve months.

The routines and strategies for storing and maintaining patient information vary between different diabetes teams and health services. The information may be stored on paper health records, in Electronic Health Care Record (EHCR) systems or both. Some hospitals even employ special software for storing diabetes health record information. The trend, however, is for health-related information to be collected in fewer and bigger systems.

In the action plan for IT development in the Norwegian health and social sectors in the period 2004-2007 (S@mspill -2007), the Norwegian Directorate for Health and Social Affairs states that one of its main strategic goals is to ensure full EHCR coverage in the Norwegian health service by 2007 .

The directorate explains that this initiative is considered to be the most beneficial IT initiative in the whole health sector, Achieving full EHCR coverage is the main precondition that will enable complete follow up throughout a patient's treatment by different providers within the health service, and will be especially helpful for the management and follow-up of patients with chronic diseases or with complex or special needs.

Methods

Drawing on the methodology and results of previous projects undertaken at the Norwegian Centre for Telemedicine (NST), we have developed and tested a prototype for wireless transfer of blood glucose values into a central database. Prototyping was chosen for three reasons: First to prove the concept and usability of wireless transfer of blood glucose data. Second, to explore the usefulness of integrating continuous transfer of blood glucose data into EHCR systems. And third, to form a tool for exchanging ideas and for mapping demands during interviews with diabetes nurses at the different health services.

The three main providers of EHCR systems for Norwegian hospitals are Siemens (Doculive, Soarian), DIPS (DIPS) and Tieto Enator (Infomedix). They were contacted, and enquiries were made as to what kind of messages and data these systems were able to receive and process. The providers were also asked whether their system provided an application programming interface enabling external parties to interact and to develop modules for the EHCR, and what their plans were for further expansions and development.

Various scenarios were written, in an attempt to visualize concepts and possible ways of presenting the blood glucose data for patients and health service personnel, as well as to evaluate the feasibility of various technical solutions. Interviews with diabetic patients and information collected in earlier projects undertaken by NST were also used.

Four diabetes nurses in different health services were interviewed about their work, and whether they believe receiving blood glucose data automatically into the EHCR would be valuable. The choice of diabetes nurses was based on criteria which included hospital location and size, and also which EHCR system the hospital was using, in order to cover the range of EHCRs.

During the course of this study, there was continuing collaboration between partners participating in the 'Wireless Health and Care' (WsHC) project, of which this study is a part. The collaboration included exchange of information and technology as well as assessment and grouping of goals and strategies.

Results

Development and testing of prototype

The prototype for wireless transfer of blood glucose data into health services is a further development of an NST prototype which automatically transfers blood glucose measures from a blood glucose monitor to a mobile phone, using Bluetooth [8]. The mobile phone (Nokia 7650) is programmed to automatically send the measurement result, by means of an SMS, to another mobile phone. The process is seamless and invisible to the user.

Figure 1- Prototype used as the basis for the study

In the WsHC project the prototype is designed to send the measurement results automatically to a PC equipped with a Nokia D211 phone card. Software was developed for managing these data by presenting them as graphs, pie charts or data logs.

Feedback from patients

Two persons with type 1 diabetes have used the system during a test period of two months. During the test period, the users contributed valuable feedback on how they preferred the data to be presented on a PC, and to how and when they preferred to use the information:

The pie chart proved useful as a motivator. The pie chart consists of three segments (red = the percentage of measurements below recommended level, green = measurements within safe levels, and yellow = measurements above recommended levels). The users felt that trying to keep the green area as large as possible was a useful motivation, and they competed to have the biggest green pie slice.
The graph proved useful in showing correspondence between blood glucose levels and insulin injections. Even though the system did not record how much insulin the patient injected, a trend showing that a too high blood glucose value is typically followed by a too low value is a good indication that the patient has a habit of using too much insulin.
The data log (listing of values, time and data), proved most useful in viewing recent blood glucose measurements. This is the traditional way of displaying blood glucose values.

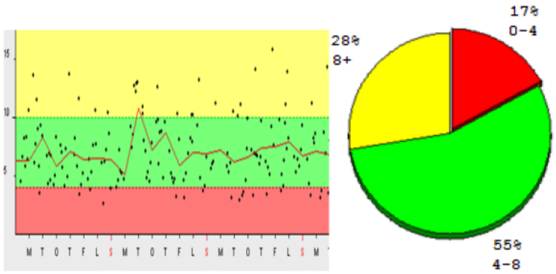

Figure 2- Developed software displaying blood glucose values

The project team has access to data from a previous project[1] where 15 children and their parents used the basic prototype (blood glucose measures via SMS, see Figure 1). In summary, most of the users of the blood glucose prototype found it helpful. Some parents expressed concern about the children being subject to too much surveillance.

Integration into EHCR

At each Norwegian hospital there are typically several different computer systems for gathering, managing and storing health information. There is a main EHCR system for storing patient record information and managing administrative tasks, as well as separate systems for gathering and storing laboratory results, systems for extensive patient monitoring and information gathering for use in the EHCR, as well as e-mail and internal software solutions.

All three EHCR providers stated that one of their key priorities was to develop more functionality for importing, storing and managing data relating to laboratory results.

To evaluate the potential for using existing EHCR systems for demonstration of imported sensor data, enquiries were made as to whether these systems could be adopted or modified to accept diabetes blood glucose data and present these data in a suitable way. The responses were that none of the EHCR systems currently have sufficient functionality. However, all the systems are provided with an application programming interface (API), which enables external players to develop modules with additional functionality for the EHCRs.

Within the scope of the WsHC project, all three suppliers of EHCR have been contacted with a request to connect a simulated EHCR system to automatically receive blood glucose measurements and other ad hoc data. At the time of writing, two of the suppliers have responded positively to the request.

Concerning the legislation affecting data transfer to and from the health-care sector, the following requirements are relevant for transfer of patient sensor data:

- Sensitive personal data should be encrypted when it is transferred via an external network.
- Communications with IT systems inside a hospital should be initiated from the hospital's IT system. SMS messages might be sent to a server in the Norwegian health care network. An application at this server could transfer the content of the message to an encrypted e-mail and send it to a hospital's e-mail system. The hospital could then retrieve the message from the e-mail server. The content of the SMS-messages could also be stored at the server in the health care network, and be made available to the user via a web browser using a secure connection (https). Information or messages from the hospital could also be sent to this server and be conveyed to the patient in the same way. The user should use a secure log-on procedure for access to the information at the server in the health care network. (The *PasientLink* open source software provided by NST is one such solution, and the *Well Arena* developed by Well Diagnostics AS is another). It is also possible to send the SMS messages to the user's own computer and to use a solution like *Well Arena* to transfer the information in a secure way to a hospital.

The National Center for Health Informatics (KITH) is responsible for developing the Norwegian EHCR standard. KITH provides the following information related to how the standard affects EHCR vendors:

- The main goals with the Norwegian EHCR standard is to show how the provision of law should be handled in EHCR systems and to ensure that the EHCRs are secured as a source of information for the present and the future. The standard is technology independent and includes a generic EHCR architecture based on the European pre-standard ENV13606. As this is a very comprehensive standard, more implementation experience is needed before it can be made mandatory. Hospitals do however refer to important parts of it in their tenders for EHCR systems and most Norwegian suppliers of EHCR systems have committed themselves to at least parts of the standard.The standard is not mandatory, but the various health sectors may require from the EHCR vendors that certain parts of the standard are followed. The standard is technology independent. A core requirement of the standard is that it should be possible to store any information that health personnel find useful in the EHCR.

Scenarios

Four alternative scenarios have been developed to provide alternatives as to how blood glucose data could be presented for diabetes nurses at hospitals:

1. EHCR scenario: Store and visualize the data in one of the existing EHCR systems. This may be accomplished by using import functions and presentation methods already available in the EHCR, or by adding modules or functionality to the EHCR.

2. E-mail scenario: Send blood glucose data as e-mail. This will require that the data is collected and managed prior to being sent. The e-mail could be sent as a weekly or monthly report, or on demand.

3. Web application scenario: The patient might obtain the data displayed on a web page. This page could also be available to the diabetes nurse, or the patient could access the page during the meetings with the nurse.

4. PC application scenario: Using a separate program for managing the data, and installing this program on the PC used by the diabetes nurse.

There are several web and PC-based diabetes management applications [9], although none of these applications automatically sends and receives blood glucose measurements.

At the Østfold hospital in Norway, there is a project where the diabetes nurse interacts with young patients via e-mail. In this project the patients transfer their blood glucose data onto a PC, and e-mail the data, and any queries which they might have, to the diabetes nurse [10].

To make the prototype of wireless transfer of blood glucose data into health services as realistic as possible, the EHCR scenario will be preferred if it proves feasible to implement.

Feedback from diabetes nurses

Diabetes nurses from four Norwegian hospitals were interviewed. They were asked how they received and used blood glucose data currently, and their opinions were sought about the prototype. General information about treatment and about nurse-patient interaction was also obtained.

Patient Interaction

The interaction between the diabetes nurse and the patients was found to be very similar at the four hospitals. A diabetes nurse typically sees five to seven patients each day, with consultations lasting between 10 and 90 minutes. Additionally, the nurses receive short phone calls from patients wanting general advice or new prescriptions for insulin. The nurses at each of the four hospitals record similar information from the patients. The routines for the number of visits per patient are also similar (1 to 2 visits each year for a well regulated patient, frequent visits for poorly regulated patients). The patients typically bring a printout or a handwritten diabetes diary showing the blood glucose data from recent measurements. Alternatively, some patients bring the blood glucose monitor, and the nurses refer to the monitor to obtain a reading of the measurements. The nurses commented that they preferred to have the diary handwritten or printed, as this made the data quicker and easier to read.

Use of EHCR and data treatment

Even though the interaction between diabetes nurses and patients is almost identical at the four hospitals, the routines for storing and managing patient data vary. At two of the hospitals, the nurse records the data by means of a tape recorder, and the data is later entered into the EHCR by secretaries. This procedure often results in long delays before the data is entered into the EHCR and the data is occasionally entered into the EHCR in the wrong order. At the two other hospitals the nurses themselves perform the data entry, a task which is sometimes time consuming. Two of the hospitals studied use Doculive, one uses Infomedix and one uses DIPS.

The routine for storing data is different between all the hospitals: One hospital holds the patient diabetes record entirely on paper, one has most of the data stored electronically but some of the data stored on paper, one has some of the data stored electronically, some of the data stored on paper and some stored both electronically and on paper. The last hospital has the entire patient diabetes record stored electronically, but on a computer application developed at the hospital and not in the EHCR system.

Views and suggestions for the prototype

Three of the nurses were positive towards the prospect of having the blood glucose data fed directly into the EHCR. The fourth nurse had some reservations, commenting that the blood glucose data itself was not very useful without additional comments on factors that affect the measurements such as food and activity. One general, positive, comment about the possibility of recording blood glucose data automatically into an EHCR, is that this will help nurses to observe that the patients are actually monitoring their blood glucose levels.

The nurses preferred to receive the data presented as a data log (date, time, measure). They said that it is easier to see the actual measure values, and that it is faster to read since the nurses are used to traditional paper-based logs. Data presented as pie charts and graphs were also found to be useful.

Generally, the nurses considered themselves and their co-workers to have a good level of IT competence.

Discussion

There are at least three main ways in which blood glucose data gathered from diabetes patients is valuable. The first is in helping the patients to manage their disease, the second is for health personnel to better help and advise their patients in managing their disease, and the third is for the blood glucose data to be used in research to gain better understanding of the disease.

One of the benefits the diabetes patients mentioned from using the prototype was as a motivating factor to keep track of data over time, and to try to improve the diabetes self-management. A possible expansion of this scheme might include enabling patients to compete with friends in the effectiveness of their management of blood-glucose levels, or by using the computer game concept to motivate younger children. One of the issues that need further exploration is the economic aspect: who should pay for such a service, and what are the economic or financial benefits of the service to the health service and to the patient.

Two important benefits for nurses are that they can more easily monitor *difficult patients* (patients who are negative towards visiting diabetes nurses, such as youth who want to distance themselves from their disease). In treating well regulated and disciplined diabetes patients, the benefit from automatic transfer of blood glucose data may not be very significant, but these patients usually manage their disease without help from the hospital.

Conclusion

In this study we have evaluated the use of a prototype for collecting blood glucose data for patient and for health personnel. To gather more accurate empirical data, the prototype will be employed in an actual or simulated patient – nurse setting. The preferred option would be to transfer the blood glucose data into an actual EHCR. If it does not prove feasible to use an actual EHCR, one of the other scenarios, or a combination of them, will be implemented. (e-mail, web application and/or stand-alone application).

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Appendix 9: Design and Evaluation Methods; HCI, eHealth and Patient-Centric Self-Help Tools

by Eirik Årsand

Unpublished paper written as part of the doctoral HCI course at NTNU, ”Advanced Topics in Human-Computer Interaction” (IT-8002), December 2006.

Appendix 9: Årsand E. Design and Evaluation Methods; HCI, eHealth and Patient-Centric Self-Help Tools. Unpublished paper written as part of the doctoral HCI course at NTNU, “Advanced Topics in Human-Computer Interaction.” (IT-8002), 2006.

Design and Evaluation Methods; HCI, eHealth and Patient-Centric Self-Help Tools

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Abstract. *This article reviews design and evaluation methods within the area of eHealth and telemedicine in general, and specifically for some of our self-help projects for people with diabetes. Results from experience in user-centred methods from three projects are presented. A list and a discussion of promising HCI methods that may be applied to eHealth and telemedicine projects are provided. The article explores relevant methods for design and evaluation of patient-centric tools. More generally, it also aims to create awareness of HCI methods and theories to consider when conducting research projects within this multidisciplinary research area.*

Keywords: User-centred design methods, Interactive television, Diabetes, Self-help tools, eHealth, Telemedicine

1 Introduction

Within eHealth and telemedicine, evaluations using questionnaires, workshops, interviews, focus groups and field studies are very common in psychological, sociological and medical informatics research. Our centre, the Norwegian Centre for Telemedicine, hosting around 100 researchers within a broad range of professions, is one example of an enterprise conducting projects where such methods are very common. Typically, the evaluations of prototypes or services are often performed independently of human-computer interface (HCI) theory and methods. The overall aim of this article is to direct attention to HCI methods that may be applied in eHealth and telemedicine research projects in general, and on my current focus: the PhD project comprising design of self-help tools assessing people with the chronic disease diabetes. Examples of relevant HCI methods are: thinking aloud, scenarios/ storytelling, personas, paper prototyping, and HCI specific usability instruments.

Using better and more adequate design methods, especially user-participatory methods, I think there is great potential for improving the design of information and communication technologies (ICT) tools for health purposes. On the basis of specific projects – both our own and those of others – I will review the use of methods and suggest aspects to keep in mind in future eHealth and telemedicine projects. The project "Digital TV and patient information" will serve as the main reference project, and data from the design process will be presented. This project focused on designing a stationary tool for people with diabetes, using the television as the basis. Two other projects from our diabetes project portfolio will also be outlined as examples, namely "Automatic transfer of blood glucose data from children with Type 1 diabetes" and "Screening for Diabetes Using HbA1c in Elderly Subjects". Finally, I will discuss implications the reviewed projects' results may have for designing patient-centric self-help tools.

2 Background

User-centred design is an important part of both the software and hardware engineering processes in designing telemedicine and eHealth applications. Even though there is a sound focus on designing reliable and user-friendly health applications, awareness of the HCI methods and theories is low. Until now, use of PCs and the Internet has formed the basis of the great majority of health applications. Telemedicine and eHealth have made vast advances during recent years, but still there is a feeling that system usability does not receive enough attention.

2.1 Technological Improvements

During the past 10 years, there has been substantial growth in the development of self-help tools for patients using information and communication technologies. This is mainly due to the biological revolution and the advances in technology. The biological revolution, with advances in both genetics and biomedical engineering, has brought us a number of new diagnostic tests and disease management tools. Advances in ICT in general have provided us with hardware and software which offer great benefits for health care. Most of the tools are based on biological sensors and stationary terminals such as personal computers and television sets. Mobile self-help tools are also emerging, based on the growing number of wireless communication standards and the miniaturisation of electronic components. These improvements have made it possible to make both wearable sensors and terminals, so-called sensor systems. Short-range communication technologies such as Bluetooth, WiFi, ZigBee and UWB as well as long-range communication technologies such as GSM, GPRS and UMTS create the potential for a new level of flexibility compared with what stationary devices have traditionally provided. Thus, the combination of these technological elements has given us new possibilities for health care delivery and self-help.

2.2 The Health Care Sector and ICT

The structure within the health care sector is considered to be strongly hierarchic, where medical doctors in particular have great power. Traditionally, the notion of “users” has been associated with health care personnel within the medical profession. Lately, patients have been recognised as playing a more important role in their own health, with reference to the “empowerment” concept, the aging population, and the scarcity of resources for dealing with health problems among this group. Anticipation of this situation has led to many products directed solely at patients, e.g. devices for measuring blood pressure, blood glucose, respiratory peak flow, body temperature, heartbeat, etc. The technological advances have made it possible and affordable to develop a vast number of devices intended for direct use by patients or potential patients – also called eHealth consumers.

2.3 Shortcomings in the Exploitation of eHealth's Potential

Many of the patient-centric health tools on the market do not fully utilise the potential that technology provides for a truly user-friendly and useful end-product. A specific example of such a tool, which our research group has worked with several years, is blood glucose monitors. Even though short-range wireless communication standards are relative mature, none of the industry players have so far made the most of such standards to simplify transfer and use of blood glucose data. Some third-party players have approached this issue, but we have not found any that have really taken users’ needs into consideration to develop sustainable self-help tools. Another example our research group has worked with is providing disease-specific information to the vast group of people who are not accustomed to using PCs and the Internet. We have made prototypes and interventions for this group using both the television and the mobile phone as alternative terminals to PCs.

2.4 The Patient as a User

The typical user in HCI settings and usability evaluations is a company employee. For most workers – in our context, medical staff – the incentives for using a new product or new service should be strong relative to patients with lifestyle-related diseases such as diabetes. HCI research seems to focus more on user groups such as medical staff than on patients. A simple reason for this may be that there are far fewer players representing the patients – usually only patient organisations.

Sainfort et al. [1] stress four specific qualities that human-computer interfaces must possess to be optimal both for the medical personnel and the patient: multimodal, personalised, context aware and adaptive. For most of the users requiring self-help tools for chronic diseases, i.e. mostly older adults, more basic factors need to be taken into consideration as well. These include age-related changes in functional abilities such as sensor-perceptual processes, motor abilities, response speed and cognitive processes. In Czaja and Lee’s review of designing computer systems for older adults [2], they conclude that issues such as screen design, input devices, and interface style are largely unexplored. They also stress the importance of knowing why the technology may be difficult to use, how to design for easier and more effective use, and how to teach users to take advantage of the available technologies. Solving issues addressed in these questions for a typical patient will also benefit all potential users.

2.5 The Case of Diabetes

The global prevalence of diabetes is today 194 million (5.1 %) [3] and is rapidly increasing due to cultural and social changes, ageing populations, increasing urbanisation, dietary changes, reduced physical activity and other unhealthy lifestyle and behavioural patterns [4]. In addition, the prevalence of impaired glucose tolerance (IGT), a precursor of diabetes, is as high as 314 million (8.2 %), and 70 % of these IGT is expected to develop diabetes [3]. Diabetes seems to be highly suitable as a case disease for research on the use of ICT for health purposes. Some of the reasons for this are: the disease requires the patient to gain as much knowledge about the disease as possible; when following the recommended health advice the patient usually manages the disease very well; the patient is advised to regularly measure one or more health parameters; the disease may involve medical personnel intensively, but is most often managed by the patient herself. The introduction of information and communication technologies thus has great potential to ease the burden for both the patient and the medical personnel. This may reduce travelling time for the patients for their appointments with medical personnel, i.e. traditional telemedicine. It may also provide patients with self-help tools that both enhance health parameters in general and provide psychological benefits - helping patients to feel that they are in control of their disease, i.e. patient empowerment. Relevant self-help tools range from stationary terminals such as TVs and PCs to mobile devices such as wearable sensors and handheld terminals, offering an exciting area of possibilities for applying HCI methods and HCI theory.

3 Methods

“The first step in the usability process is to study the intended users and use of the product” Jakob Nielsen argues [5], a known but a difficult principle for many project teams and designers to follow. Nielsen represents the Scandinavian HCI tradition with a strong design focus on the end-users. HCI-specific methods are still rare within eHealth and telemedicine projects. I will first present examples of user-centred methods that are typically used within telemedicine and eHealth projects, and then methods that are mostly described in HCI literature. I hope that this overview of methods in this multidisciplinary research area will help to promote awareness of the various methods, to encourage experimentation with them, and to inspire researchers to learn from others’ experience with user-centred methods.

3.1 User-Centred Methods Used in Telemedicine and eHealth Projects

Heuristic Evaluation and Workshops. For the “Digital TV and patient information” project, the design process included two persons in the project team who were potential users of the prototype, i.e. had diabetes themselves. We analysed how users can currently acquire information about their chronic disease, and identified the potential for using television as a “new” media for this purpose. A workshop was arranged with participants comprising users, technological and social-science researchers, and a crew from Norway’s main television channel (NRK). The potential of the future digitalisation of the TV distribution was discussed in a patient-information context. Experience from the digital television project “Living Health” in England [6] was also input to the design of our prototype. However, we focused on designing our project as an information service for a specific disease (diabetes), rather than a general health service such as Living Health. The fact that two members of the project team were potential users of the system enabled us to produce a better prototype through continuous evaluation and an iterative design process.

Focus groups. As part of the “Digital TV and patient information” project, focus groups were arranged, each with 5-7 participants, prior to the intervention. A semi-structured agenda was prepared for the 2-hour session with the focus groups. The main agenda for the focus group was to find out how the informants usually obtain information about their disease today, in which situations they typically need information the most, and how they would ideally like to acquire disease-specific information. The discussion was taped and transcribed. Due to the difficulties of recruiting enough informants in the town where our centre is located, we also had to recruit informants from a larger town in southern Norway. Transcriptions from focus groups are generally said to be hard to analyse, but we found some interesting trends. I have analysed the data and will in the result section summarise how the individuals and the different groups responded to the moderator’s questions.

Prototyping. Prototypes may be used in many ways, typically to investigate, explore and demonstrate future systems. Houde and Hill [7] divide the different aspects that prototypes prototype into three dimensions: role; look and feel; and implementation. The authors advocate that awareness of these dimensions makes it easier to develop and communicate about prototyping strategy. They also state that the prototype's level of detail needs to be adjusted to the audience, e.g. paper prototypes or prototypes with a more realistic look. Focusing on the purpose of the prototype simplifies the decision about the level of detail and which kind of prototype to build.

The prototype in the "Digital TV and patient information" project demonstrated how the future digitalisation of television service may make it possible to provide disease-specific patient information as an interactive service. To prototype this, we designed an interactive DVD with nearly 1000 pages of diabetes-related patient information. The patient information was adapted to fit the low resolution that ordinary television sets require, and it was quality assured by a diabetes specialist. We used the "Interactive Television Style Guide" from the BBC [8] as a guideline for designing our prototype. The prototype required distribution of a DVD player for those participants who did not have one. The installed system provided the user with interactive patient information and hypertext-like navigation using a remote control.

Interviews. The three main types of interviews are structured, semi-structured and open interviews. In the project "Automatic transfer of blood glucose data from children with Type 1 diabetes," we designed both questionnaires and interviews with the parents of the children with diabetes, for gaining insights into the appropriateness of the concept, feasibility of use, and ideas for further development and research. A semi-structured guide for the parent interviews was designed. The interview posed open-ended questions addressing the three overriding issues: stress and coping, the parent/child relationship, and system functionality. Parents were encouraged to share experiences and thoughts freely. All but one of the interviews were conducted over the phone. The interviewer was unacquainted with the parents. After interviewing 10 parents, no new information emerged, i.e. we reached "data saturation", and further interviews were deemed unnecessary. We did not use any predefined code scheme, but coded the data with respect to the patterns emerging from the data. Our general impression is that this is the case for feasibility studies in general, e.g. the study by Mamykina et al. [9].

Questionnaires. The main benefit of questionnaires is that they are cheap and easy to apply to large samples of users. When designed in the proper way, they can quickly provide both quantitative and qualitative data. There are two main types of questions in questionnaires: multiple choice and open-ended questions. In my current doctoral project [10] I plan to investigate changes in health status, nutrition and exercise using a questionnaire consisting of selected items from the widely used and validated questionnaire SF-36 Health Survey [11], as well as selected questions from two questionnaires [12], [13] used in previous larger national diabetes projects, the MoRo [14] and the HUNT2 [15] projects. The SF-36 Health Survey is a well-known and often used questionnaire, e.g. by Tahbaz's study [16], making it possible to compare the results from different studies. By standardising the measures to a 100-point scale, it is even possible to compare between different measures, i.e.:

$$\text{Standardised score} = \frac{\text{actual raw score - lowest possible raw score}}{\text{possible raw score range}} \times 100 \qquad (1)$$

Field Studies. Observation can be considered as a basic aspect of any science, and requires that the system is tested in its natural use environment, a reason for using the term "field study". Within telemedicine and eHealth projects, field studies seem to be used less frequently than the five methods mentioned above. Field studies are typically used in somewhat larger projects, and have been used at our telemedicine centre in projects such as "Telemedicine in homecare- and nursing homes - SES@m Tromsø" [17], "Intelligent Communication Uniforms for health care workers" [18] and "MedIMob - Instant Messaging and Presence in Healthcare" [19]. These are all projects with a time frame of several years. Field studies may also be used on a small scale, with a small sample over a shorter time frame, such as the observation of mealtime routines for three families in the project "NutriStat: Tracking Young Child Nutrition" [20]. The main aim of this field study was to create several scenarios as part of the scenario-based design.

Logging and Medical Observation Techniques. Obviously, it is important to measure medical and general health conditions within eHealth and telemedicine applications. Examples are the various tests performed in [16]; blood test, urine samples, weight, height, waist circumference, hip circumference, diet history and exercise level. Some of these measures have to be tested by medical personnel, but others may be determined by the patient herself. Furthermore, some parameters may be logged automatically and digitised, while others must be measured manually. The technique used obviously influences the accuracy of the measure as well as patients' compliancy. An example from our research is the technique for automatic transfer of blood glucose data after being manually sampled. In this case, the "no-touch" transfer function of the data was reported as a necessity for acceptance by the user [21].

3.2 User-Centred HCI-Methods

The ISO Standards. The ISO Standard 13407 “Human-centred design processes for interactive systems” is intended to help those responsible for managing hardware and software design processes to identify and plan effective and timely human-centred design activities [22]. Patient-centric self-help tools are often composites of both hardware and software, so this standard’s scope initially seems to be very relevant. The standard basically addresses planning, management, and an overview of human-centred design activities, not detailed coverage of the methods and techniques required for human-centred design. It focuses on using multi-disciplinary teams and on an iterative design process, where feedback from users is a critical source of information. Each iteration basically includes a specification of the context of use, a specification of the requirements, production of design solutions, and an evaluation of the designs against the requirements. More specific ISO standards are ISO 9241-1 to ISO 9241-17, aimed at system developers, specifiers and purchasers of systems.

The ETSI Standards. There are also several recommendations and relevant documents from the European Telecommunications Standards Institute (ETSI) which are useful for designing patient-centric tools. The most relevant ones are these five: “ETSI TR 102 415 - Human Factors (HF); Telecare services; Issues and recommendations for user aspects” [23], “ETSI TR 102 068 - Human Factors (HF); Requirements for assistive technology devices in ICT” [24], “ETSI EG 202 191 - Human Factors (HF); Multimodal interaction, communication and navigation guidelines” [25], “ETSI EG 202 132 - Human Factors (HF); User Interfaces; Guidelines for generic user interface elements for mobile terminals and services [26], and “ETSI EG 201 472 - Human Factors (HF); Usability evaluation for the design of telecommunication systems, services and terminals” [27]. The latter document describes pros and cons for several methods such as experiments, field observation, heuristic evaluation, focus groups, input logging, surveys, questionnaires, interviews, performance measures, thinking aloud and audio-video recording. Some of these are not often used within eHealth and telemedicine, and a brief description of how they may be applied in this research field is given below.

HCI-specific Questionnaires. Examples of questionnaires designed for research within HCI are the 50-question Software Usability Measurement Inventory (SUMI) evaluation questionnaire [28], the 10-question software usability scale (SUS) [29], the 27-item Questionnaire for User Interaction Satisfaction (QUIS) [30], the 19-question Computer System Usability Questionnaire (CSUQ) [31], and the 118-word check-box scheme Microsoft’s Product Reaction Cards [32]. A study of four of these instruments was performed by Tullis et al. [32], and showed that one of the simplest questionnaires, SUS, yielded some of the most reliable results across sample sizes. The same study showed that for assessment of websites, sample sizes of at least 12-14 participants are needed to yield reasonably reliable results. The advantage of being able to compare your own data with others researchers’ data when using one of these standard questionnaires is obvious, but if a customised questionnaire is needed the above mentioned ETSI standard EG 201 472 [27] provides detailed advice for questionnaire design. Some other questionnaires in HCI are the following: Perceived Usefulness and Ease of Use (PUEU), Nielsen's Attributes of Usability (NAU), Nielsen's Heuristic Evaluation (NHE), After Scenario Questionnaire (ASQ), Practical Heuristics for Usability Evaluation (PHUE), Unified Theory of Acceptance and Use of Technology (UTAUT), Computer User Satisfaction Inventory (CUSI), and the Purdue Usability Testing Questionnaire (PUTQ).

The conclusion from the case study described by Jokela et al. [33] is that most industrial development projects have specific constraints and limitations, so that an ideal use of usability methods is not generally feasible. They researched qualitative requirements for developing user interfaces for mobile phones, and strongly recommend the use of measurable usability requirements, but state that usability methods should be selected and tailored based on the specific context of the project. This suggestion is supported by many authors e.g. [34], where the research team used a subset of the “Behavior Risk Factor Surveillance System Survey Questionnaire”.

Thinking Aloud. The thinking aloud method involves having a test subject use the prototype while continuously thinking out loud. Used in usability testing (in contrast with cognitive psychology), the focus is on reporting not only thoughts, but also expectations, feelings and other things that the test subjects want to report [35]. It is important that the informants are told that the test probes the usability of the prototype, and not the user’s skills or experience. The advantage of the thinking aloud method is that the user’s verbalisation allows the researchers to understand how the prototype is perceived during the whole period of use. This creates more opportunities to distinguish between user errors and makes it possible to obtain a large volume of qualitative data with only a few users. There are different approaches to the thinking aloud method such as “constructive interaction”, where two subjects co-operate and verbalise simultaneously, and “retrospective testing” where the subject views/listen to the video/audio recording and makes comments about the task afterwards.

In the design phase of PmEB, an application for mobile phones that allows users to monitor their caloric balance as a part of weight management [36], the users were encouraged to think aloud through the process. The project group noted the user interface issues that caused confusion, frustration or other difficulties. This process was followed by interviews and a discussion session. Various methods of documenting the think aloud process involve using audio, video, or forms. The type of interaction also varies. For example, in the study of the validity of the Media Equation for PDAs and Smartphones, Goldstein et al. used an intercom system for keeping in contact with the informants during the think aloud process [37]. Interestingly enough, this study suggested that the Media Equation only applies for stationary computers.

Paper Prototyping and Sketching. The above-mentioned project NutriStat [20] combined the paper prototyping and the think aloud methods. The researchers followed Apple's "Ten Steps for Conducting a User Observation" and asked the participants to "think aloud" as they worked with the paper prototypes. The project group found the paper-based prototypes a good tool for quickly and inexpensively obtaining design feedback. Their prototypes consisted of a series of prefabricated cut-outs that represented various states of a mobile phone application. Another term for paper prototyping is paper-and-pencil evaluation. Jeffrey Rubin describes this as a way of quickly and inexpensively collecting critical information about an aspect of a prototype [38]. Lim et al. [39] state that for their low-fidelity prototypes the major limitation was the abstractness and unclearness, but still find it a valuable approach to evaluate usability at an early stage. Tohidi et al. [40] developed a variant of paper prototyping called the "sketching exercise", which involves the user in sketching the ideal system design. They found that enabling users to sketch their ideas facilitated reflection, and provided a rich medium for discovery and communication of design ideas. Reviewing the user sketches alone could have uncovered much of the essential findings of the more commonly used usability test methods. These are very interesting findings, and even more impressive is their conclusion that sketching exercise "did so at a fraction of the time and money required to facilitate, record, and analyze the think aloud protocol, interview and questionnaire data" [40].

Scenarios and Storytelling. Even though we have used scenarios as part of our telemedicine and eHealth projects, their use is often very simple and for explanation purposes only. The main advantage for our use of scenarios is that this method provides a very good way of explaining the problem and the solution to a health-related challenge. The SuperAssist project [41] used scenario-based design as the main technique to develop research ideas in the project. They also used user scenarios in publishing their work. Their scenario is typical for eHealth application research, namely describing the history of the patient prior to the main problem, the introduction of the main problem followed by an introduction of the eHealth application, and finally some examples on how this application eases the patient's everyday life. Another example on this approach is described by Alsos and Svanæs [42], where the focus is on using handheld devices together with stationary displays in a hospital setting.

Personas. While scenarios describe concrete work processes, personas are fictional characters that may live a virtual and dynamic "life", but are based on real data. By creating virtual persons with real characteristics who are examples of the users for the case, personas may be a valuable basis for communication and common understandings within the project group. The characteristics may both be based on real data and be fictional. Pruitt and Grudin [43] demonstrate the use of personas for both small and large projects. They present a comprehensive use of personas, where a great effort was made to obtain as much quantitative and qualitative information about the virtual users as possible. One of the effects Pruitt and Grudin report is how strongly the use of personas was able to engage the project team members ("a certain level of Persona mania").

Logging and Other Observation Methods. As the test users are testing prototypes, data about use most often have to be recorded prior to analysis and conclusions. Typically, video recorders, audio recorders, manual forms and automatically recorded logs are used for this purpose. Sometimes, the most important issue is to capture what happens on the prototype, e.g. using a mini-camera mounted on the mobile phone or wireless capture of the screen activity as a video stream, instead of capturing the users themselves. Joseph S. Dumas states that "the goal is to record key events while they happen rather than having to take valuable time to watch videotapes later" [35]. Dumas refers to three ways of recording data more easily: using good data collection forms, using data logging software, and automatically capturing activities in log files. When users are testing prototypes over a longer period in their home environments, it may be feasible for them to write a diary. It is challenging to motivate the users to actually write down their experiences, concerns or impressions. The DELTA project described by Venturi and Bessis [44] did get 5 out of 16 users to return their diaries at the end of their project. They promised two awards as an encouragement, to the two best diaries.

4 Results

I present some of our research group's experiences with the traditionally user-centred methods within eHealth and telemedicine. Two of the three presented studies encompass unpublished results.

4.1 Digital TV and Patient Information

In the project "Digital TV and patient information" [45], we recruited a total of 24 patients through local diabetes groups at two different locations. Our research group wanted to find answers on how people with type 2 diabetes may use digital and interactive TV in future as an information and education channel related to their chronic disease. A prototype of an interactive TV system, based on an ordinary TV, a DVD player and a remote control, was designed and provided to the informants. The methods used were focus groups before and after the intervention, based on a semi-structured question guide for the meetings. The user input from the four focus groups was transcribed and analysed. The analysis of the results from the focus groups has been published as a report, but only in Norwegian. Below, an analysis of the focus-group process as one of the user-centred methods is presented in more detail. I hope this may be a way to provide insight into what may be expected from this method within this setting.

Focus Group Findings – Questioning and Answers. The way one frames questions to the focus group is obviously of high importance, and I found some good examples of this. Formulating simple questions to the informants such as "How often do you measure your blood glucose values?" may generate long answers. In one of the focus groups and among four informants, it generated on average a 107-word answer. The minimum length of the answer was 68 words, while the longest was 158 words. In another of the focus groups, the question was formulated slightly differently: "Do you measure your blood glucose regularly?" This generated one-word answers, which had to be followed up with the question "What does that mean?" This again generated short answers of 2-4 words.

Even though the reason may be that different groups will always have different internal social relationships (social chemistry), this underlines the impact of the interviewer's questioning. The impact of internal social relationships is indicated by the difference in the length of answers to the general questions among the four focus groups. To a general question about each group participant's disease history and feelings about having diabetes, we received a wide variation in the average answer length between the four groups: Group 1: 368 words, Group 2: 256 words, Group 3: 98 words and Group 4: 204 words. The first group stands out as the most communicative, which may be caused by the fact that some of the participants knew each other in advance of the meeting.

There is also a difference between regions, where the first two groups from northern Norway have an average answer of 312 words to this question, and the second two groups from southern Norway have an average of 151, i.e. less than half. This trend is confirmed by the total length of the transcriptions: Group 1: 16 056 words, Group 2: 16 065 words, Group 3: 7 923 words, Group 4: 10 305 words. Thus, the transcriptions from the two groups in southern Norway comprised just 57 % of the words compared with the two groups from northern Norway. See Table 1 for a summary.

Table 1. Length of answer depending on themes, groups and regions.

Question theme	Group 1	Group 2	Group 3	Group 4
Blood measuring frequency	107 words	1 word	1 word	(left out)
Disease history and feelings	368 words	256 words	98 words	204 words
	Northern region: 312 words		Southern region: 151 words	
Length of the transcriptions	16 056 words	16 065 words	7 923 words	10 305 words
	Northern region: 16 060 words		Southern region: 9 114 words	

Gender ratios in the groups may also be a reason for the difference. For Group 1 and Group 2 the percentages of women were respectively 60 and 71 percent, and for Group 3 and Group 4 the percentages of women were 20 and 57 percent. The focus group meetings were held in different types of settings in the north and south. In the north the meetings were held in the hospital's meeting room while in the south they were held in a formal conference room.

4.2 Automatic Transfer of Blood Glucose Data

Until now, the majority of self-management systems for achieving better blood glucose control have required the patient to type the blood glucose value into a terminal, typically a mobile phone, PDA or PC. We implemented a "no-touch" system, i.e. a system that did not require any technical skills or any user intervention for transfer of the blood glucose values [46]. This system was tested in a concept where the data was automatically sent as SMS messages to the parents of children with Type 1 diabetes. The methods used for feedback on our prototype were questionnaires, interviews and patient diaries.

Interview and Questionnaire Findings. We designed four different questionnaires; two to the main users of the prototype, the children with diabetes, and two to their parents. One questionnaire was delivered to each of these two groups before the intervention and the other was delivered after the intervention. In this way we received concrete written feedback on the users’ views of the prototype design. Since this was a feasibility study with relative few informants (15 children and 15 parents), we aimed mainly for qualitative results. We also aimed to obtain background information such as the specific numbers of times the children measured their blood glucose daily. This specific case was approached by asking the open-ended question “How many times does your child usually measure their blood glucose value each day?” This generated responses such as “5-8”, which were not easy to analyse statistically.

Analysis of all the answers to the open-ended questions made it clear that we needed to supplement the data with interviews of the parents. After 10 interviews were conducted, the findings were classified into nine themes: (1) sense of security and reassurance, (2) nagging and scolding, (3) control, responsibility, and independence, (4) surveillance and opposition, (5) learning and age-phased appropriateness, (6) focus upon illness, (7) if it’s not automatic, forget it, (8) system type and functionality, and (9) it depends on how you use it. The data from the questionnaires and the semi-structured interviews were analysed and published [21].

Patient-Use Diaries. We also provided space on the last page of the user manual for users to write down positive and negative things about the system, i.e. a kind of “using-the-prototype-diary”. It was followed by a written instruction that the page should be sent to us together with the last questionnaire. However, none of the 15 families did send us this page, a result that we now think we should have expected since we did not encourage or promise any rewards for spending this extra effort. As earlier referred, in the DELTA project [44] only 5 out of 16 users returned such a diary, despite the incentive of two awards to the two best diaries.

4.3 Screening for Diabetes

This study was started in 2001 and completed in 2003, managed and published by Jorde et al. [47]. The project included 228 participants, all over 69 years old. The main objective of the study was to determine the prevalence of known diabetes among elderly subjects receiving nursing care in a north Norwegian population, to screen for new cases using HbA1c measurement, and to evaluate the quality of care for those with diabetes. I will here focus on my contribution with designing an electronic questionnaire, and the outcome of some questions addressing the use of mobile phones and the feeling of security among the informants, as agreed with Jorde.

Using an Electronic Questionnaire in the Field. I designed an electronic questionnaire that was managed using a laptop. The diabetes nurse entered the answers directly into a database on the laptop while visiting the informants in their own home, and this may thus be regarded as “in-field data gathering”. The user involvement in this project was small, but the fact that the data was gathered at the informant’s own home, face to face with a member of the project group, is considered more fruitful than sending the questionnaire by mail. The high average age of the participants, 78 years, was one of the reasons that this method was considered superior. ¬The electronic questionnaire was designed and implemented using the database application Microsoft Access, and exported to SPSS using Microsoft Access queries.

Use of Mobile Phone, Security and Information Sources. The medical result have been presented earlier in [47], but the data referred to in the following have not been published before. Our research team had designed five questions related to use of mobile phone, their main health supervisors, and the target group’s view on use of monitoring equipment for health purposes in their own home. At that time, 2001-2003, a relatively small percentage of the target group had a mobile phone. Thirty-five informants reported they had a mobile phone and 193 did not have a mobile phone. Of the 35 who had a mobile phone, 14 answered that they used it as an extra security measure both indoors and outdoors, 10 reported that they used it as an extra security measure only outdoors, while 11 did not use the mobile phone for extra security. To the question whether they would have felt safer if there were some kind of device inside their home that monitored if they were OK, 82 answered “yes” and 146 answered “no”. Data on their main human information source in relation to their disease was only captured for 43 patients. Of these, 44% reported that it was the community nurse, 32% that it was their family doctor, 12% that it was their family, and 12% that it was their diabetes nurse.

5 Discussion

Based on both our own previous experience with user-centred design methods and the reviewed HCI methods, I will briefly discuss use of the methods in the eHealth and telemedicine settings, and also which of the methods I find promising when designing patient-centric self-help tools.

Methods for Advanced User Involvement. The paper-prototype variant "sketching exercise" mentioned in [40], entails high user involvement in that it requires users to propose their own solutions on the design. The same is true for the patient-use diary [44], which involves users over a long period in their home environments. Common to such methods is that they require both a high degree of encouragement and users that are cognitively highly functional. Having worked with both older adults and adolescents in eHealth projects has reminded me that neither of the requirements is easy to fulfil; these methods must thus be consciously used. The Scandinavian tradition of a high degree of user involvement with relatively few users must be considered together with the US tradition of contextual design at the start of every project. Contextual design is described as a "customer-centred" design approach, and might have success in "late-stage" eHealth projects where most of the user clarifications have been completed in previous feasibility projects. That is, contextual design may be more relevant when organisational challenges in health care systems are to be solved.

Methods for a Common Understanding. Using personas seems to be a very good method for educating and coordinating the project team within, for example, a health problem and exploring the functions of an ICT self-help tool. The fictive persons' problems should however be based on real disease-specific data, obtained by either involving medical expertise or real patients, or both. There is reason to expect that which of these three actors is involved will mean quite different results. Scenarios are a good way of exemplifying specific health problems and solutions to these. We have experienced that a paragraph describing a scenario managed to transfer a necessary understanding of the project scope in workshops and meetings. Thinking aloud may be a key method for a deeper knowledge of the patient's real needs, before and in an early phase of implementing a self-help tool. We have positive experience with receiving feedback from focus groups, but a different kind of feedback is often achieved at a personal level.

Applying Tight or Light Structure to the Methods. Choosing among the various design and evaluation methods is a challenging task in most research projects. A change or supplementation of methods may result in a completely different outcome. An example of this was experienced by our research team when we decided to supplement the parent-child interaction study [21] with interviews. Another observation from the "Digital TV and Patient Information" project was the challenge of using the focus group method consistently, i.e. formulating the identical question among more focus groups. This is essential if the answers are to be compared or used statistically. All four focus groups in this project ended up getting slightly different questions related to the frequency of blood glucose measurements, and one of the groups got no question at all. This exemplifies the dilemma of choosing between tightly structured questioning or less structured questioning. The same dilemma applies to some of the other methods, choosing between little structure and subsequently often a loose and perhaps more creative design process, or a tight structure that provides comparable data. The benefits of using a standard questionnaire such as SUS, QUIS and PUEU are obvious.

I have tried to prioritise the HCI-specific methods according to use in an eHealth setting, with short comments on use in designing patient-centric self-help tools as well, see Table 2 below. The "sketching exercise" seems to be very relevant for the kind of user-centred tools we aim to design, and thus ranked highest. However, all the methods should really be considered in every HCI-related project. The same is true for the ISO and ETSI standards reviewed earlier in this article, which I unfortunately did not find the space to discuss in more detail. However, this article marks the start of a stronger focus on HCI for me and my project team, and I hope it inspires some of the readers as well.

Table 2. Prioritised list of promising HCI methods used in eHealth settings.

Method	Relevancy in eHealth settings with user-centred design?	Relevancy for mobile self-help tool designs?
Paper prototyping	When needing quick prototyping.	The "sketching exercise" variant seems very promising.
Thinking aloud	When needing qualitative data.	For patient feedback on user interfaces on mobile terminals.
HCI-specific questionnaire	When aiming to compare the results.	The SUS, QUIS and PUEU look especially relevant.
Logging and observation	Video/audio, when aiming for a deeper understanding of the patients' situation.	A patient-use diary may be valuable, but need encouragement.
Scenario	When explaining the concepts to the (new) users, or to develop research ideas.	As an explanatory and communicative tool.
Personas	When involving patients and/or medical expertise.	When need for extensive coordination of the project team.

6 Conclusion

Our research group is currently focusing on patient-centric self-help tools for people with diabetes. The current focus of both the European Commission and others is on how to escalate the efforts to provide patients and people in general with tools that help them to take care of their own health. The background is of course the ageing population, population growth in general, the increase in chronic diseases due to changes in lifestyle, and finally the possibilities that new technology, especially mobile terminals and wearable sensors, provides. I focus on the above-mentioned issues in my PhD thesis, "Self-help through a mobile ICT tool - Supporting lifestyle changes for preventing secondary diseases for people with Type 2 diabetes using a digital diabetes diary". Designing applications and services that are patient-centric obviously requires user-centred methods for achieving the best results. HCI methods such as paper prototyping, the sketching exercise, thinking aloud, HCI-specific questionnaires, scenarios and personas should be included in our standard set of methods to consider within telemedicine and eHealth patient-centred projects. Furthermore, based on the recommendation from C.H. Wilson [48] and many other authors, our future projects should definitely use triangulation, i.e. using not one but several methods, measures and approaches, in the process of designing good patient-centric tools.

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Appendix 10. The Few Touch Application - Experience with a Diabetes Diary based on a Mobile Phone

by Årsand E, Varmedal R, Nilsen H, Østengen G, and Hartvigsen G.

Poster presentation at the 2nd International ATTD Conference on Advanced Technologies & Treatments for Diabetes, Athens, Greece, February 25-28, 2009.

Appendix 10: Årsand E, Varmedal R, Nilsen H, Østengen G and Hartvigsen G. The Few Touch Application - Experience with a Diabetes Diary based on a Mobile Phone. Poster presentation at the 2nd International ATTD Conference on Advanced Technologies & Treatments for Diabetes, Athens, Greece, February 2009.

The Few Touch Application

EXPERIENCE WITH A DIABETES DIARY BASED ON A MOBILE PHONE

NST | Norwegian Centre for Telemedicine
UNIVERSITY HOSPITAL OF NORTH NORWAY
WHO Collaborating Centre for Telemedicine

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Background

Self-management of blood glucose levels and other parameters is very important in reducing long-term diabetes complications and in achieving healthy habits. This study focused on designing a system operated by patients rather than health workers. Our research group is working with a self-help tool for people with Type 2 diabetes. The Few Touch application is based on smartphones, with functions addressing each of the three cornerstones of diabetes management: physical activity, nutrition, and healthy blood glucose values.

Discussion

This study shows that applying technologies and methods from informatics can provide new insight into the design of a mobile tool to support lifestyle changes for people with diabetes. Sound and innovative ICT designs have been achieved, but the mobile-phone-based diabetes diary we present is still not commercially available. To provide it as a service, health authorities, the industry and health service providers need to collaborate in finding ways to fund and realize the elements in the future.

"My doctor thinks this is great, but he asked for a function to identify the fasting blood glucose values."

"I eat in a healthier way now than before. I eat five times a day and I eat more fruits and vegetables."

"The system is very simple – which is important, and I think it should be kept that way."

Research Aim and Approach

The overall aim is to generate knowledge about how to design a mobile tool for supporting lifestyle changes among people with Type 2 diabetes [1]. Our approach focuses on extremely easy-to-use user interfaces and functionalities, involving the patients in the system design [2]. Data from a blood glucose monitor [3] and a self-manufactured step counter [4] are automatically transferred using a "no-touch" principle, while recording food habits requires only two touches on the smartphone [5]. The Few Touch application also provides general tips, and motivates patients to set and monitor their personal goals.

Findings

The mobile-phone-based diabetes diary was tested on a cohort of 12 patients from Sept. 2008 – March 2009. In general, they appreciated all elements of the application, and found the automatic transfer and display of blood glucose especially useful. The manual two-touch function for logging food habits was used surprisingly often. The general tips function was appreciated, but the least frequently used.

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Appendix 10: Årsand E, Varmedal R, Nilsen H, Østengen G and Hartvigsen G. The Few Touch Application - Experience with a Diabetes Diary based on a Mobile Phone. Poster presentation at the 2nd International ATTD Conference on Advanced Technologies & Treatments for Diabetes, Athens, Greece, February 2009.

Appendix 11: Focus Group Sessions: Plans and Facilitators’ Scripts

Focus group meeting 1 – February 2007

English Summary of the Script for Meeting 1:

The main themes for this meeting were:

- Introduction of the members of the cohort to each other;
- Presentation of the research project;
- Discussion of use of step counters in general in two groups;
    - including the users’ background;
    - perceived usefulness;
    - perceived usability; and
    - the users’ suggestions
- Discussions in one group, around step counters and the highlights from the discussions in the small groups;
- The users view on a system that transfers to, and presents step count data on a mobile phone;
- Paper-prototype session around presentation of the step count data on a mobile phone;
- Give the users an ordinary commercially available step counter; and
- Plan for the next meeting.

Original Norwegian Script for Meeting 1:

Timeplan for første brukermøte, 13. og 15. februar:

19:00-19:10 Oppstart

Velkommen, og litt om bruk av video som dokumentasjonsmedium.
Dele ut navnemerkelapper

19:10 – 19:20 Presentasjon av hverandre
19:20 – 19:35 Presentasjon av NST og forskningsprosjektet

19:40 – 20:10 Vi deler oss i to grupper og diskuterer bruk av stegteller generelt

(G.Ø. leder gruppe 1 og E.Å. gruppe 2, R.V. gjør notater og hjelper til)
Brukernes bakgrunn:
Er dere fornøyd med hvor fysisk aktive dere er?
Hvor aktive er dere til daglig?
Bruker noen av dere stegteller?
Hvilke erfaringene har dere?
Opplevd nytteverdi:
Er det nyttig å bruke / tror dere det kan være nyttig å bruke stegteller?
Hva skal til for at det kan bli nyttig / mer nyttig?
Be brukerne argumentere for og imot bruk av stegteller.
(si at vi ønsker så mange argumenter for og imot som mulig)
Tror du en slik kan motivere deg til å være mer fysisk aktiv?
Opplevd brukervennlighet:
La de få se på en konkret stegteller og kommentere denne
Hvordan tror du denne vil være å bruke i hverdagen?
Brukernes forslag:
Hva skal til for at du skal bruke stegteller over lengre tid?
Er det noe annet vi burde diskutere? (gode ideer, forslag, el.l)

20:10 – 20:30 Samles og refererer hovedsynspunktene fra gruppediskusjonen og diskuterer videre

Diskusjon fram til 20:40

20:20 – 20:40 Tilbakemelding på et system som overfører og presenterer data på mobiltelefon:

Forklar konseptet kort.
Hvordan blir det å se verdien på mobiltelefonen i stedet for på selve stegtelleren?
Diskuter brukernes syn første inntrykk av dette.

20:40 – 21:00 Del ut ark med handtegnede skisser som beskriver alternativer for å se antall steg på mobiltelefonen, og la de rangere alternativene og tegne egne forslag.

Til slutt: Del ut stegteller, hør om hvem som kan komme på neste møtet, 6 mars og 8. mars. Tema vil da være oppfølging av stegteller + blodsukkermåling.

Focus group meeting 2 – March 2007

English Summary of the Script for Meeting 2:

The main themes for this meeting were:

- Summarize the users' experience from using the step counter they received at the last meeting;
- Introduce the theme of this meeting – blood glucose measuring, e.g.:
  - How do they measure?
  - Why did they choose their BGM?
  - Which functions do you use?
  - Experience with different BGMs?
  - Why do you measure?
  - How often do you measure?
  - Who has told you to measure?
  - Where are you when you measure?
  - Are you using a diary?
  - Do you transfer data to a PC?
  - Etc.
- Break
- How can the use of BGMs be improved?
  - Make sketches
  - Make mind map(s) together in the group
- Introduce "homework" – a paper-based diary; and
- Plan for the next meeting.

Original Norwegian Script for Meeting 2:

Timeplan for andre brukermøte, 6. og 8. mars

Første kvarter:
Oppsummere bruk av stegteller: Har dere noen nye tanker omkring bruken av stegtellere generelt?

Neste tre kvarter:
Hvordan måler du blodsukker i dag?
Hvorfor har du valgt den blodsukkermåleren du bruker i dag?
Hvilke funksjoner bruker du på blodsukkermåleren din i dag?
Har du forskjellig erfaringer med ulike målere?
Hvorfor måler du blodsukker?
Hvor ofte?
Har du fått noen beskjed om hvor ofte du bør måle?
Hvor er du når de måler?
Hva bruker du resultatene til?
Viser du målingene til noen?
Diskuterer du de med noen?
Fører du dagbok?
    Hvordan fører du dagbok?
    Hva bruker du dagboka til?
    Hvor lenge har du ført dagbok?
    Hvorfor bruker du denne dagboka du bruker nå?
Overfører du data'ene dine til PC/annet sted?
Overfører du dataene til helsevesenet (lege/sykepleier)?
Hvorfor bruker du ikke kabel til å overføre data til PC og ser på sammenhengen der?

10 minutter pause.

Siste 50 minutter:
Ideutviklingsprosess: hvordan kan blodsukkermålere brukes bedre?
Skissere opp hvordan de kan tenke seg dette generelt – i første omgang på et ark.
Lag tankekart på digital skjerm eller flip-over.

Orientere om at vi sende ut det forslaget vi kommer fram til (hovedelementene i et verktøy) så raskt som mulig etter møtet og be de om å teste dette fram til neste møte. La det være mulighet til å skrive inn andre ideer på baksiden. Ett ark for hver uke.

Orientere til slutt om at neste møte vil handle om oppfølging av det opplegget vi nettopp har laget, og snakke om matvaner. Datoer for møtene er tirsdag den torsdag den 22. mars og tirsdag den 27. mars klokka 19-21.

Focus group meeting 3 – March 2007

English Summary of the Script for Meeting 3:

The main themes for this meeting were:

- Introduce the theme of this meeting – food habits, i.e. not nutrition;
- Positive and negative things about your food habits;
- What inspires you to eat in a healthy way?
- Do you think you know enough about food and food habits?
- Break;
- Summary of the "homework from the last meeting;
- Possible future solutions;
- Willingness to record food habits;
- Plan for the next meeting.

Original Norwegian Script for Meeting 3:

Timeplan for tredje brukermøte 22. og 27. mars

19:00 – 19:50 Matvaner (E.Å.)
Introduser at teamet er matvaner og ikke ernæring.
A) Hva er positivt og hva er negativt med dine matvaner? (Hva påvirker dine matvaner? Hvor mye har familien å si? Hvor mange måltider spiser du pr. dag? Hvor mange mellommåltider? Når spiser du? Hvor spiser du? Hvilken type mat spiser du?)

B) Hva inspirerer deg til å spise sundt?

C) Synes du selv du kan nok om mat og matvaner? (Hva ønsker du å lære mer om når det gjelder mat og matvaner)

19:50 – 20:00: Pause

20:00 – 20:55 Oppsummere hjemmeoppgave fra forrige gang, og ideer ut fra oppgavene. (G.Ø.)
A) Mulige framtidige løsninger: Hvordan vil du kunne bedre matvanene dine vha. en tenkt løsning. Hva vil en ENKEL måte å følge opp matvanene dine i hverdagen kunne være. Basert på et belønningssystem (ros)? Basert på ris? Basert på at andre fikk vite status om dine vaner?

B) Innsatsvilje: Hva tror du er realistisk å gjøre av ekstra innsats ved hvert måltid (skrive i en bok?, ett tastetrykk på din mobiltelefon?, to tastetrykk?, flere tastetrykk?, trykk på en annen enhet? [for eksempel på stegtelleren]) Annet?

20:55 – 21:00 Om neste møte
Orientere til slutt om at neste møte vil handle om å bruke en mobiltelefon som hjelpemiddel i forhold til fysisk aktivitet, blodsukker og matvaner, og hva som kan være gode valg når vi skal designe et system (skjermstørrelse, taster eller trykkfølsom skjerm, størrelse på mobil, osv.) Datoer for møtene er tirsdag den 24. april og torsdag den 26. april, klokka 19-21.

Focus group meeting 4 – April 2007

English Summary of the Script for Meeting 4:

The main themes for this meeting were:

- Introduce the theme of this meeting – use of mobile phone;
- Give out questionnaire: How do you use your mobile phone?
- Discussion in the group – when is it not ok to use your mobile phone?
- Future use of the mobile phone – how?
- Test of the early prototype (html) of a digital diary on the mobile phone;
    - Ask users to fill inn questionnaire when testing the early prototype;
- Break;
- Future use of the mobile phone as a diabetes self-help tool;
- Present the results of the paper-prototype method from Meeting 1;
    - Ask for new thought about the feedback screens now.
- Plan for the next meeting.

Original Norwegian Script for Meeting 4:

Timeplan for fjerde brukermøte 24. og 26. april

19:00 – 19:20: Bruk av mobiltelefon
E.Å. : *Del ut spørreskjema: "Hvordan bruker du mobiltelefonen din"*
Diskuter i plenum:
Når passer det IKKE å ta fram mobiltelefonen?
I hvilke situasjoner?
På hvilke steder?
På hvilke tidspunkter?
(Hvis de tenker kun på telefondelen, spør om dette gjelder andre funksjoner også)

19:20 – 19:40: Framtidig bruk av mobiltelefonen
G.Ø.: *Spør brukerne om hvordan de kunne tenke seg å bruke mobiltelefonen i framtida:*
Vil det være praktisk for deg å alltid ha med deg mobiltelefonen? Dersom noen svarer negativt til dette, spør: Vil dette være aktuelt i perioder?
Når trur du at du skal bytte mobiltelefon neste gang? Hva slags mobiltelefon ønsker du deg neste gang?
Hvordan trur du det vil være å trykke med fingeren rett på skjermen i stedet for på knapper?

19:40 – 20:05: Test av selv-hjelp verktøy på mobiltelefon
R.V.: Felles presentasjon av konseptet i plenum først (posteren på storskjerm).
La brukerne få prøve "Enkel DiaDagbok" og fyll ut spørreskjema i lag med de. Gjør det med en og en, E.Å. og R.V. hver sin. Deretter fyller de ut spørreskjemaet. Se vedlegg. De andre har pause på gangen. Husk å samle inn spørreskjema etterpå.

20:05 – 20:10 Felles pause

20:10– 20:40: Framtidig bruk av mobiltelefonen til selv-hjelp av diabetesen
Hva synes du om det du nettopp har sett?
Bruk handsopprekning + be om kommentarer i tillegg:
Tenk deg at du skal trykke EN GANG på mobilen hver gang du spiser noe. Hvordan vil det være for deg?
Oppfølging: I hvilke tilfeller tror du dette kan være vanskelig?
Ute på restaurant? / På jobb? / På besøk?
Rett etter at du har kjøpt en sjokolade i kiosken og før du spiser den gående bortover storgata?
Hvordan tror du at du ville bruke et slikt verktøy. *(Oppfølging: spør over hvor lang tid det kunne være aktuelt)*
Hvordan tror du det ville være for deg å bruke en av disse to telefonene (vise de to HTC'ene fram)?

20:40 – 20:50: Vise brukerne resultatet av spørreskjemaet "fysisk aktivitet.
Dette var det spørreskjemaet om hvilket skjermbilde de likte beste for vising av fysisk aktivitet (fra brukermøte 1). Se vedlegg.
Spør om de har noen nye tanker om dette nå.

20:55 – 21:00: Orientering om neste brukermøte
Tirsdag den 29. mai og torsdag den 31. mai.
Tema: Mobilt selvhjelpsverktøy basert på en mobiltelefon.

Focus group meeting 5 – May 2007

English Summary of the Script for Meeting 5:

The main themes for this meeting were:

- Information regarding the progress of the project and the meetings;
- Ask who wants to continue next year;
- Introduce the theme of this meeting – information on the mobile phone;
    - Present two different phones;
    - Search for information on the phone;
    - Which type of information?
    - Information push;
    - Examples of SMS-based information;
    - Listen to tips on the phone:
- Discussion about use of step counter connected to the mobile phone;
    - Description of functionality;
    - Comments from the cohort;
- Break;
- Discussion about food habits on the mobile phone;
    - Presentation of different concepts;
- Discussion generally about the mobile self-help tool;
- Feedback on the focus group meetings from the participants;

Original Norwegian Script for Meeting 5:

Timeplan for femte brukermøte 29. og 31. mai

19:00 – 19:10: Litt om at dette er siste brukermøte i år og litt om neste år (E.Å.)
Er et team i NST som jobber med dette videre. Si litt om hva jeg skal gjøre i Seattle. Hvem vil være med på nytt møte i januar?

19:10 – 19:30: Informasjon på mobilen (E.Å.)
Ikke snakket så mye om dette tidligere. Ta med de to ulike telefonene slik at de ser skjermstørrelsen.
Slå opp informasjon om diabetes på telefonen?
    Hvilken informasjon ville være praktisk å kunne slå opp?
Få tilsendt informasjon om diabetes på telefonen (a la SMS)?
Lage eksempler fra SMS-tekstene? (ha. videokanon.)
Høre informasjon om diabetes på telefonen:
Høre enkelt-tips på telefonen?
Høre lengre "innslag" om et tema på telefonen (a la podcast/hørespill)?

19:30 – 19:50: Bruk av stegteller – 1. versjon, koblet til mobiltelefonen (E.Å.)
Funksjonalitet

1. Den vil ikke ha noen skjerm – mobilen blir stegtellerens skjerm
2. Sender antall steg hver kveld klokka 9 (eller et annet tidspunkt).
3. Kan når som helst trykke på selve telleren for å få sendt antall skritt til telefonen.
4. Send rundt ulike esker for å få tilbakemelding på størrelsen til stegtelleren, både i 3x5 og 2x3 cm og kanskje andre størrelser.

Få kommentarer på hvert av punktene.

19:50 – 20:00: Pause

20:00 – 20:30: Matvaner på mobilen (G.Ø.)

1. Presentasjon av positiv matvaner
2. Presenterer eksempler på positive matvaner: 1) Antall glass vann 2) Fem om dagen 3) Grovt brød 4) Fisk 5) Antall måltider
    a. Test av konseptet "Registrering av positive matvaner" – vise dette på skjermen (videokanon)
3. To ulike ting å jobbe med:
    a. Trenger du et verktøy til å bli bevisst dine matvaner (slik vi fikk demonstrert forrige gang)
    b. Trenger du et verktøy til å endre dine matvaner slik forslått ?

20:30 – 20:45: Generelt om mobil-verktøyet: (G.Ø.)
Hvem tror du vil ha nytte av slike verktøy vi har diskutert?
I din bekjentskapskrets, hvem?
Hva er særegent med de?
Hva mener du vil være spesielt nyttig?

20:45: Tilbakemelding på opplegget fra brukerne

21:00: Slutt

Focus group meeting 6 – April 2008

English Summary of the Script for Meeting 6:

The main themes for this meeting were:

- Update the participants about the progress since the last meeting
- Feedback on our suggestion for a plan
- About the mobile phone chosen for the study
- Feedback on the chosen mobile phone
- Presentation of the step counter application
    - User test of transfer button
- Break
- Presentation of the current functions of the food habit registration concept
    - User test of the system
    - Test recordings of food
- Presentation of the blood glucose registration system
    - User test, measure blood glucose and receive result on the mobile phone
- Feedback from the users on all the presented concepts
- Plan for the next meeting.

Original Norwegian Script for Meeting 6:

Timeplan for sjette brukermøte, 1. og 3. april

19:00 – 19:15: Generell informasjon (E.Å.)
Hva vi har gjort siden sist (Utvikling: programvare og maskinvare, nye forskere, studenter)
Litt om at på dette møtet ønsker vi din tilbakemelding på det vi legger opp til av funksjonalitet, mobiltelefon, blodsukkermåler, skritteller og matvaneregistrering.
Vi legger opp til ett møte til før sommerferien – i juni, og at vi håper på å la alle få teste det ferdige systemet i tre måneder fra ca. 1. september til 1. desember.
E.Å.s opphold i Seattle (test på 6 diabetikere, samarbeid, publiseringer)

19:15 – 19:35: Mobiltelefonen (E.Å. og G.Ø.)
Litt om hvorfor vi valgte denne telefonen.
Del ut en til hver og la de få trykke.
Vis en presentasjon av telefonen samtidig med dette, og gå igjennom hovedfunksjonene.
Forklar de viktigste funksjonene i plenum, og la de følge med og trykke samtidig (både demoen på selvhjelp-verktøyet og noen telefon-funksjoner).

Si litt om at det er en liten mulighet at det blir en annen telefon, eventuelt at grensesnittet på telefon-funksjonene vil endres.
Si at det vil bli gitt opplæring i bruken av telefonen og at de vil kunne ringe oss og spørre underveis i testperioden.
Spør brukerne om flytting av kontakter og annen informasjon på sin nåværende telefon til denne, vil bli problematisk .
→ Få brukernes reaksjoner på valget av denne telefonen og på å bruke denne i 3 måneder.

19:35 – 19:55: Stegtelleren – koblet til mobiltelefonen (E.Å.)
Forklar funksjonaliteten
Den vil ikke ha noen skjerm – mobilen blir stegtellerens skjerm
Sender antall steg hver kveld klokka 10. (ok tidspunkt?)
Kan når som helst trykke på selve telleren for å få sendt antall skritt til telefonen.
Del ut stegtelleren og la brukerne få feste den på seg.
Si at de som ikke har belte vil enten måtte bruke belte under den 3-måneder lange testen eller finnen en annen god innfesting av den.
Be de om å trykke ned knappen slik at det blir rødt lys (= indikasjon på at den sender data).
→ Få brukernes kommentarer og synspunkter på å bruke denne i 3 måneder.

19:55 – 20:05: Pause

20:05 – 20:25: Matvane-registrering på mobilen (E.Å.)
Forklaring av hensikten: å bli bevisst hva man spiser og hvor ofte/sjelden man spiser, få en oppsummering etter hver registrering, kanskje bli motivert til å endre matvanene sine til det bedre.
Presentasjon av funksjonaliteten: målsetting og registrering (på Web'en på storskjerm).
Øvelse: La brukerne få prøve selv – på telefonen (trykk ned "Fotoknappen"):
Test 1 – endre mål: øk fra 3 daglige frukter til 4. Gå tilbake til hovedmenyen.

Test 2 – endre mål: Sett deg et mål om å kun spise 15 karbohydrat-holdige måltider hver uke (reduser fra 19 til 15).
Test 3 – registrere måltid: Registrer at du akkurat har spist et måltid med lite karbohydrater.
Test 4 – registrere snacks: Registrer at du akkurat har spist et eple som snacks.
Test 5 – registrere drikke: Registrer at du akkurat har drukket et glass juice.
→ Få brukernes kommentarer og synspunkter på å bruke dette i 3 måneder.

20:25 – 20:45: Blodsukkermåling koblet til mobil-verktøyet: (E.Å. + R.V.)
Forklar hvorfor vi valgte denne blodsukkermåleren.
Forklar funksjonalitetene.
Demonstrer funksjonalitetene både på blodsukkermåleren og på applikasjonen.
Del ut de blodsukkermålerne og la brukerne få måle blodsukkeret og prøve ut overføringen til telefonen.
→ Få brukernes kommentarer og synspunkter på å bruke dette i 3 måneder.
Be brukerne skrive navnet sitt på en gul lapp og legge inn i blodsukkermåleren (hygieniske årsaker, dermed får de "sin egen" måler under testperioden.

20:45 – 20:55: Få generelle tilbakemeldinger fra brukerne (G.Ø.)
Både på enkeltkomponentene og konseptet samlet sett.

20:55 – 21:00: Litt om neste møte og hvem som kan på de to datoene (E.Å.)
Samle inn utdelt utstyr.
Litt om neste møte tirsdag den 17. og torsdag den 19. juni.

Focus group meeting 7 – September 2008

English Summary of the Script for Meeting 7:

The main themes for this meeting were:

- General information about using the mobile phone
- Theoretical walk-through of the most important functions of the mobile phone
- Closing of their current phone (contacts to SIM-card, etc.)
- Startup of their new phones (the HTC Touch Dual)
- Break
- Practical walk-through of the most important functions of the mobile phone
- Plan for the next meeting.

Original Norwegian Script for Meeting 7:

Timeplan for syvende brukermøte, 9. og 11. september

19:00 – 19:10: Generell informasjon (E.Å.)
Viktigheta av å bruke kun en telefon.
Om dette møtet og om neste møte om ei uke: 4 måneder, stegtelleren om 1-2 mnd., spørsmål underveis

19:10 – 19:40: Hvordan bruke telefonen (teoretisk)
Se på lysbildepresentasjon: - Vise hvordan setter inn SIM-kortet, sende sms, ringer, skrur av/på telefonen, sjekker strømstatus, tastelås, låse med PIN-kode eller ikke, (Ex. For å ringe: Trykk på rød-knapp, skyv ut tastaturet, slå nummeret, trykk på grønn-knapp) Del ut lysarkene etterpå.

19:40-19:50: Avslutt gammeltelefon
Overfør kontakter til SIM-kort.

19:40 – 20:00: Dele ut telefonene, klargjøring av de nye telefonene
Sette inn SIM-kortet
Kalibrering av skjermen
Orienter om skjerm-plast, kan taes av – pose anbefales da.
Trenger ikke å være ekstra redd for telefonen, vil vite om telefonene holder vanlig bruk.

20:00-20:10: Pause

20:10-20:50 Gå igjennom det teoretiske i praksis
(bruk lysbider fra i stad)
Be de ringe meg som en øvelse.

20:50 – 21:00 Avslutning
Skriv ned til neste gang det du plages med.
Ring hvis problemer: E.Å. xxx xxxxx / R.V. yyy yyyyy (evt. send SMS og be oss ringe dere).
Neste møter tirsdag 16. og torsdag 19. september.

Focus group meeting 8 – September 2008

English Summary of the Script for Meeting 8:

The main themes for this meeting were:

- Summary from the last meeting
- Experience from using the new phones
- Fill in questionnaire
- How to use the total system
- Explanation of the blood glucose monitor
- If errors – what to do?
- Break
- Practical tests of the systems by the participants
- Plan for the next meeting.

Original Norwegian Script for Meeting 8:

Timeplan for åttende brukermøte, 16. og 19. september

19:00 – 19:15: Oppsummering fra forrige uke (E.Å.)
Samle inn telefoner.
Erfaringer med ny-telefonene
Dele ut spørreskjema

19:15 – 19:25 Fylle ut spørreskjema
Se på lysbildepresentasjon

19:25 – 20:00 Hvordan bruke systemet
Teoretisk gjennomgang ved E.Å.
Forklar også blodsukkermåleren
Feil-situasjoner og hva gjør man.

20:00 – 20:10 Pause

20:10 – 21:00: Praktisk utprøving av systemet
Gjennomgang av funksjonene.

Neste møte: Vi kontakter dere når stegtelleren er klar.
Ring hvis problemer: E.Å. xxx xxxxx/ R.V. yyy yyyyy (evt. send SMS og be oss ringe dere).

Focus group meeting 9 – October 2008

English Summary of the Script for Meeting 9:

The main themes for this meeting were:

- Installation of the Tips function on the users' phone
- Filling in the questionnaire
- Asking users for experience from using the system
    - Problems?
    - Phone
    - BGM
    - Touch-sensitive screen
    - System as a whole
    - When do you use the system, and the different parts of it?
    - Food habit registration – when?
    - When and why do you not use the system?
    - Wishes for improvements?
- Break
- The Tips-function, presentation and demonstration
- Emphasize the aim of the Tips function (inspiration to seek more information)
- Practical test of the function
- Questions?
- Plan for the next meeting.
- Help with the phone – for those who need it.

Original Norwegian Script for Meeting 9:

Timeplan for niende brukermøte, 28. og 30. oktober

19:00 – 19:10: Orientering
Vi samler inn en og en telefon og installerer Tips funksjonaliteten.
Hjelp til å stille klokka på blodsukkermåleren.

19:10 – 19:30: Spørreskjema
Del ut, minn på viktigheta av å fylle ut alle feltene.

19:30 – 20:00: Erfaringene med å bruke systemet
Husk – vi trenger ærlige svar her!
Har dere skrevet ned ting som dere plages med, eller ideer dere har fått?
Problemer?

- Med telefonen…
- Med blodsukkermåleren…
- Med å trykke på skjermen…
- Med systemet som helhet…

Erfaringer?
Når bruker dere systemet?
Når bruker dere de ulike delene av systemet?
Når bruker dere ikke systemet?
Når registrerer dere matvanene: før dere spiser / etter dere har spist / på slutten av dagen / registrerer ikke matvanene.
I hvor stor grad opplever du at din egen opplevelse av ditt blodsukkernivå stemmer overens med det du måler?
Hvorfor brukes ikke systemet som helhet eller deler av systemet?
Ønsker om forbedringer?

20:00 – 20:10: Pause

20:10-20:30: Den nye funksjonaliteten - Tips
Demonstrer bruken.
Si at det er 80 tips som er inndelt i kategoriene: Generelt, mat, blodsukker, sykdom, fysisk aktivitet.
Understrek av tipsene ikke nødvendigvis er 100% sanne for alles situasjon, og at det ikke er absolutte sannheter.
Målet er at de skal få inspirasjon til å lese mer om emnene, samt litt kunnskap fra tipsene.
La de få bla i tipsene.
Spørsmål.

20:30 – 20:40 Avslutning
Ring hvis problemer: E.Å. xxx xxxxx/ R.V. yyy yyyyy (evt. send SMS og be oss ringe dere).
Neste møte er når stegtelleren er ferdig, antagelig november/desember.

20:40 – 21:00 Hjelp med mobiltelefonen eller systemet
De som trenger hjelp kan bli igjen og vi kan hjelpe.

Focus group meeting 10 – March 2009

English Summary of the Script for Meeting 10:

The main themes for this meeting were:

- Explanation of how we have divided this meeting into four stations
- Visits to the four stations
    - Questionnaire 1 station
    - Interview station
    - Questionnaire 2 station
    - Phone-installation station
- Break
- Focus group session in plenum
    - Experiences with the use of the system for this half year?
    - Positive and negative feedback
    - Feedback on usability issues (PowerPoint presentation of all the mobile phone screens)
- About participating more than the past half year, what it implies.
- Explain changes in the new version of the Few Touch application
- Feedback on these changes
- Ask who want to participate in a continuation of this study
- Practical issues, battery, etc.
- Give a big thanks to all the participants!

Original Norwegian Script for Meeting 10:

Timeplan for tiende brukermøte, 17. og 19. oktober

19:00 – 19:05: Orientering
Forklar hvordan de 6 deltagerne skal bevege seg mellom de fire ulike stasjonene

19:05 – 20:00: Besøke de fire stasjonene

A. ***Spørreskjema-stasjon 1*** [15 min.] (G.Ø.; Siste versjon av "det vanlige spørreskjemaet").
B. ***Intervju-stasjon*** [10 min.] (S.W.; Intervju om bruk av blodsukker- og stegdata)
C. ***Spørreskjema-stasjon 2*** [15 min.] (N.T./E.Å.; SUS-spørreskjema + Usability-spørreskjema)
D. ***Ordne telefonen*** [15 min] (N.A., T.S., T.C.; Installasjon av ny programvare og nedlasting av data)

20:00 – 20:10: Pause

20:10-20:40: Fokusgruppe
Spør generelt om erfaringene med Diabetesdagboka, og få fram om det er erfaringer – negative som positive – som flere har opplevd.
Se guide for usability spørsmål: Gå en runde og la de få si noe om deres opplevelse med den siste, komplette versjonen av diabetesdagboka, mens vi viser de to Powerpoint-presentasjonene.

20:40 – 21:00: Om videre deltagelse og om praktiske ting

1. Forklare ny funksjonalitet og endringer i den nye versjon av Diabetesdagboka
2. Spør dem om hva de synes om disse endringene i Dagboka.
3. Orienter om opplegget framover. De som vil delta videre vil møtes ca. en gang i kvartalet, og fortsette ut året. De som ikke vil delta videre vil bli spurt om å delta på et minimums-nivå, der de bruker systemet slik de vil, evt. ikke bruker det, men møter oss en gang til på slutten av året der vi oppsummerer og samler inn utstyret.
4. Spør hvem som vil være med videre, og be disse om å fylle ut samtykkeerklæring.
5. Dele ut ekstra batterier til adapterte og måleren for de som vil fortsette.

21:00 Takke alle deltagerne deltagelse i prosjektet!

Appendix 12: Thinking aloud Sessions Round 2: Test Plan & Facilitator Script

Thinking aloud Sessions Round 2: Test Plan & Facilitator Script

Version 11/19/07
J. Tufano w/input from E. Årsand

Greeting and Orientation (5min)

- LUTE facility & purpose (improving the design of information technologies to make them easier for people to use)
- Basic process description (simulated tasks, video recording, *we are testing the system, not the users*)
- Eirik's role
- My role
- Juice and crackers, restroom, etc

Consent and Context-Setting (5min)

- Highlight "Purpose of the Study" and "Procedures" from the consent form; get signature, provide gift certificate
- Read additional text to set context for the overall usability test session:

As you read in the consent form, our research group aims to develop information technologies that enable people with diabetes to better manage their health. Our previous studies have involved development of Websites that enable people to post and exchange information, and communicate with their health care providers over the Internet in between regular clinic visits.

Based on feedback from users of these Web applications, we have developed a new messaging system that integrates the use of cell phones with these patient Web sites. The system allows patients to use cell phones to capture, upload, and receive feedback on blood glucose readings, nutritional habits, insulin administration, exercise habits, and other factors relevant to blood glucose control. This information is then also available on the Web site for patient's personal use, and/or to share and discuss with their physicians and other care providers.

The purpose of this study is to receive feedback from you as a representative person with diabetes about how best to design this new system. Specifically, in this session we'll be asking you to test and provide feedback on several different technology design approaches to monitoring and managing eating habits and the nutritional facets of blood glucose control. In previous sessions like this we've asked people to try different design approaches and functions of our system aimed mostly at glucose monitoring, and in other future sessions we'll focus on physical activity – but the primary emphasis for our session will be eating habits and nutrition, and maybe if there's some time left near the end we'll talk a little bit about insulin dosing. But for the most part we'll be spending the next hour or so running through tests that involve the use of our system to support your needs for monitoring and managing eating habits. Any questions?

So the way this works is that I'll be providing some demonstrations of software on this cell phone [note: we're using the Wing] and this PC, and then assigning small tasks for you to perform using these devices. While you perform these tasks I would like you to "think aloud". That is, I would like you to talk out loud about what you are thinking as you use the devices and the software. After you complete each of these tasks, I'll also ask you a few specific questions about the experience. Then we'll move on to the next demo and the next task. So next I'll demonstrate the Think Aloud protocol, but do you have any questions so far?

<u>Demo of the Thinking aloud Protocol (5min)</u>

- Read paragraphs below
- Demo the Thinking aloud Protocol using stapler reloading test case

In these tests, we're interested in what you say to yourself as you perform some tasks that we give you. In order to do this, we'll ask you to think out loud as you work on the tasks. What I mean by this is that I want you to say out loud everything that you think or say to yourself silently as you perform the task. Just act as if you are alone in the room speaking to yourself. If you are silent for any length of time, I'll ask you a question or remind you to think out loud. We want to know what you expect to happen and whether or not it meets with your expectations. We want to know what surprises, what pleases, what confuses, or even frustrates you, and why. When you share with us what you're thinking as you go along, we get a better understanding of how the process works for you.

<u>Demo and Test Case #1: CliniPro and Picklist [15min]</u>

- "In this next exercise, I'll show you how we've designed the system to enable you to upload data from a glucometer to a patient Website using a cell phone, view the data at the Website along with nutritional data, and then log foods you've eaten into the Website from the desktop PC."
- Demo starting with OneTouch upload → CliniPro Chart page view → CliniPro Nutrition page view → entering a meal using the pick list → viewing entry
- Provide instruction sheet for Test Case 1 (***task will be to log onto CliniPro as testpatient ; view the Chart page, noting meal entries; go to the Nutrition page; enter 3 meals; and view results***)

Post-Test #1 questions:

1. Would you use a system like this on a routine basis? Why or why not?
2. Would you find a system like this useful? Why or why not?
3. What goals do you think an approach like this is designed to support? What are we trying to achieve with this design approach?
4. What do you think about sharing this Website with your physician? What about sharing it with your nutritionist?
5. If you could tell the designers to change just one thing about this system, what would it be?
6. What might be a more useful approach to using IT to support goals pertaining to managing eating habits?

Demo and Test Case #2: HealthReach and Pix Messaging Blog [20min]

- This next set of tasks involves receiving and sending messages using the cell phone. Imagine that you've met with a diabetes case manager or nutritionist, and together you've established a care plan and some personal health goals focused on your eating habits. Specifically, you've decided that you need to improve your skills at estimating the nutritional content of the foods that you're eating, and the impact that different foods have on your blood sugars. In this next task, I'll show you how we're taking a different approach to the Website design that will enable you to add digital pictures of food, and to add either typed notes to these pictures or to attach audio recordings to them. We've designed this so that you can use your cell phone to take pictures of foods that you eat, and that you can then send these pictures directly to this Website from your cell phone. You can also use your cell phone to attach your estimates of the grams of carbohydrates in the food, and/or the portion sizes in ounces. So before you eat something, you snap a picture of it with your phone, add your estimates of carbohydrate grams, and then upload the picture and the estimates to your Website. Later on you can review this page yourself or with your case manager.
- Demo starting with HealthReach logon, then go to the to-be-determined Nutrition Blog section (or window or link-out, etc), then: take pic → annotate pic → post pic to blog → view and edit posting via PC → share → receive and view nutritionist's notes/annotations *[***note: this may change significantly as Jan develops the nutrition blog and I see the design and workflows it can support***]*
- Provide instruction sheet for Test Case #2: *[***again, specific tasks and sequencing TBD, but essentially it's the same workflow as the demo in the bullet point above***]*

Post-Test #2 questions:

1. Would you use a system like this on a routine basis? Why or why not?
2. Would you find a system like this useful? Why or why not?
3. Do you think this design approach would be helpful in achieving goals related to carbohydrate estimation skills? Why or why not?
4. Would you ever want to share access to this blog with someone other than your nutritionist? Why or why not? If yes, who would you want to share it with?
5. If you could tell the designers to change just one thing about this system, what would it be?
6. What might be a more useful approach to using IT to support goals pertaining to carbohydrate estimation?

Demo and Test Case #3: Eirik's Smartphone Application [20min]

- This next set of tasks involves only the cell phone and no contact with the health care system, i.e., think about it as a tool for just your own personal use. Imagine that you've decided to set some personal goals pertaining to changing your eating habits. For example, you've decided to routinely eat more fruits and vegetables as part of your regular diet. In this next task, I'll show you how we've designed a concept that runs on your cell phone to help you set and achieve these goals.
    1. Use 5 minutes to explain the goal of the tool and the functionalities. Go through STEPS, BLOOD GLUCOSE, FOOD, MY GOALS, TIPS and PHONE functions once. Then as the second round, go through:
       MY GOALS AND FOOD again, setting a food habit goal from 3 to 4 fruits, and register a meal. Explain that the focus is on food <u>habits</u> and not on nutrition. Also note that this system design option aims to register <u>eating habits</u>

very roughly, with the assumption that it is better to obtain a rough overview of one's eating habits than none at all. Underline that this is a pure self-help tool.

2. Use 10 minutes letting the users tries the self-help tool. Let them use it generally (without guidance) for approx. 3 minutes.
   Then, ask the user to do the following:
   - Case 1 – changing goal: Increase the initial goal of eating 3 fruits a day, to eating 4 fruits a day. Return to main menu.
   - Case 2 – changing goal: Set your goal for number of meals per day to 4. Return to main menu.
   - Case 3 – changing goal: Set your goal for maximum number of carbohydrate meals per week, down from 19 to 15.
   - Case 4 – register meal: Register that you have just eaten a low carb. meal.
   - Case 5 – register snack: Register that you have just eaten an apple as snack.
   - Case 6 – register drink: Register that you have just drunken a glass of juice.
3. Last 5 minutes: let the participant play with register some other food habits as well, and try out the tool generally. Encourage her/him to comment on what he does (I guess most of the reflections come at this stage).

Post-test #3 Questions

General

- How could this system be useful to you?
- Would you use a system like this on a routine basis? Why or why not?
- Do you think this design approach would be helpful in managing your diabetes? Why/why not? If so, how?
- Would you ever want to share the data from this system with anyone else? Why or why not? If yes, who would you want to share it with?
- If you could tell the designers to change just one thing about this system, what would it be?

Specific questions for this solution

- What do you think of the "goal-setting" procedure?
- What do you think of the procedures for registering food habits?
- What do you think of the feedback screens?
- Do you think that using this system you would eat more fruits/vegetables?
- Do you think that using this system you would change how often you eat, or any of your other eating habits?
- Do you think that using this system you would eat less carb-rich meals?
- Do you have any suggestions for improvement of the design or functionality of this system?

Demo and Test Case #4: Pix Messaging Blog for Insulin Dosing [10min]

- In this last exercise, we're going to shift gears and focus on the use of these technologies to help you manage your insulin administration. Referring back to the first task that involved the glucometer upload, we're going to explore two different approaches to tracking your insulin dosing patterns.
- Demo starting with OneTouch upload → CliniPro Chart page view → CliniPro Insulin page view → entering a dose → view an entry → view entry on Chart page

- Provide instruction sheet for Test Case 5 (***Task 1 will be to log onto CliniPro as testpatient ; view the Chart page, noting insulin entries; go to the insulin page; enter a dose; and view results; Task 2 will be to log into HealthReach as testpatient; go to blog; use phone to take picture of syringe; annotate & post; go back to PC view entry via HealthReach***)

Post-Test #4 questions:

1. Would either of these approaches be useful?
2. Which design approach do you prefer? Why?
3. If you could tell the designers to change just one thing about either system, what would it be?
4. Are there entirely different design approaches that you think would be preferable for capturing and using insulin dosing information?

Post-Session Exit Interview Questions [10min]

1. Which of the four systems would you be most likely to use?
2. Which of the four systems do you find most likely would provide you with valuable information so that you may better manage your diabetes?
3. Which of the three food-related systems would you be least likely to use?
4. Are there specific components of the design of any of these systems that you think are particularly good?
5. Do you have other suggestions about how we should design systems for helping people better manage the nutritional challenges associated with controlling their diabetes?
6. What are your thoughts on involving your physician or other healthcare providers in the use of any of these systems?
7. What are your thoughts on involving friends, family members, or other non-medical people in the use of any of these systems?

Appendix 13: Paper Prototyping Session

The following paper prototype schemes were used to get feedback on:

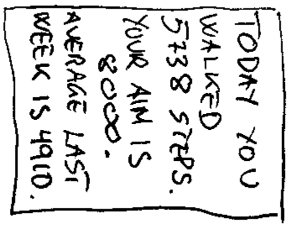
a) How the users valued eight different feedback screens for physical activity.

b) Users’ own suggestions.

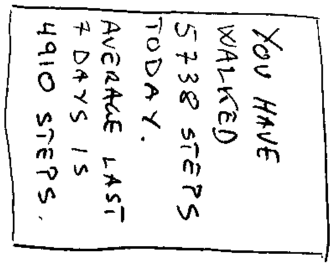
Translated, English version:

The heading for this scheme "a" is: "How do you want 'Today's steps' for the step counter summarized on your phone? Rank from 1 to 8, where 1 is the best."

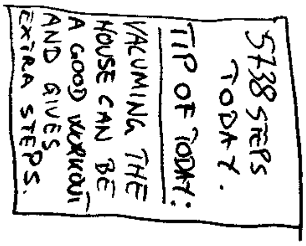
Under each picture, the text "Ranking: ______" was displayed.



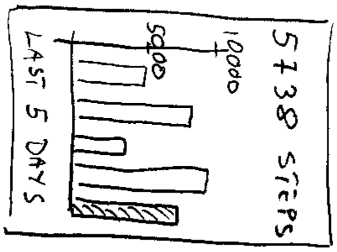
E



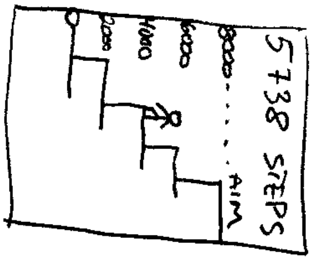
A



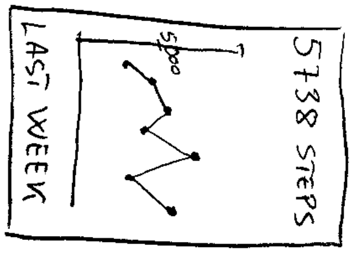
F



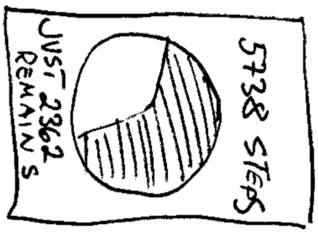
B



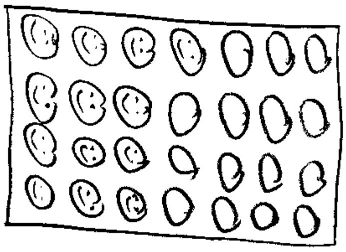
G



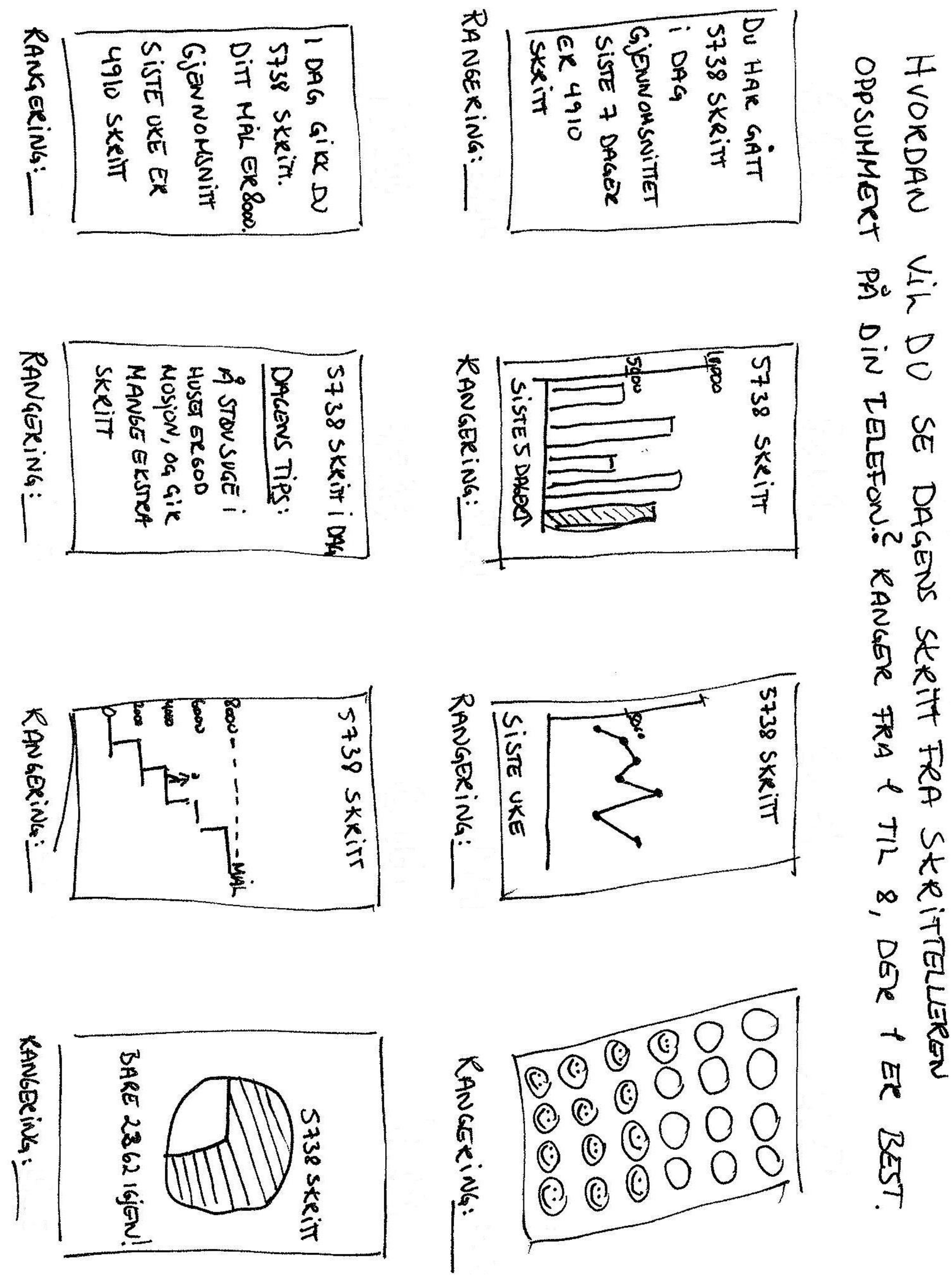
C



H


D

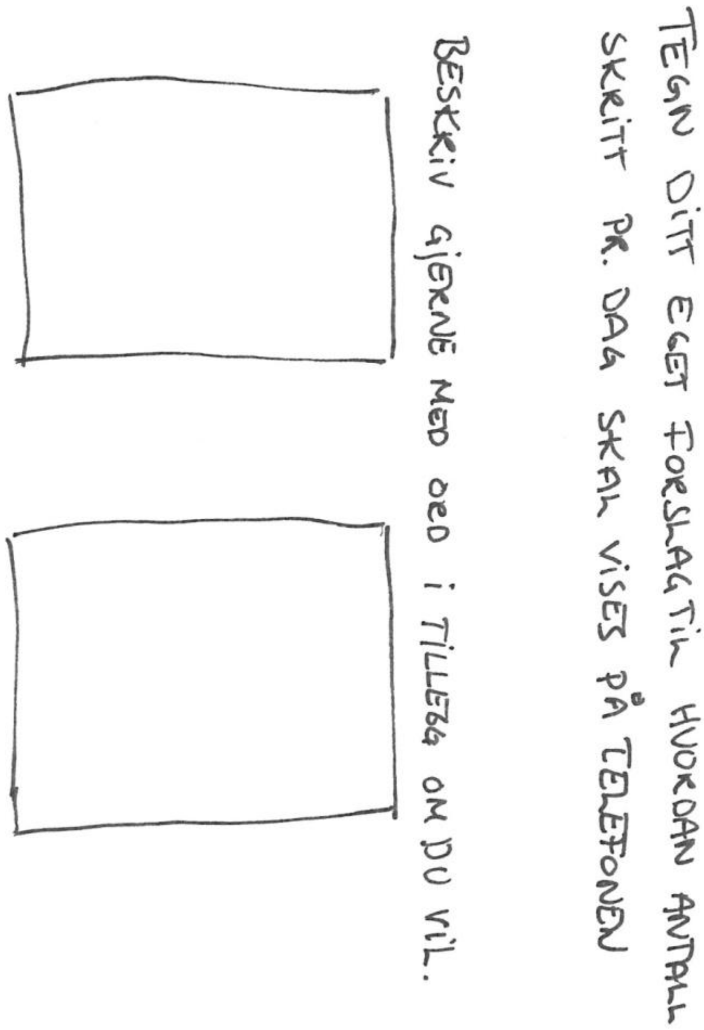
Original, Norwegian version, scheme "a":



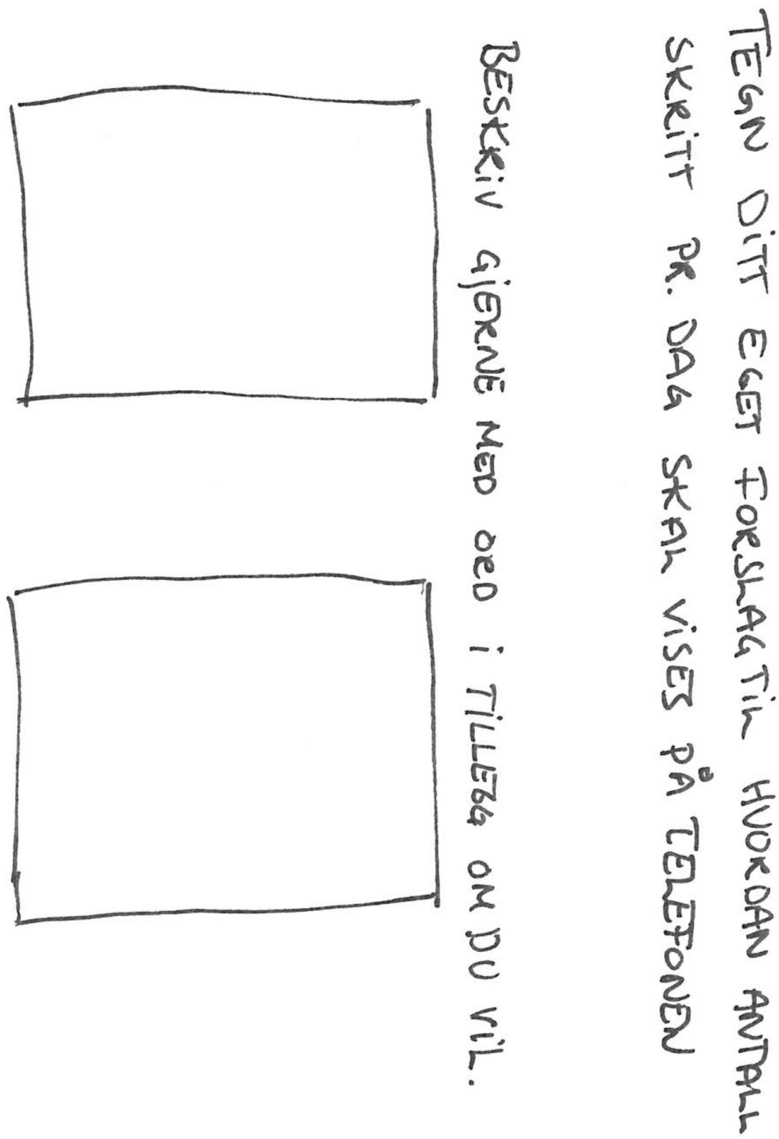
Translated, English version:

Heading for this scheme ”b” is: “Draw your own suggestions for how the number of daily steps should be displayed on the phone.”

Sub-heading: “Please use words in addition if wanted.”



Original, Norwegian version, scheme "b":



Appendix 14: Questionnaires used as part of the Type 1 Diabetes study

Questionnaire 1, General Questions (Spørreskjema 1)

English translation/explanation (Note: questionnaire should not be used as is in English, but is offered for consideration as described by Erkut et al. [97]):

This questionnaire, which is to be completed by the parents, addresses the following:

1. The sex of the child?

2. Age?

3. No. of family members/friends that have the daily responsibility for the child's diabetes management?

4. Who lives together with the child?

5. No. of years the child has had diabetes?

6. How does the child inject the insulin?

7. If using a syringe/pen – how many injections per day?

8. Which kind of blood glucose monitor is used today?

9. How many blood glucose measurements per day?

10. The number of times the child has been hospitalized due to an emergency?

11. How often do the parents use mobile phones?

12. How often does the child use the mobile phone?

13. How often is blood glucose measurement data transferred using cable to PC software?

14. HbA1c before the intervention (entered by your hospital)?

15. HbA1c after the intervention (entered by your hospital)?

See next page for the original, Norwegian version.

Generelle spørsmål om deltageren (barn med diabetes type 1) som deltar i prosjektet ”Automatisert måling av blodsukker”: (fylles ut av foreldrene)

1. Gutt ☐ Jente ☐
2. Alder: ______
3. Hvor mange familiemedlemmer/venner har det daglige ansvaret for kontrollen av barnets diabetes? ________

   Kommentarer: ____
4. Hvem bor barnet sammen med?
   Mor og far☐ En av foreldrene☐ En av foreldrene og en annen voksen☐

   Annet:____

   ____
5. Hvor mange år har barnet hatt diabetes?________________
6. Hvordan får barnet insulin? Igjennom insulinpumpe☐ Igjennom sprøyte☐
7. Hvis barnet bruker sprøyte, hvor mange ganger får barnet insulin i løpet av et døgn? _______
8. Hvilken blodsukkermåler(e) bruker dere i dag?

   ____

   ____
9. Hvor mange ganger måles vanligvis barnets blodsukker i løpet av et døgn?_______________
10. Hvor mange ganger har barnet vært akutt-innlagt på sykehus som følge av sin diabetes etter sykdommen ble oppdaget? ________________
11. Bruker dere (foreldre/omsorgspersoner) mobiltelefon? Ofte☐ Sjelden☐ Aldri☐
12. Bruker barnet mobiltelefon? Ofte ☐ Sjelden☐ Aldri☐
13. Bruker dere å overføre verdiene fra måleren til et dataprogram? Ofte ☐ Sjelden ☐ Aldri ☐

    Kommentarer:____

    ____
14. HbA1C før prøveperioden: _________________ (fylles ut av sykehuset)
    Dato:_____________
15. HbA1C i slutten av prøveperioden: ________________ (fylles ut av sykehuset)
    Dato:_____________

Questionnaire 2a, Children, Before Intervention (Spørreskjema 2a)

English translation/explanation (Note: questionnaire should not be used as is in English, but is offered for consideration as described by Erkut et al. [97]):

This questionnaire, which is to be completed by the child, addresses the following:

1. How do your parents check that you have an OK blood glucose level when they are not present?
2. How do you know how much insulin you should inject or how much food you should eat:
    a. At school?
    b. During visits, without my parents present?
    c. At clubs/exercise without my parents present?
3. How do you think it would be if mum/dad automatically got your blood glucose values right after you have measured, even if they were at another place?
4. How satisfied are you today with your equipment for managing your blood glucose level:
    a. The blood glucose monitor?
    b. The mobile phone?
    c. Other equipment?
5. Are there any problems with the equipment you are using today?
6. Do you think that your current blood glucose monitor is easy to use?
7. How often do you have hypoglycaemia during a month?
8. How many times do you usually have such a high blood glucose value that it is unpleasant, during a month?
9. Which blood glucose level do you think that you have usually?
10. Where do you usually keep your blood glucose monitor today?

See the next two pages for the original, Norwegian version.

Spørsmål til BARNET med diabetes, FØR prøveperioden
(fylles ut av barnet, med hjelp fra foreldrene hvis nødvendig)

1. Hvordan kontrollerer mamma/pappa at du har et greit blodsukkernivå når de ikke er til stede?

   Ringer☐ Ringer din mobiltelefon☐ Jeg klarer meg selv☐

   Annet: ____

   ____

   ____

2. Hvordan vet du hvor mye insulin du skal sette eller hvor mye mat du skal spise:

   a. På skolen? Læreren hjelper meg☐ Setter samme mengde insulin hver dag☐ Finner ut selv☐ Ringer mamma/pappa☐

      Annet: ____

      ____

      ____

   b. På besøk uten mamma/pappa tilstede?

      En voksen hjelper meg☐ Finner ut selv☐ Ringer mamma/pappa☐

      Annet: ____

      ____

      ____

   c. På ungdomsklubb/trening uten mamma/pappa tilstede?

      En voksen hjelper meg☐ Finner ut selv☐ Ringer mamma/pappa☐

      Annet: ____

      ____

      ____

3. Hvordan tror du det ville være om mamma/pappa fikk tilsendt automatisk blodsukkernivået ditt rett etter at du hadde målt, selv om de var på et annet sted?

   Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

   Kommentar: ____

   ____

   ____

   ____

   ____

4. Hvor fornøyd er du med det utstyret du har i dag til å hjelpe deg med at blodsukkeret er bra:

   a. Blodsukkermåleren? Veldig bra ☐ Ganske bra ☐ Sånn passe ☐ Dårlig ☐

      Kommentar: ____

      ____

      ____

   b. Mobiltelefon? Veldig bra ☐ Ganske bra ☐ Sånn passe ☐ Dårlig ☐

      Kommentar: ____

      ____

      ____

   c. Annet utstyr? Veldig bra ☐ Ganske bra ☐ Sånn passe ☐ Dårlig ☐

      ____

      ____

      ____

5. Er det problemer med det utstyret du bruker idag? Ofte ☐ Av og til ☐ Aldri ☐

   Hva skjer? ____

   ____

   ____

   ____

6. Synes du at blodsukkermåleren du bruker i dag er enkel å bruke?

   Veldig enkel ☐ Ganske enkel ☐ Sånn passe ☐ Vanskelig ☐

   Kommentar: ____

   ____

   ____

   ____

7. Hvor mange ganger har du vanligvis føling i løpet av en måned?________________________

8. Hvor mange ganger har du vanligvis så høyt blodsukker at det er ubehagelig, i løpet av en måned? _______________

9. Hvilket blodsukkernivå tror du at du har vanligvis? _______________(ikke desimaler)

10. Hvor har (oppbevarer) du vanligvis blodsukkermåleren din i dag? ______________________

    ____

    ____

    ____

Appendix 14: Questionnaires used as part of the Type 1 Diabetes study

Questionnaire 2b, Parents, Before Intervention (Spørreskjema 2b)

English translation/explanation (Note: questionnaire should not be used as is in English, but is offered for consideration as described by Erkut et al. [97]):

This questionnaire, which is to be completed by the parents, addresses the following:

1. How does you check that your child has an OK blood glucose level when you are not present?
2. How does your child receive advice about which amount of insulin (s)he must inject, or how much food (s)he must eat:
    a. At school/kindergarten?
    b. At visits, without you being present?
    c. At clubs/exercise without you being present?
3. How would you feel about getting an SMS with the child's blood glucose values right after (s)he had measured them, including when you are not together with the child?
4. How satisfied are you today with the equipment for managing your child's blood glucose level:
    a. The blood glucose monitor?
    b. The mobile phone?
    c. Other equipment?
5. Are there any problems with the equipment you are using today?
6. Does it look as though your child finds it easy to use the blood glucose monitor you have today?
7. How often does your child have hypoglycaemia during a month?
8. How many times does your child usually have such a high blood glucose value that it is unpleasant, during a month?
9. Which blood glucose level do you think that your child has usually?
10. Where do you usually keep your blood glucose monitor today?

See the next two pages for the original, Norwegian version.

Spørsmål til FORELDRENE, FØR prøveperioden

1. Hvordan kontrollerer dere at barnet har greit blodsukkernivå når dere ikke er til stede?
   Ringer☐ Ringer barnets mobiltelefon☐ Barnet klarer seg selv☐
   Annet: ____
   ____
   ____

2. Hvordan får barnet ditt råd om hvilke mengder insulin det skal sette eller hvor mye mat det skal spise:
   a. På skolen/barnehage? Læreren hjelper☐ Setter samme mengde insulin hver dag☐
      Barnet finner det ut selv☐ Dere ringes☐
      Annet: ____
      ____
      ____
   b. På besøk uten foreldrene tilstede?
      En voksen hjelper☐ Barnet finner det ut selv☐ Dere ringes☐
      Annet: ____
      ____
      ____
   c. På ungdomsklubb/trening uten mamma/pappa tilstede?
      En voksen hjelper☐ Barnet finner det ut selv☐ Dere ringes☐
      Annet: ____
      ____
      ____

3. Hva ville dere syntes om å få en SMS med barnets blodsukkernivå rett etter måling, også når dere var et annet sted enn barnet?
   a. Tror dere at dette ville gjort dere tryggere? Ja☐ Litt☐ Nei☐ Usikker☐
   b. Tror dere at dere ville bli engstelige av slike meldinger? Ja☐ Litt☐ Nei☐ Usikker☐
   c. Ville dere stolt på et slikt utstyr? Ja☐ Litt☐ Nei☐ Usikker☐
      Kommentar:____
      ____
      ____
   d. Hva ville dere da gjort om dere fikk en SMS om at blodsukkeret var veldig lavt eller veldig høyt?____
      ____
   e. Tror dere at et slikt utstyret ville gjort det enklere for dere å regulere blodsukkeret til barnet deres? Ja☐ Litt☐ Nei☐ Usikker☐
      Kommentarer:____

____

____

4. Hvor fornøyde er dere med dagens utstyr som hjelp til å regulere blodsukkeret:
   a. Blodsukkermåleren? Veldig bra ☐ Ganske bra ☐ Sånn passe ☐ Dårlig ☐
      Kommentar:____

      ____

      ____

   b. Eventuelt mobiltelefon? Veldig bra ☐ Ganske bra ☐ Sånn passe ☐ Dårlig ☐
      Kommentar:____

      ____

      ____

   c. Annet utstyr? Veldig bra ☐ Ganske bra ☐ Sånn passe ☐ Dårlig ☐
      Kommentar: ____

      ____

      ____

5. Er det problemer med det utstyret dere bruker idag? Ofte ☐ Av og til ☐ Aldri ☐
   Hva skjer? ____

   ____

   ____

6. Ser det ut som at barnet ditt synes blodsukkermåleren dere bruker i dag er enkel å bruke?
   Ja, enkelt ☐ Ganske enkelt ☐ Sånn passe ☐ Vanskelig ☐
   Kommentar:____

   ____

   ____

7. Hvor mange ganger har barnet ditt vanligvis føling i løpet av en måned? ______________
8. Hvor mange ganger har barnet ditt vanligvis så høyt blodsukker at det er ubehagelig for barnet, i løpet av en måned?______________
9. Hvilket blodsukkernivå tror du/dere at barnet har vanligvis?_____________ (ikke desimaler)
10. Hvor oppbevarer dere/barnet ditt vanligvis blodsukkermåleren i dag?_____________________

    ____

    ____

    ____

Questionnaire 3a, Children, After Intervention (Spørreskjema 3a)

English translation/explanation (Note: questionnaire should not be used as is in English, but is offered for consideration as described by Erkut et al. [97]):

This questionnaire, which is to be completed by the child, addresses the following:

1. How did the automatic system work?
    a. Do you wish that you yourself could have decided whether the blood glucose values should be sent to your parents or not?
    b. Do you wish that you could get a message back when mum/dad had received the blood glucose value?
    c. Other things?
2. Did the system help you in figuring out how much insulin you should inject and how much you should eat:
    a. At school? Comments?
    b. At visits without mum/dad being present? Comments?
    c. At clubs/exercise without your parents being present? Comments?
3. How would you feel if mum/dad automatically got your blood glucose values right after you have measured them, even if they were at another place?
    a. Was it OK that mum/dad got a message about your blood glucose? Comments.
    b. Did you sometimes feel afraid that the equipment would not work? Comments?
    c. Did the equipment always work? Comments?
    d. What usually happened when mum/dad got a message that your blood glucose was high?
4. How did you think the system you used in the test period worked?
    a. The blood glucose monitor? Comments?
    b. The mobile phone? Comments?
    c. The transfer of the blood glucose values? Comments?
    d. Did you sometimes during the test period think that you should rather have had your old equipment? Comments.
    e. Do you think it got easier to have diabetes with this new equipment? Comments?
5. Were there any problems with the equipment you used?
    a. What happens?
6. Do you think that this new equipment for blood glucose monitoring was easy to use? Comments?
7. How often do you have hypoglycaemia during a month?
8. How many times do you usually have such a high blood glucose value that it is unpleasant, during a month?
9. Which blood glucose level do you think that you have usually?
10. Where did you usually keep your blood glucose monitor system during the test period?
11. Would you like to be able to use this system from now on? Why/why not?
12. Do you have some suggestions to how this system could have been better to use for you?
    a. Was it difficult to remember to charge the mobile phone?
    b. Was the blood glucose monitor too big or heavy?
    c. Was the phone too big or heavy?
    d. Was it difficult to remember that the phone must be near the blood glucose monitor to have the measurements transferred?
    e. Were you afraid to lose the mobile phone?
    f. Other things?

See the next three pages for the original, Norwegian version.

Spørsmål til BARNET med diabetes, om systemet "Automatisert måling av blodsukker"
(fylles ut av barnet, med hjelp fra foreldrene hvis nødvendig)

1. Hvordan fungerte automatikken i systemet?
   a. Skulle du ønsket at du selv kunne bestemme om blodsukkerverdiene skulle sendes eller ikke? Ja☐ Nei☐
   b. Skulle du ønsket at du fikk en melding tilbake når mamma/pappa hadde mottatt blodsukkerverdien din? Ja☐ Nei☐

   Annet:____

   ____

   ____

2. Hjalp utstyret deg til å finne ut hvor mye insulin du skulle ta og hvor mye mat du skulle spise:

   a. På skolen? Ja☐ Litt☐ Nei☐

   Kommentar:____

   b. På besøk uten mamma/pappa? Ja☐ Litt☐ Nei☐

   Kommentar:____

   c. På ungdomsklubb/trening uten mamma/pappa? Ja☐ Litt☐ Nei☐

   Kommentar:____

3. Hva syntes du om at mamma/pappa fikk vite om blodsukkernivået ditt rett etter at du hadde målt, selv om de var et annet sted?

   a. Var det bra at mamma/pappa fikk beskjed om blodsukkeret ditt?
   Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

   Kommentar:____

   ____

   b. Ble du noen ganger redd for at utstyret ikke skulle virke? Ja☐ Nei☐

   Kommentar:____

   ____

   c. Fungerte utstyret alltid? Ja☐ Nesten alltid☐ Nei☐

   Kommentar:____

   ____

d. Hva skjedde når mamma/pappa fikk beskjed om at blodsukkeret var veldig lavt eller veldig høyt? ____

____

____

4. Hvordan syntes du utstyret du brukte i prøveperioden fungerte:

a. Blodsukkermåleren? Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

Kommentar:____

____

b. Mobiltelefonen? Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

Kommentar:____

____

c. Overføringen av blodsukkerverdiene?

Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

Kommentar:____

____

d. Ønsket du i løpet av prøveperioden at du heller skulle hatt ditt gamle utstyr?
Ja, mange ganger☐ Noen ganger☐ Nei☐

Kommentar:____

____

e. Syntes du at det ble enklere å ha diabetes med det nye utstyret?
Ja, veldig mye enklere☐ Ganske mye enklere☐ Litt enklere☐ Nei☐

Kommentar:____

____

5. Var det problemer med det utstyret du brukte? Ofte☐ Av og til☐ Aldri☐

Hva skjedde:____

____

____

____

6. Synes du at det nye utstyret for blodsukkermåling var enkelt å bruke?
   Veldig enkelt☐ Ganske enkelt ☐ Sånn passe☐ Vanskelig☐

   Kommentar:____

   ____

7. Hvor mange ganger har du vanligvis føling i løpet av en måned? ____________________

8. Hvor mange ganger har du vanligvis så høyt blodsukker at det er ubehagelig, i løpet av en måned?_____________

9. Hvilket blodsukkernivå har du vanligvis?________________ (ikke desimaler)

10. Hvor hadde (oppbevarte) du vanligvis blodsukkermåleren i prøveperioden?

____

____

11. Kunne du tenkt deg å bruke dette systemet videre, og hvorfor/hvorfor ikke?

____

____

12. Har du noen forslag til hvordan systemet kunne ha vært bedre for deg?

    a. Var det vanskelig å huske på å lade mobiltelefonen? Ja☐ Nei☐

    b. Var blodsukkermåleren for stor eller tung? Ja☐ Nei☐

    c. Var telefonen for stor eller tung? Ja☐ Nei☐

    d. Var det vanskelig å huske på at telefonen måtte være i nærheten av blodsukkermåleren for at målingene skulle bli sendt? Ja☐ Nei☐

    e. Var du redd for å miste mobiltelefonen? Ja☐ Nei☐

    f. Andre ting: ____

    ____

    ____

    ____

    ____

    ____

    ____

Questionnaire 3b, Parents, After Intervention (Spørreskjema 3b)

English translation/explanation (Note: questionnaire should not be used as is in English, but is offered for consideration as described by Erkut et al. [97]):

This questionnaire, which is to be completed by the parents, addresses the following:

1. How did the automatic system work?
    a. How was it to automatically get a message when your child had measured the blood glucose? Comments?
    b. Did you wish that the child herself/himself could have decided whether the blood glucose values should be sent, or not?
    c. Other things?
2. Did the system help you in figuring out how much insulin the child should inject and how much to eat:
    a. When the child was at school/kindergarten? Comments?
    b. At visits without mum/dad being present? Comments?
    c. At clubs/exercise without the parents being present? Comments?
3. How did you feel about automatically getting an SMS with the child's blood glucose value right after (s)he had measured
    a. Did you feel safe? Comments?
    b. Did you sometimes get more anxious? Comments?
    c. Did the equipment always work? Comments?
    d. What usually happened when you got a message that the blood glucose was very low or very high?
    e. Do you think that the system made it easier to manage your child's blood glucose? Comments?
4. How did you think the system you used in the test period worked?
    a. The blood glucose monitor? Comments?
    b. The mobile phone? Comments?
    c. The transfer of the blood glucose values? Comments?
    d. Did you sometimes during the test period think that you rather should have had the old equipment? Comments?
    e. Do you think it became easier to handle the child's diabetes using this new equipment? Comments?
5. Were there any problems with the equipment that you used?
    a. What happened?
6. Do you think that the system was easy to use? Comments?
7. How often does your child have hypoglycaemia during a month?
8. How many times does your child usually have such a high blood glucose value that it is unpleasant, during a month?
9. Which blood glucose level do you think that your child has usually?
10. Where did you/your child usually keep the blood glucose monitor system during the test period?
11. Did the use of the system have any effects on the relationship with your child concerning diabetes? Comments?
12. Did you learn something new about your child's diabetes during the test period, and if so – which things?
13. Would you like to be able to use this system from now on, and why/why not?
14. Do you have some suggestions to how this system could have been better to use for you?

a. Was it difficult to remember to charge the mobile phone?
b. Was the blood glucose monitor too big or heavy?
c. Was the phone too big or heavy?
d. Was it difficult to remember that the phone must be near the blood glucose monitor to make the measurements transferred?
e. Were you afraid that your child should lose the mobile phone?
f. Other things?

Willingness to pay:

An improved version of the blood glucose system will cost a total of NOK 6500 including the mobile phone.
In addition, a yearly maintenance fee of NOK 1500 and approximately NOK 1100 in SMS use each year (assuming three messages on average are sent each day).

The price will then be NOK 6500 as a one-time investment, in addition to a yearly expense of NOK 2600, which is approximately NOK 200 per month (all included).

15. Would you be willing to pay this price as described above, to get this blood glucose system?

☐ Yes

☐ No

If "No", what would be the maximum price you would be willing to pay for the equipment (the one-time investment)? NOK____________. Note. The yearly expense for the use of SMS and maintenance at a minimum total fee of NOK 2600 will be added.

16. How many persons are in your household? ___________persons.
17. How many of these are children under age of 16 years? ___________ persons
18. What was your total gross income in your household for the year 2002?

☐ under NOK 100 000 ☐ NOK 300-400 000 ☐ NOK 600-700 000

☐ NOK 100-200 000 ☐ NOK 400-500 000 ☐ NOK 700-800 000

☐ NOK 200-300 000 ☐ NOK 500-600 000 ☐ NOK 800-900 000 ☐ over NOK 900 000

See the next four pages for the original, Norwegian version.

Spørsmål til FORELDRENE, om systemet "Automatisert måling av blodsukker"

1. Hvordan fungerte automatikken i systemet?
    a. Hvordan var det å få automatisk beskjed når barnet hadde målt blodsukkeret?
    Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

    Kommentar:____

    ____

    b. Ville du ønsket at barnet selv kunne bestemme om blodsukkerverdien skulle sendes eller ikke? Ja☐ Nei☐

    Annet:____

    ____

    ____

2. Hjalp utstyret dere til å passe på hvor mye insulin og hvor mye mat barnet skulle ha:

    a. Når barnet var på skolen/barnehage? Ja☐ Litt☐ Nei☐

    Kommentar:____

    b. Når barnet var på besøk uten dere foreldre? Ja☐ Litt☐ Nei☐

    Kommentar:____

    c. Når barnet var på ungdomsklubb/trening uten dere foreldre? Ja☐ Litt☐ Nei☐

    Kommentar:____

3. Hva syntes dere om å få en SMS med barnets blodsukkernivå rett etter måling?

    a. Ble dere trygge? Ja☐ Litt☐ Nei☐

    Kommentarer:____

    b. Ble dere mer engstelige? Ja☐ Litt☐ Nei☐

    Kommentarer:____

    c. Fungerte utstyret alltid? Ja☐ Nesten alltid☐ Nei☐

    Kommentarer:____

d. Hva gjorde dere når dere fikk SMS om at blodsukkeret var veldig lavt eller veldig høyt?____

____

____

e. Syntes dere at utstyret gjorde det enklere å regulere blodsukkeret til barnet deres?
Ja☐ Litt☐ Nei☐

Kommentarer:____

____

4. Hvordan syntes dere det utstyret dere brukte i prøveperioden fungerte:

a. Blodsukkermåleren? Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

Kommentar:____

____

b. Mobiltelefonen? Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

Kommentar:____

____

c. Overføringen av blodsukkerverdiene?

Veldig bra☐ Ganske bra ☐ Sånn passe☐ Dårlig☐

Kommentar:____

____

d. Syntes dere noen ganger at dere heller skulle hatt det gamle utstyret
Ja, mange ganger☐ Noen ganger☐ Nei☐

Kommentarer:____

____

e. Syntes dere at det ble enklere å handtere barnets diabetes med det nye utstyret?
Ja, veldig mye enklere☐ Ganske mye enklere☐ Litt enklere☐ Nei☐

Kommentarer:____

____

____

____

5. Hadde dere problemer med systemet? Ofte☐ Av og til☐ Aldri☐

Hva skjedde?____

____

____

6. Syntes dere at systemet var enkelt å bruke?

Veldig enkelt☐ Ganske enkelt ☐ Sånn passe☐ Vanskelig☐

Kommentar:____

____

____

7. Hvor mange ganger har barnet ditt vanligvis føling i løpet av en måned? ______________

8. Hvor mange ganger har barnet ditt vanligvis så høyt blodsukker at det er ubehagelig for barnet, i løpet av en måned?______________

9. Hvilket blodsukkernivå har barnet ditt vanligvis? _______________ (ikke desimaler)

10. Hvor oppbevarte dere/barnet ditt blodsukkermåleren i prøveperioden?____________________

____

____

11. Gjorde bruken av utstyret noe med forholdet til barnet når det gjelder diabetes?
Ja☐ Litt☐ Nei☐

Kommentar:____

____

____

12. Lærte dere noe nytt om barnets diabetes i prøveperioden, og eventuelt hva?

____

____

____

13. Kunne dere tenkt dere å bruke dette systemet videre, og hvorfor/hvorfor ikke?

____

____

14. Har dere noen forslag til hvordan systemet kunne ha vært bedre for dere?

a. Var det vanskelig å huske på å lade mobiltelefonen? Ja☐ Nei☐

b. Var blodsukkermåleren for stor eller tung? Ja☐ Nei☐

c. Var telefonen for stor eller tung? Ja☐ Nei☐

d. Var det vanskelig å huske på at telefonen måtte være i nærheten av blodsukkermåleren for at målingene skulle bli sendt? Ja☐ Nei☐

e. Var du redd for at barnet skulle miste mobiltelefonen? Ja☐ Nei☐

f. Andre ting: ____

____

____

____

____

____

____

____

Betalingsvillighet

En forbedret versjon av blodsukkerutstyret vil koste totalt 6500 kr inkludert mobiltelefon. I tillegg kommer vedlikehold på 1500 kr og omtrent 1100 kr i årlige SMS kostnader (dersom vi regner med at det sendes 3 meldinger hver dag).

Prisen blir da 6500 kr som vil være en engangsinvestering i tillegg til en årlig kostnad på 2600 kr som er omtrent 200 kr pr. måned de påfølgende år (alt inkludert).

15. Kunne du tenke deg å betale prisen som beskrevet over for å få blodsukkermålingssystemet?

☐ Ja

☐ Nei

Hvis nei, hva er maksimum beløp du kunne tenke deg å betale for utstyret (engangsinvesteringen)? ____________kr. NB. De årlige kostnader for bruk av SMS og vedlikehold på minimum 2600 kr kommer i tillegg.

16. Hvor mange personer er det i deres husholdning? ___________personer

17. Hvor mange av disse er barn under 16 år? ___________ personer

18. Hvor stor samlet bruttoinntekt hadde din husholdning i 2002?

☐ under 100.000,-	☐ 300-400.000,-	☐ 600-700.000,-	
☐ 100-200.000,-	☐ 400-500.000,-	☐ 700-800.000,-	
☐ 200-300.000,-	☐ 500-600.000,-	☐ 800-900.000,-	☐ over 900.000,-

Appendix 15: Questionnaires used as part of the Type 2 Diabetes study

Questionnaire A – Early Feedback on the HTML demo

(Used both on the cohort of 20 healthy people 12 – 14 June 2006,
and on the 12-person Type 2 cohort in focus group meetings on 24 and 26 April 2007)

English Summary of Questionnaire A:

The main themes for this questionnaire were:

1. Your thoughts about this idea?
2. Do you see any need for such a system?
3. Useful as a daily tool?
4. Frequency of potential use?
5. Should it be on a PC or a mobile phone?
6. Touch-sensitive screen or navigation button?
7. Advice or comment to us?

Questionnaire A, original Norwegian version:

Spørsmål angående dine reaksjoner til "Enkel DiaDagbok"

(Vi ønsker å få tilbakemelding på dette konseptet.)

---

1. Hva er dine **tanker** om denne ideen?

   Dårlig ide Genialt Andre tanker:
   0 1 2 3 4 5 6 7

2. Ser du noe **behov** for en slik løsning?

   Nei Ja, helt klart Andre kommentarer:
   0 1 2 3 4 5 6 7

3. Tror du at brukerne vil bruke dette som et DAGLIG verktøy?

   Aldri Ja, helt klart Andre kommentarer:
   0 1 2 3 4 5 6 7

4. Hvor ofte tror du at man vil bruke det?

   Aldri Ved hvert måltid Andre kommentarer:
   0 1 2 3 4 5 6 7

5. Tror du at det spiller noen rolle om "Enkel DiaDagbok" er på en PC eller på en mobiltelefon?

   Bør være på en mobiltelefon ☐ Bør være på en PC ☐ Bør være på begge ☐
   Andre kommentarer:

6. Tror du at mobiltelefonen med trykkfølsom skjerm eller mobiltelefonene med navigasjonsknapp vil være enklest å bruke?

   Trykkfølsom skjerm ☐ Navigasjonsknapp ☐ Like enkel ☐
   Andre kommentarer:

7. Har du noen råd eller kommentarer til oss i vårt videre arbeid med konseptet?

Questionnaires B – Mobile Phone Use, in Focus Group Meetings Spring 2007

English Summary of Questionnaire B1 – How do you use your mobile phone?

The main themes for this questionnaire were:

- Do you always wear your phone?
- Where is it placed?
- Which functions do you use?
- Problems with seeing the information on the screen?
- Problems with entering phone numbers?
- Which kind of mobile phone do you have?

Questionnaire B1, original Norwegian version:

Spørreskjema 1: Hvordan bruker du mobiltelefonen din?

Navn: _________

Har du den alltid med deg?

Hvor har du den (lomma, veska, annen plass)?

Hvilke funksjoner på mobilen bruker du (ringe, SMS, telefonbok, kalender, spill, annet)?

Har du problemer med å se skjermen på den mobiltelefonen du har nå?

Har du problemer med å slå telefonnummer på den mobiltelefonen du har nå?

Hvilken mobiltelefon bruker du til daglig?

English Summary of Questionnaire B2 - Usability – Mobile Phone

The main themes for this questionnaire were:

1. Age
2. Used mobile phone more than 2 years?
3. Used any electronic disease tool before?
4. Use of calendars or reminders on your phone?
5. Which kind of exercise do you do?
6. Rate unpleasant situations regarding phone usage.
7. Wishes for improvements regarding mobile phones?

Questionnaire B2, original Norwegian version:

Spørreskjema 2: Om brukervennlighet – mobiltelefon

1. I hvilken aldersgruppe er du?

<45 ☐ 46-55 ☐ 56-65 ☐ 66-75 ☐

2. Har du brukt mobiltelefon lenger enn 2 år?

Ja ☐ Nei ☐

3. Har du brukt noe elektronisk sykdoms-hjelpemiddel før?

Ja ☐ Nei ☐ Hvis ja, oppgi noen detaljer: ______________________________

4. Bruker du å angi påminnelser for avtaler/oppgaver på din mobiltelefon / PC?

Ja ☐ Nei ☐

5. Hva gjør du når du trimmer?

Går/jogger ☐ Gym ☐ Husarbeid/hagearbeid ☐

Annet (Spesifiser):_____________________________________

6. Kan du vurdere følgende ubehagelige situasjoner. Angi med tall, der 1 = ikke ubehagelig, og 5 = veldig ubehagelig.

☐ Mobiltelefonen ringer høyt når du er i et viktig møte eller samtale.

☐ Tap av en viktig telefonsamtale fordi du ikke hørte ringingen.

☐ Motta en oppringing på en støyfull plass der du knapt kan høre den som prater i telefonen.

☐ Gå tom for strøm på telefonen når du ikke har med deg laderen eller tilgang til en strøm-kontakt.

☐ Motta en feiloppringing når du ligger og sover klokka 3 på natta.

☐ Lese SMS i mørket og displayet på telefonen er veldig lyst.

7. Hvilke forbedringer ville du ønsket deg på mobiltelefonen?

____

Questionnaire C – Before Introduction of the Few Touch Application, Sept. 2008

English Summary of Questionnaire C:

The main themes for this questionnaire were:

- About your diabetes
  - Medication
  - Satisfaction with management
  - Satisfaction with knowledge
  - Feelings about your diabetes
- Blood glucose
  - Frequency of measurements
  - HbA1c
  - Hyperglycaemia and hypoglycaemia
- Physical activity
  - Duration of being physically active
  - Exercise, frequency
  - Duration of exercise
  - Satisfaction with exercise
- Food
  - Knowledge about food
  - Fruits and vegetables
  - Which kinds of food do you eat?
  - Drinks
- Aids and use of mobile phone
  - Which kinds of tools do you use?
  - Kind of mobile phone?
  - Expectations of mobile diabetes self-help tool?
  - Usage of your current mobile phone
- Details about your mobile phone usage sorted by actions, locations and modes
  - User fills in the table

Questionnaire C, original Norwegian version:

Spørsmål 16. og 18. september 2008 – Selvhjelpsverktøy for Type 2 diabetes – FØR utprøving av verktøyet "elektronisk diabetesdagbok"

Dato for utfylling av skjemaet:________________ Initialer: ________ (for å kunne sammenligne FØR og ETTER svarene)

Alder:_______ Kjønn: __________ (mann / kvinne)
Hvor mange år har du hatt diabetes? _______

OM DIN DIABETES (Sett ring rundt de alternativene du synes passer best)

Bruker du insulin (spøryter, penn) i din diabetesbehandling nå? Ja / Nei

Bruker du tabletter i din diabetesbehandling? Ja / Nei

Hvor fornøyd er du med hvordan du styrer diabetes'en din?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor fornøyd er du med din kunnskap om din diabetes?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor ofte tenker du på at du har diabetes? Flere ganger daglig / Daglig / Ukentlig / Sjelden

Hvordan føler du deg når du tenker på diabetes'en din?

Dårlig samvittighet /Avmakt / Ikke noe spesielt /At jeg har litt kontrol /At jeg har god kontroll
Annet: ____

BLODSUKKER

Omtrent hvor mange ganger måler du blodsukker i løpet av ei vanlig uke? ___ ganger
Hvis sjeldnere, hvor ofte? ____________

Husker du hva ditt langtidsblodsukker var forrige gang du målte? Nei / Ja – verdi: ___% den ________ 2007 / 2008

Ca. hvor mange ganger i løpet av siste måned har du hatt HØYT blodsukker? __________ og LAVT blodsukker? __________

FYSISK AKTIVITET

Hvor mange minutter regner du at du er i fysisk aktivitet hver dag (gå til og fra jobb, husarbeid, hagearbeid, osv.)?_________minutter

Hvor ofte driver du mosjon?
Aldri / Sjeldnere enn en gang i uka / En gang i uka / 2-3 ganger i uka / Omtrent hver dag

Hvor lenge holder du på hver gang?
Mindre enn 15 minutter / 16-30 minutter / 30 minutter – 1 time / Mer enn 1 time

Hvor fornøyd er du med tiden du bruker på mosjon?
Veldig fornøyd / middels fornøyd / verken eller / middels misfornøyd / veldig misfornøyd

MAT

Føler du at du vet nok om hva slags mat du kan spise? Ja / Nei

Jeg tror jeg har god oversikt over hva jeg spiser til daglig: Ja / Nei

Hvor mange frukt/grønnsaker (både rå og kokte) spiser du omtrent hver dag?________

Hvor ofte spiser du vanligvis matvarene nevnt nedenfor:

Hovedmåltid med få karbohydrater (f.eks. fisk-, kylling-, kjøtt- retter med lite karbohydratholdig tilbehør) Sjelden eller aldri / 1-3 g. pr.mnd. / 1-3 g. pr.uke. / 4-6 g. pr.uke / 1-2 g. pr.dag. / 3 g.el. mer pr.dag

Hovedmåltid med mye karbohydrater (f.eks. pasta, ris, og ellers retter med mye karbohydratholdig tilbehør) Sjelden eller aldri / 1-3 g. pr.mnd. / 1-3 g. pr.uke. / 4-6 g. pr.uke / 1-2 g. pr.dag. / 3 g.el. mer pr.dag

Hvor mye drikker du vanligvis av følgende:

Vann………………Sjelden eller aldri / 1 - 6 glass pr. uke / 1 glass pr. dag / 2-3 glass pr. dag / 4 glass el. mer pr.dag.

Te/kaffe………… Sjelden eller aldri / 1 - 6 glass pr. uke / 1 glass pr. dag / 2-3 glass pr. dag / 4 glass el. mer pr.dag.

Sukkerholdig drikke (brus, juice, melk, øl, osv.) Sjelden eller aldri / 1 - 6 glass pr. uke / 1 glass pr. dag / 2-3 glass pr. dag / 4 glass el. mer pr.dag.

HJELPEMIDLER / BRUK AV MOBILTELEFON

Bruker du noen hjelpemidler (dagbok, støttegruppe, osv.) for å bedre mestre din diabetes?
Nei / Ja: ____________________________

Hvordan var den forrige mobiltelefonen du hadde å bruke? Enkel / Sånn passe / Vanskelig.

Hva forventer du at det mobitelefon-baserte systemet du nå får utlevert skal gi deg i forhold til din diabetes? (sett gjerne ring rundt flere)

Mye bedre oversikt / Litt bedre oversikt / Motivasjon / Bedre HbA1c /
Andre ting: __________________________________

Når bruker du mobiltelefonen din – utenom ringe- og meldingstjenesten? (Hvilke funksjoner bruker du og hvor ofte?) F.eks.: Bruker den som vekkerklokke på alle arbeidsdager / Tar bilder ved passende anledninger / Annet: _____________________

Når lader du mobiltelefonen din? ____

Vi vil gjerne vite mer om hvordan og når du bruker mobiltelefonen din.

Ved de opplistede anledningene, hvor er telefonen plassert, og i hvilken modus er telefonen innstilt?

Bruk svaralternativene "A - E" for Plassering, og "a – f" for Modus, etter hva som passer best for deg, eller kommenter fritt.

Anledning	Plassering	Modus
Du sover		
Du spiser frokost		
På vei til/fra jobb		
På jobb		
Til lunch		
Du trener		
Utendørsaktiviteter (eks. butikken, på tur)		
Du spiser middag		
Hjemmeaktiviteter (innen- og utendørs)		

Annet:

Alternativer for plassering av telefonen
A. Har den nesten alltid med meg (f. eks. i lomma, i belteveska osv.)
B. I ei veske eller et sted hvor du ikke ser telefonen, men hvor du hører at det ringer/merker at det vibrerer. Telefonen er da ikke tilgengelig i kortere perioder (eksempelvis når du ikke har veska med deg).
C. Telefonen er plassert i samme rom som deg (ligger på f.eks. et bord, ei hylle) slik at du enkelt registrerer når den ringer/vibrerer. Du tar den imidlertid ikke med når du er ute av rommet i kortere perioder.
D. Du lar med vilje være å ta telefonen med deg for lengre perioder.
E. Annet

Alternativer for telefonmodus		
a. Vibrasjon	c. Vibrasjon + Ringetone PÅ	e. Stille
b. Ringetone PÅ	d . Slått av	f. Annet

Questionnaire D – 7 weeks after the introduction of the Few Touch application, prior to test of the tips and step counter applications, Oct. 2008

English Summary of Questionnaire D:

The main themes for this questionnaire were:

- About your diabetes
    - Satisfaction with management
    - Satisfaction with knowledge
    - Feelings about your diabetes
- Blood glucose
    - Frequency of measurements
    - HbA1c
    - Hyperglycaemia and hypoglycaemia
- Food
    - Knowledge about food
    - Fruits and vegetables
    - Which kinds of food do you eat?
    - Drinks
- Aids and use of mobile phone
    - Kind of mobile phone?
    - Which kinds of tools do you use?
    - When do you register food habits on the mobile diabetes self-help tool?
    - General impression of the mobile diabetes self-help tool?
    - Changes in use of the mobile phone after starting using the mobile diabetes self-help tool?
    - Most useful system of the mobile diabetes tools?
    - Least useful system of the mobile diabetes tools?
    - Would you have recommended it to a peer with diabetes?
    - How often do you think you will use it?
- Details about your mobile phone usage sorted by actions, placements and modes
    - User fills in the table

Questionnaire D, original Norwegian version:

Spørsmål 28. og 30. oktober 2008 – Selvhjelpsverktøy for Type 2 diabetes – ETTER 7 uker, men FØR utprøving av tips-funksjon og stegteller

Dato for utfylling av skjemaet:________________ Initialer: ________ (for å kunne sammenligne FØR og ETTER svarene)

Hvor mange år av samlet skole/utdanning har du?

☐ 9 år eller mindre ☐ 10-11 år ☐ 12 år ☐ 13-16 år ☐ 17 år eller mer

OM DIN DIABETES **(**Sett ring rundt de alternativene du synes passer best)

Hvor fornøyd er du med hvordan du styrer diabetes'en din?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor fornøyd er du med din kunnskap om din diabetes?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor ofte tenker du på at du har diabetes? Flere ganger daglig / Daglig / Ukentlig / Sjelden

Hvordan føler du deg når du tenker på diabetes'en din?
Dårlig samvittighet /Avmakt / Ikke noe spesielt /At jeg har litt kontrol /At jeg har god kontroll
Annet: ____

BLODSUKKER

Omtrent hvor mange ganger måler du blodsukker i løpet av ei vanlig uke? ___ ganger.
Hvis sjeldnere, hvor ofte? ____________

Husker du hva ditt langtidsblodsukker var forrige gang du målte? Nei / Ja – verdi: _____% den ________ 2007 / 2008

Ca. hvor mange ganger i løpet av siste måned har du hatt HØYT blodsukker? __________ og LAVT blodsukker? __________

MAT

Føler du at du vet nok om hva slags mat du kan spise? Ja / Nei

Jeg tror jeg har god oversikt over hva jeg spiser til daglig: Ja / Nei

Hvor mange frukt/grønnsaker (både rå og kokte) spiser du omtrent hver dag?_______

Hvor ofte spiser du vanligvis matvarene nevnt nedenfor:

Hovedmåltid med få karbohydrater (f.eks. fisk-, kylling-, kjøtt- retter med lite karbo-hydratholdig tilbehør) Sjelden eller aldri / 1-3 g. pr.mnd. / 1-3 g. pr.uke. / 4-6 g. pr.uke / 1-2 g. pr.dag. / 3 g.el. mer pr.dag

Hovedmåltid med mye karbohydrater (f.eks. pasta, ris, og ellers retter med mye karbo-hydratholdig tilbehør) Sjelden eller aldri / 1-3 g. pr.mnd. / 1-3 g. pr.uke. / 4-6 g. pr.uke / 1-2 g. pr.dag. / 3 g.el. mer pr.dag

Hvor mye drikker du vanligvis av følgende:

Vann…………Sjelden eller aldri / 1 - 6 glass pr. uke / 1 glass pr. dag / 2-3 glass pr. dag / 4 glass el. mer pr.dag

Te/kaffe………Sjelden eller aldri / 1 - 6 glass pr. uke / 1 glass pr. dag / 2-3 glass pr. dag / 4 glass el. mer pr.dag

Sukkerholdig drikke (brus, juice, melk, øl, osv.) Sjelden eller aldri / 1 - 6 glass pr. uke / 1 glass pr. dag / 2-3 glass pr. dag / 4 glass el. mer pr.dag

HJELPEMIDLER / BRUK AV MOBILTELEFON

Hvilken mobiltelefon hadde du før du fikk utdelt den som Diabetesdagboka er på?
Merke:_________________ Modell:______________

Bruker du noen hjelpemidler (dagbok, støttegruppe, osv.) for å bedre mestre din diabetes?
Nei / Ja: _____________________________

Når registrerer du matvanene på diabetesdagboka? Før du spiser / Etter du har spist /
På slutten av dagen / Registrerer ikke / Annet:_____________________________________

Hva synes du at det mobitelefon-baserte systemet du har fått utlevert har gitt i forhold til din diabetes? (sett gjerne ring rundt flere):
Mye bedre oversikt / Litt bedre oversikt / Motivasjon / Bedre HbA1c / Andre ting:
____

Har Diabetesdagboka på mobiltelefonen ført til at du bruker mobiltelefonen din til flere ting enn tidligere? Nei / Ja: _________________Hvilke ting?_____________________________

Hva har vært mest nyttig med diabetesdagboka på mobiltelefon:
____
____

Hva har vært den største ulempen med diabetesdagboka på mobiltelefon:
____
____

Ville du ha anbefalt diabetesdagboken på mobiltelefon til en venn med diabetes? Ja / Nei

Hvor ofte tror du at du kommer til å fortsette å bruke diabetesdagboken på mobiltelefon?
Daglig / Ukentlig / Månedlig / Sjeldnere

Vi vil gjerne vite mer om hvordan og når du bruker mobiltelefonen din.

Ved de opplistede anledningene, hvor er telefonen plassert, og i hvilken modus er telefonen innstilt?

Bruk svaralternativene "A - E" for Plassering, og "a – f" for Modus, etter hva som passer best for deg, eller kommenter fritt.

Anledning	Plassering	Modus
Du sover		
Du spiser frokost		
På vei til/fra jobb		
På jobb		
Til lunch		
Du trener		
Utendørsaktiviteter (eks. butikken, på tur)		
Du spiser middag		
Hjemmeaktiviteter (innen- og utendørs)		

Annet:

Alternativer for plassering av telefonen
A. Har den nesten alltid med meg (f. eks. i lomma, i belteveska osv.)
B. I ei veske eller et sted hvor du ikke ser telefonen, men hvor du hører at det ringer/merker at det vibrerer. Telefonen er da ikke tilgengelig i kortere perioder (eksempelvis når du ikke har veska med deg).
C. Telefonen er plassert i samme rom som deg (ligger på f.eks. et bord, ei hylle) slik at du enkelt registrerer når den ringer/vibrerer. Du tar den imidlertid ikke med når du er ute av rommet i kortere perioder.
D. Du lar med vilje være å ta telefonen med deg for lengre perioder.
E. Annet

Alternativer for telefonmodus		
a. Vibrasjon	c. Vibrasjon + Ringetone PÅ	e. Stille
b. Ringetone PÅ	d . Slått av	f. Annet

Questionnaire E – 4 months after the introduction of the Few Touch application, prior to test of the step counter application, Jan. 2009

English Summary of Questionnaire E:

The main themes for this questionnaire were:

- About your diabetes
  - Satisfaction with management
  - Satisfaction with knowledge
  - Feelings about your diabetes
- Blood glucose
  - Frequency of measurements
  - HbA1c
  - Hyperglycaemia and hypoglycaemia
- Tips function
  - Satisfaction with this function
  - Frequency of use
  - Types of tips most useful
  - How can the tips be improved?
- Physical activity
  - Duration of being physically active
  - Exercise, frequency
  - Duration of exercise
  - Satisfaction with exercise
- Aids and use of mobile phone
  - Benefits of the mobile phone-based system regarding your diabetes
  - Changes in use of the mobile phone after starting using the mobile diabetes self-help tool?
- Rating of 12 statements around: self-management, exercise, blood glucose measurements, usefulness of the self-help system.
- Which things have been the most useful for the mobile self-help system?
- Which things have been the biggest disadvantages of the mobile self-help system?
- Would you have recommended it to a peer with diabetes?
- How often do you think you will use it?
- How do you experience that your feeling regarding your blood glucose value, in accordance with what you measure?
- To which degree do you experience that your blood glucose value is related to your physical activity?

Questionnaire E, original Norwegian version:

Spørsmål januar 2009 – Selvhjelpsverktøy for Type 2 diabetes – samme dag som utdeling av stegteller

Dato for utfylling av skjemaet:________________ Initialer: ________ (for å kunne sammenligne FØR og ETTER svarene)

OM DIN DIABETES **(**Sett ring rundt de alternativene du synes passer best)

Hvor fornøyd er du med hvordan du styrer diabetes'en din?
Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor fornøyd er du med din kunnskap om din diabetes?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor ofte tenker du på at du har diabetes? Flere ganger daglig / Daglig / Ukentlig / Sjelden

Hvordan føler du deg når du tenker på diabetes'en din?
Dårlig samvittighet / Avmakt / Ikke noe spesielt / At jeg har litt kontroll / At jeg har god kontroll /
Annet: ____

BLODSUKKER

Omtrent hvor mange ganger måler du blodsukker i løpet av ei vanlig uke? ___ ganger.
Hvis sjeldnere, hvor ofte? ____________

Husker du hva ditt langtidsblodsukker var forrige gang du målte? Nei / Ja – verdi: _____% den ________ 2008

Ca. hvor mange ganger i løpet av siste måned har du hatt HØYT blodsukker? __________ og LAVT blodsukker? __________

BRUK AV TIPS-FUNKSJONEN

Hvor fornøyd er du med TIPS-funksjonen?
Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Omtrent hvor mange ganger leser du i TIPS-delen av Diabetesdagboka (på telefonen) i løpet av ei vanlig uke? ____ ganger. Hvis sjeldnere, hvor ofte? ____________

Hvilke typer tips synes du er mest nyttige?
____

Hvordan mener du at tipsene kunne blitt mer nyttige eller mer interessante?
____

FYSISK AKTIVITET

Hvor mange minutter regner du at du er i fysisk aktivitet hver dag (gå til og fra jobb, husarbeid, hagearbeid, osv.)?_________minutter

Hvor ofte driver du mosjon?
Aldri / Sjeldnere enn en gang i uka / En gang i uka / 2-3 ganger i uka / Omtrent hver dag

Hvor lenge holder du på hver gang?
Mindre enn 15 minutter / 16-30 minutter / 30 minutter – 1 time / Mer enn 1 time

Hvor fornøyd er du med tiden du bruker på mosjon?

Veldig fornøyd / middels fornøyd / verken eller / middels misfornøyd / veldig misfornøyd

HJELPEMIDLER / BRUK AV MOBILTELEFON

Hva synes du at det mobitelefon-baserte systemet du har fått utlevert har gitt i forhold til din diabetes? (sett gjerne ring rundt flere)

Mye bedre oversikt / Litt bedre oversikt / Motivasjon / Bedre HbA1c / Andre ting:
____

Har Diabetesdagboka på mobiltelefonen ført til at du bruker mobiltelefonen din til flere ting enn tidligere? Nei / Ja: ____

Vennligst ta stilling til hvor riktig hvert enkelt av de følgene utsagnene er for deg, med henblikk på din diabetes.

Sett kryss i den ruten på skalaen som passer best.

1) Jeg føler meg trygg på min evne til å håndtere diabetes.	Ikke sant i det hele tatt	☐	☐	☐	☐	☐	☐	☐	Veldig sant
2) Jeg er i stand til å håndtere min diabetes nå.	Ikke sant i det hele tatt	☐	☐	☐	☐	☐	☐	☐	Veldig sant
3) Jeg er i stand til å utføre min rutine-messige egendiabetesbehandling nå.	Ikke sant i det hele tatt	☐	☐	☐	☐	☐	☐	☐	Veldig sant
4) Jeg føler meg i stand til å møte utfordringen med å kontrollere min diabetes.	Ikke sant i det hele tatt	☐	☐	☐	☐	☐	☐	☐	Veldig sant
5) Jeg føler meg sikker på min evne til å mosjonere regelmessig.	Ikke i det hele tatt	☐	☐	☐	☐	☐	☐	☐	Veldig sikker
6) Jeg føler meg nå i stand til å mosjonere regelmessig	Ikke i det hele tatt	☐	☐	☐	☐	☐	☐	☐	I veldig stor grad

7) Jeg er i stand til å mosjonere regelmessig i det lange løp	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
8) Jeg er i stand til å møte utfordringen med å mosjonere regelmessig.	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
9) I hvilken grad synes du mosjon er viktig for å kontrollere din diabetes?	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
10) I hvilken grad synes du at å måle blod-sukkeret er viktig for å kontrollere din diabetes?	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
11) Jeg har planlagt tidspunkter for når jeg skal være i aktivitet.	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
12) Hvor nyttig synes du diabetesdagboka på mobiltelefon har vært for å kontrollere din diabetes?	Ikke nyttig i det hele tatt	☐☐☐☐☐☐☐	Veldig nyttig

13) Hva har vært mest nyttig med diabetesdagboka på mobiltelefon:

____

____

14) Hva har vært den største ulempen med diabetesdagboka på mobiltelefon:

____

____

15) Ville du ha anbefalt diabetesdagboka på mobiltelefon til en venn med diabetes? Ja / Nei

16) Hvor ofte tror du at du kommer til å fortsette å bruke diabetesdagboka på mobiltelefon?

Daglig / Ukentlig / Månedlig / Sjeldnere

Sette et kryss på strekene under for å angi:

17) I hvor stor grad opplever du at din egen opplevelse av ditt blodsukkernivå stemmer overens med det du måler?

Lav sammenheng ←——————————→ Høy sammenheng

18) I hvor stor grad opplever du at det er en sammenheng mellom ditt blodsukkernivå og din fysiske aktivitet?

Lav sammenheng ←——————————→ Høy sammenheng

Questionnaire F – 6 months after the introduction of the Few Touch application, March 2009

English Summary of Questionnaire F:

The main themes for this questionnaire were:

- About your diabetes
  - Satisfaction with management
  - Satisfaction with knowledge
  - Feelings about your diabetes
- Blood glucose
  - Frequency of measurements
  - HbA1c
  - Hyperglycaemia and hypoglycaemia
  - Frequency of use of the blood glucose function of the mobile self-help tool
- Tips function
  - Satisfaction with this function
  - Frequency of use
  - Types of tips most useful
  - How can the tips be improved?
- Physical activity
  - Duration of being physically active
  - Exercise, frequency
  - Duration of exercise
  - Satisfaction with exercise
  - Satisfaction with the step counter
  - Frequency of use of the step counter system as part of the mobile self-help tool
  - Has the step counter motivated you to be more active?
- Food
  - Knowledge about food
  - Fruits and vegetables
  - Which kinds of food do you eat?
- The Diabetes Diary
  - When do you register food habits?
  - Benefits of the system regarding your diabetes
- Rating of 12 statements around: self-management, exercise, blood glucose measurements, usefulness of the self-help system.
- Which things have been the most useful for the mobile self-help system?
- Which things have been the biggest disadvantage with the mobile self-help system?
- Would you have recommended it to a peer with diabetes?
- How often do you think you will use it?
- How do you experience that your feeling regarding your blood glucose value, in accordance with what you measure?
- To which degree do you experience that your blood glucose value is related to your physical activity?

Questionnaire F, original Norwegian version:

Spørsmål 17. og 19. mars 2009 – Selvhjelpsverktøy for Type 2 diabetes – Etter utprøvingen av verktøyet ”elektronisk diabetesdagbok”

Dato for utfylling av skjemaet:________________ Initialer: ________ (for å kunne sammenligne FØR og ETTER svarene)

OM DIN DIABETES **(**Sett ring rundt de alternativene du synes passer best)

Hvor fornøyd er du med hvordan du styrer diabetes’en din?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor fornøyd er du med din kunnskap om din diabetes?

Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Hvor ofte tenker du på at du har diabetes? Flere ganger daglig / Daglig / Ukentlig / Sjelden

Hvordan føler du deg når du tenker på diabetes’en din?
Dårlig samvittighet / Avmakt / Ikke noe spesielt / At jeg har litt kontroll / At jeg har god kontroll
Annet: ____

BLODSUKKER

Omtrent hvor mange ganger måler du blodsukker i løpet av ei vanlig uke? ___ ganger.
Hvis sjeldnere, hvor ofte? ____________

Husker du hva ditt langtidsblodsukker var forrige gang du målte? Nei / Ja – verdi: _____% den ________ 2008 / 2009

Ca. hvor mange ganger i løpet av siste måned har du hatt HØYT blodsukker? __________ og LAVT blodsukker? __________

Omtrent hvor mange ganger ser du på Blodsukker-sida i Diabetesdagboka (på telefonen) i løpet av ei vanlig uke? ____ ganger Hvis sjeldnere, hvor ofte? ____________

BRUK AV TIPS-FUNKSJONEN

Hvor fornøyd er du med TIPS-funksjonen?
Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Omtrent hvor mange ganger leser du i TIPS-delen av Diabetesdagboka (på telefonen) i løpet av ei vanlig uke? ____ ganger Hvis sjeldnere, hvor ofte? ____________

Hvilke typer tips synes du er mest nyttige?

____

Hvordan mener du at tipsene kunne blitt mer nyttige eller mer interessante?

____

FYSISK AKTIVITET

Hvor mange minutter regner du at du er i fysisk aktivitet hver dag (gå til og fra jobb, husarbeid, hagearbeid, osv.)?_________minutter

Hvor ofte driver du mosjon?
Aldri / Sjeldnere enn en gang i uka / En gang i uka / 2-3 ganger i uka / Omtrent hver dag

Hvor lenge holder du på hver gang?
Mindre enn 15 minutter / 16-30 minutter / 30 minutter – 1 time / Mer enn 1 time

Hvor fornøyd er du med tiden du bruker på mosjon?
Veldig fornøyd / middels fornøyd / verken eller / middels misfornøyd / veldig misfornøyd

Hvor fornøyd er du med Stegtelleren?
Veldig fornøyd / ganske fornøyd / verken eller / ganske misfornøyd / veldig misfornøyd

Omtrent hvor mange ganger ser du på Stegteller-sida i Diabetesdagboka (på telefonen) i løpet av ei vanlig uke? ____ ganger Hvis sjeldnere, hvor ofte? ____________

Har stegtelleren motivert deg til å være mer fysisk aktiv? Ja / Nei
Hvorfor/hvorfor ikke? ____

MAT

Føler du at du vet nok om hva slags mat du kan spise? Ja / Nei

Jeg tror jeg har god oversikt over hva jeg spiser til daglig: Ja / Nei

Hvor mange frukt/grønnsaker (både rå og kokte) spiser du omtrent hver dag?_______

Hvor ofte spiser du vanligvis matvarene nevnt nedenfor:

Hovedmåltid med få karbohydrater (f.eks. fisk-, kylling-, kjøtt- retter med lite karbohydratholdig tilbehør) Sjelden eller aldri / 1-3 g. pr.mnd. / 1-3 g. pr.uke. / 4-6 g. pr.uke / 1-2 g. pr.dag. / 3 g.el. mer pr.dag

Hovedmåltid med mye karbohydrater (f.eks. pasta, ris, og ellers retter med mye karbohydratholdig tilbehør) Sjelden eller aldri / 1-3 g. pr.mnd. / 1-3 g. pr.uke. / 4-6 g. pr.uke / 1-2 g. pr.dag. / 3 g.el. mer pr.dag

DIABETESDAGBOKA

Når registrerer du matvanene på diabetesdagboka?
Før du spiser / Etter du har spist / På slutten av dagen / Registrerer ikke /
Annet:____

Hva synes du at det mobiltelefon-baserte systemet du har fått utlevert har gitt i forhold til din diabetes? (sett gjerne ring rundt flere)
Ikke noe / Litt bedre oversikt / Mye bedre oversikt / Motivasjon / Bedre HbA1c /
Andre ting: ____

Vennligst ta stilling til hvor riktig hvert enkelt av de følgene utsagnene er for deg, med henblikk på din diabetes.

Sett kryss i den ruten på skalaen som passer best.

Jeg føler meg trygg på min evne til å håndtere diabetes.	Ikke sant i det hele tatt	☐☐☐☐☐☐☐	Veldig sant
2) Jeg er i stand til å håndtere min diabetes nå.	Ikke sant i det hele tatt	☐☐☐☐☐☐☐	Veldig sant
3) Jeg er i stand til å utføre min rutine-messige egendiabetesbehandling nå.	Ikke sant i det hele tatt	☐☐☐☐☐☐☐	Veldig sant
4) Jeg føler meg i stand til å møte utfordringen med å kontrollere min diabetes.	Ikke sant i det hele tatt	☐☐☐☐☐☐☐	Veldig sant
5) Jeg føler meg sikker på min evne til å mosjonere regelmessig.	Ikke i det hele tatt	☐☐☐☐☐☐☐	Veldig sikker
6) Jeg føler meg nå i stand til å mosjonere regelmessig	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
7) Jeg er i stand til å mosjonere regelmessig i det lange løp	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
8) Jeg er i stand til å møte utfordringen med å mosjonere regelmessig.	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
9) I hvilken grad synes du mosjon er viktig for å kontrollere din diabetes?	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
10) I hvilken grad synes du at å måle blod-sukkeret er viktig for å kontrollere din diabetes?	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
11) Jeg har planlagt tidspunkter for når jeg skal være i aktivitet.	Ikke i det hele tatt	☐☐☐☐☐☐☐	I veldig stor grad
12) Hvor nyttig synes du diabetesdagboka på mobiltelefon har vært for å kontrollere din diabetes?	Ikke nyttig i det hele tatt	☐☐☐☐☐☐☐	Veldig nyttig

13) Hva har vært mest nyttig med diabetesdagboken på mobiltelefon:

____

14) Hva har vært den største ulempen med diabetesdagboken på mobiltelefon:

____

15) Ville du ha anbefalt diabetesdagboken på mobiltelefon til en venn med diabetes? Ja / Nei

16) Hvor ofte tror du at du kommer til å fortsette å bruke diabetesdagboka på mobiltelefon?

Daglig / Ukentlig / Månedlig / Sjeldnere:______________________________

Sette et kryss på strekene under for å angi:

17) I hvor stor grad opplever du at din egen opplevelse av ditt blodsukkernivå stemmer overens med det du måler?

Lav sammenheng ←————————————————→ Høy sammenheng

18) I hvor stor grad opplever du at det er en sammenheng mellom ditt blodsukkernivå og din fysiske aktivitet?

Lav sammenheng ←————————————————→ Høy sammenheng

Appendix 15: Questionnaires used as part of the Type 2 Diabetes study

Questionnaire G – The System Usability Scale, 6 months after the introduction of the Few Touch application, March 2009

The original English version of the System Usability Scale is available online at the address: http://www.usabilitynet.org/trump/documents/Suschapt.doc

System Usability Scale (SUS)

Norwegian version (translated by Eirik Årsand)

	Helt uenig				Helt enig
1. Jeg kunne tenke meg å bruke dette systemet ofte	1	2	3	4	5
2. Jeg synes systemet er unødvendig komplisert	1	2	3	4	5
3. Jeg synes systemet er enkelt å bruke	1	2	3	4	5
4. Jeg skulle gjerne hatt teknisk hjelp for å være i stand til å bruke systemet	1	2	3	4	5
5. Jeg synes de ulike delene i systemet henger fint i sammen	1	2	3	4	5
6. Jeg synes det var for mye uoverensstemmelse mellom de ulike delene i systemet	1	2	3	4	5
7. Jeg vil tro at de fleste vil kunne lære seg dette systemet veldig raskt	1	2	3	4	5
8. Jeg synes dette systemet er veldig tungvint å bruke	1	2	3	4	5
9. Jeg føler at jeg mestrer dette systemet veldig bra	1	2	3	4	5
10. Jeg trenger å lære meg mange flere ting før jeg kan komme i gang med å bruke systemet	1	2	3	4	5

Questionnaire H – Usability Issues, 6 months after, March 2009

English Summary of Questionnaire H:

The main themes for this questionnaire were:

- Experienced malfunctions with the blood glucose sensor system?
- Experienced malfunctions with the step counter sensor system?
- Did you lose any information?
  - Which kind of information?
- Please rate the statements below:
  - I forget to use the system
  - Use of the system to record food habits encourages me to better self-management
  - Use of the blood glucose system encourages me to better self-management
  - Use of the step counter system encourages me to better self-management
  - Use of the Tips function encourages me to better self-management
- Please rate your satisfaction with the following issues of the systems
  - The size of the mobile phone
  - The screen-size of the mobile phone
  - The capacity of the mobile phone's battery
  - Response time (from pressing to action) for the Few Touch application
  - The size of the buttons for the Few Touch application
  - The colours used in the Few Touch application
  - How clearly the text is presented in the Few Touch application
  - How easy it is to understand the blood glucose graph
  - How easy it is to understand the step graph
  - How easy it is to add a food habit entry
  - How easy it is to understand the food feedback presented in the Few Touch application
  - How easy it is to change the aims
  - How easy it is to get to the different screens in the Few Touch application
- Please rate how much you agree or disagree with the following future proposed functions of the application:
  - A reminder for measuring the BG
  - A reminder for recording food habits
  - A smaller and easier-to-wear step counter
  - Automatic pop-up tips on the phone
  - Frequent transfer of data to your GP
  - Transfer of data to your GP when your values necessitate it
  - Feedback from the health care sector related to my disease on my mobile phone
  - Use of the system for communication with others with the same disease, about data, goals, tips, etc.
  - Automatic feedback from the system, based on your measurements/data
  - Be able to use my own mobile phone

(Authors: Naoe Tatara and Eirik Årsand)

Questionnaire H, original Norwegian version:

Spørsmål 17. og 19. mars 2009 – Selvhjelpsverktøy for Type 2 diabetes – Etter ½ års bruk av verktøyet "Diabetesdagboka"
OM BRUKERGRENSESNITT

Dato for utfylling av skjemaet:________________ Initialer: ________

Har du opplevd noen feil i overføringen av blodsukkerdata til mobiltelefonen?
Nei / Ja : _______ ganger

Har du opplevd noen feil i overføringen av antall skritt fra stegtelleren til mobiltelefonen?
Nei / Ja : _______ ganger

Ble noe av informasjonen borte (at du ikke fant den i Diabetesdagboka etterpå)?
Ja / Nei

Hvis "Ja", hva slags data ble borte? ____

Vennligst ta stilling til hvor enig eller uenig du er med hvert enkelt av de følgene utsagnene.

(Sett kryss i den ruta som passer best.)

	helt enig	enig	verken eller / vet ikke	uenig	helt uenig
Jeg glemmer ofte av å bruke Diabetesdagboka					
Bruk av Diabetesdagboka til registrering av matvaner motiverer meg til bedre egenbehandling					
Blodsukker-funksjonen i Diabetesdagboka motiverer meg til bedre egenbehandling					
Stegteller-funksjonen i Diabetesdagboka motiverer meg til bedre egenbehandling					
Tips-funksjonen i Diabetesdagboka motiverer meg til bedre egenbehandling					

Vennligst ta stilling til hvor fornøyd eller misfornøyd du er med de følgene tingene med Diabetesdagboka.

(Sett kryss i den ruta som passer best.)

	veldig fornøyd	ganske fornøyd	verken eller/ vet ikke	ganske misfornøyd	veldig misfornøyd
Størrelsen på selve mobiltelefonen					
Skjermstørrelsen på mobiltelefonen					
Batterilevetiden på mobiltelefonen					
Reaksjonstida (fra jeg trykker til det skjer noe) for Diabetesdagboka					
Størrelsen på knappene i Diabetesdagboka					
Fargene som er brukt i "Diabetesdagboka"					
Hvor tydelig teksten er i Diabetesdagboka					
Hvor enkelt det er å forstå BLODSUKKER-grafen					
Hvor enkelt det er å forstå STEG-grafen					
Hvor enkelt det er å legge til en matvane-registrering					
Hvor enkelt det er å forstå mat-tilbakemeldingene i Diabetesdagboka					
Hvor enkelt det er å endre målene					
Hvor enkelt det er å komme til de ulike skjermbildene i Diabetesdagboka					

Vennligst ta stilling til hvor enig eller uenig du er med at følgende framtidige funksjoner vil øke motivasjonen din til å bruke Diabetesdagboka.

(Sett kryss i den ruta som passer best.)

	helt enig	enig	verken eller / vet ikke	uenig	helt uenig
Påminnelse for å huske på å måle blodsukkeret					
Påminnelse for å huske å registrere matvaner					
En stegteller som er mindre og enklere å ha på seg					
Tips som dukker opp automatisk på telefonen					
Jevnlig overføring av data til din fastlege					
Overføring av data til din fastlege når verdiene tilsier at dette er nødvendig					
Tilbakemelding fra helsevesenet angående min sykdom - på mobiltelefonen					
Bruk av systemet til å kommunisere med andre med samme sykdom, om data, mål, tips, osv.					
Automatisk tilbakemelding fra systemet, basert på dine målinger / data					
Å kunne bruke min egen mobiltelefon					

Appendix 16: Interview guide used as part of the Type 1 Diabetes study

English Summary of Type 1 Study Interview Guide:

The main themes and questions for this interview guide were:

- Demographic inquiries
- Introduction, right to stop at any time of this interview
- Functionality
  - Mobile phone
  - SMS
  - In case of malfunction
  - Trust in the system
  - Positive things with the system
  - Negative things with the system
  - Suggestions for improvements
  - General impression
- Management of the disease
  - Hypoglycaemia
  - Child's responsibility
  - Child's knowledge about the disease
  - Has the system made you more "proactive" about the disease?
  - Has the system changed the child's way of managing the disease?
  - Has the system changed your way of managing the disease?
  - The system's influence on your interest for the disease
- Relations and Power
  - Physician versus patient
    - Have you stored the BGM-measurements in other ways than SMS?
    - Has the system taught you something new?
    - Has the system made you do anything to learn more?
    - Have you used the received measurements in discussions with health care personnel?
    - Have you been in contact with health care personnel in the project period?
      - Have you discussed the system with them?
  - Parents versus child
    - Who in the family is the one caring for the child's disease the most?
      - Has it changed?
    - What is your impression of how the child has perceived the system?
    - Have you had any surprises or new information?
    - How much have you talked with the child about the system?
    - Do you feel more confident that the child is able to manage the disease herself/himself?
    - How has the system changed the relationship between you and the child?

- Practically easier
    - How did you check that the child had measured the blood glucose before you got this system?
    - Which activities were difficult for the child to participate in, but were easier with this system?
    - Has it been difficult for the child to remember to bring along the system?
    - Do you think it has been easier for the child to show the BGM equipment, and that (s)he measures glucose?
    - Has it been difficult for the child to remember to measure?
    - How important is it to receive the measurement fully automatically?
- Worrying / stress
    - Has it become easier to let the child participate in activities on her own?
    - Did you usually answer the SMSs you received?
    - Were there any messages that made you worry?
        - What was that message?
    - Were there any messages that made you want to contact a physician?
    - Were there any messages that did not give you any information?
    - Were there any cases where you expected to receive SMSs, but when you did not get any?
        - How did that feel?
        - What was the reason that the SMS did not arrive?
        - What did you do then?
- Willingness to pay
    - Information about the expense of the system
    - Would you pay what it costs to use such a system?
        - If “no”, what is the maximum amount you would pay?
        - ______ NOK for the equipment
        - ______ NOK for service and SMS yearly

(Authors: Deede Gammon, Martin Jenssen, Eirik Årsand)

Type 1 Study Interview Guide, original Norwegian version:

Intervju av foreldre til barn med Type 1 diabetes

Demografiske variabler:

Kjønn voksen:		Kjønn barn:	
Alder voksen:		Alder barn:	
Bosted			

Innledning

I forbindelse med utprøvingen av systemet "Automatisert overføring av blodsukkerdata", ønsker vi å intervjue en del av deltakerne i forsøket. Totalt var det 15 familier som deltok og vi vil i løpet av januar og februar intervjue mellom fem og ti foreldre. Resultatene fra intervjuene vil sammenfattes til en artikkel og vi håper å ha denne klar til innsending innen utgangen av juni. Jeg har en del spørsmål som vi må gjennom, men jeg ser gjerne at du selv er aktiv og spinner videre på de spørsmålene som jeg stiller. Du kan når som helst avbryte og komme med innskytelser eller spørsmål dersom du kommer på noe som du opplever som viktig. Det finnes ingen "riktige" og "gale" svar – det er din opplevelse av systemet som teller.

[Evt. Starte med et overordnet spørsmål om teknologi som hjelpemiddel i helse + holdninger til teknologi(utvikling/samfunnsutvikling) generelt].

Funksjonalitet

- Hadde du/dere mobiltelefon fra før?
    - Brukte du den i forbindelse med ditt barns sykdom (for eksempel at foreldre ringte for å minne på etc.?

- Hvor ofte har du mottatt SMS om blodsukkerverdier?
    - Flere ganger om dagen
    - En gang om dagen
    - En gang i uka
    - Har ikke brukt det noe særlig

- Har det vært tilfeller der systemet ikke har fungert?
    - Hva skjedde?

- Følte du at du kunne stole på at de meldingene som kom inn var riktige?

- Alt i alt, føler du at du kan stole på at systemet fungerer som det skal?
    - Følg opp.

- Hva vil du trekke fram som særlig positivt ved systemet?

- Hva vil du trekke fram som særlig negativt?

- Hvis du skulle gjøre en endring på systemet, hva ville det vært (spør igjen ved slutten av intervjuet)?
    - Andre ting du vil endre på?

- Hva er ditt generelle inntrykk av systemet?

Mestring av sykdom

- Har barnet hatt føling i perioden?
    - Hvor mange ganger? Er det normalt i forhold til før systemet?

- Føler du at barnet tar mer ansvar for sin egen sykdom nå enn før prøveperioden

- Har barnet i løpet av perioden gitt uttrykk for at han/hun har lært seg noe nytt om sin diabetes?

    - Har barnet i løpet av perioden gitt uttrykk for at han/hun har lært seg nye måter å håndtere sin diabetes på?

- På hvilken måte kan det å få blodsukkerdata sendt på SMS hjelpe dere til å ”være i forkant” av sykdommen?

- På hvilken måte kan systemet hjelpe deg/barnet ditt til å bedre forutse hvordan sykdommen forløper seg? (komme i forkant)
    - På hvilken måte kan systemet hjelpe deg/barnet ditt til å bedre kontrollere hvordan sykdommen forløper seg?

- Hvordan tror du systemet har innvirket på måten barnet mestrer sykdommen på?

- Hvordan tror du systemet har innvirket på måten du mestrer barnets sykdom på?

- Litt om deres ”interesse” for helse og sykdom:
    - Er slike løsninger med på å øke mestring av sykdom eller fører de bare til at man bruker unødvendig mye tid på å tenke på sykdom og helse?
    - Er det muligheter for at løsninger som for eksempel den dere har prøvd ut nå bidrar til økt ”hysteri” om helse? Kan den føre til at en blir overdrevent opptatt av helse?

Relasjoner/Makt

Lege/pasient:

- Har dere gjort noe for å ta vare på de blodsukkermålingene som kommer på mobiltelefonen? Ført statistikk eller liknende.
    - Hvem er det som gjør dette?

- Har systemet ført til at du har lært noe om diabetes som du ikke visste fra før?

- Har systemet ført til at du har gjort noe ekstra for å lære mer om diabetes? (for eksempel søkt etter info på Internett).

- Har det hendt at du har brukt disse målingene som et utgangspunkt for diskusjoner med helsepersonell?
- Har dere hatt kontakt med lege i forbindelse med barnets diabetes i prosjektperioden?
    - Har du diskutert systemet med helsepersonell?

Foreldre/barn:

- Hvem er det i familien som følger mest med? (mor eller far)
    - Har dette endret seg på noen måte?

- Hva er ditt inntrykk av hvordan barnet har oppfattet systemet (spør om alle reaksjoner).

- Har dere fått noen overraskelser? (Oppdaget noe de ellers ikke ville oppdaget?)
    - Hvordan fulgte dere det opp?
    - Har du oppdaget noe om barnet ditt som du ikke visste om? (for eksempel spiser sjokolade i langfri, andre avvik).

- Har dere snakket mye med barnet om systemet?
    - Hvis ja: Om hva (Konflikter? Føle seg kontrollert?). Hvem har tatt initiativ til samtalen?
    - Hvis nei: Har dere ikke snakket om det i det hele tatt?

- Har du fått mer tillit til at barnet kan klare å håndtere sin diabetes selv?
    - Hvis ja: Tror du årsaken til dette er at barnet faktisk har bedre kontroll med systemet, eller at du tidligere ikke har klart å stole helt på at barnet hadde kontroll?

- På hvilken måte har systemet påvirket relasjonen mellom dere?

Praktisk lettere

- Hva gjorde dere tidligere for å forsikre dere om at barnet målte blodsukker?

- Kan du komme på noen aktiviteter det var vanskelig for barnet å være med på tidligere som ble lettere med systemet?

- Har det vært vanskelig for barnet å huske å ta med seg systemet?

- Tror du det har blitt lettere for barnet å tørre å vise måleutstyret og at han/hun måler?

- Har det vært vanskelig for barnet å huske å måle? (Hvis ja – hva gjorde dere for å minne på?).

- Hvor viktig er det at målingene sendes automatisk? (Et alternativ er jo at barnet selv skriver inn verdiene på SMS og sender manuelt).

Bekymring/Stress

- Føler/opplever du at det ble lettere å slippe barnet ut på aktiviteter på egenhånd?

- Brukte du å besvare de meldingene som kom?

- Var det tilfeller der du fikk en melding som gjorde at du ble mer bekymret?
    - Hva stod i meldingen?

- Hendte det at du fikk meldinger som gjorde at du ville kontakte lege.
    - Hendte det at du fikk meldinger som ikke ga noen mening? (falske målinger).

- Var det tilfeller der du forventet å motta en melding om blodsukker og den ikke kom?
    - Hvordan følte/opplevde du det?
    - Hva var årsaken til at meldingen ikke kom?
    - Hva gjorde du?

Betalingsvillighet

En forbedret versjon av blodsukkerutstyret vil koste totalt 5200 kr inkludert mobiltelefon. I tillegg kommer vedlikehold på 1500 kr og omtrent 1100 kr i årlige SMS kostnader (dersom vi regner med at det sendes 3 meldinger hver dag).

Prisen blir da 5200 kr (en engangsinvestering) i tillegg til en årlig kostnad på 2600 kr de påfølgende år (alt inkludert).

Kunne du tenke deg å betale prisen som beskrevet over for å få blodsukkermålingssystemet?

- ☐ Ja
- ☐ Nei

Hvis nei, hva er maksimum beløp du kunne tenke deg å betale?

____________kr for utstyret (engangsavgift).

____________kr for vedlikehold og SMS kostnader (årlig beløp).

Annet

- Har du andre kommentarer?
- Hvis du skulle gjøre en endring på systemet, hva ville det vært (spør igjen ved slutten av intervjuet)?
    - Andre ting du vil endre på?

Appendix 16: Interview guide used as part of the Type 1 Diabetes study

Appendix 17: Interview guides used as part of the Type 2 Diabetes study

Interview Guide 1 – Individual talks 4 months after the introduction of the Few Touch application, prior to test of the step counter application, Jan. 2009

English Summary of Interview Guide 1:

The main themes and questions for this interview guide were:

1. General things you would like to comment about the system?
2. Frequency of use?
3. Impression/experience of the Tips function?
4. How do they work for you?
5. How does the blood glucose system work?
6. How often do you measure blood glucose daily?
7. How does the food habit registration system work?
8. How often do you use it?
9. For the system as a whole – which things work well and which do not?
10. Which things do not work?
11. Should the system be more advanced /intelligent, have more possibilities for recordings, or are the current ones sufficient?
12. Is it sufficient that the system is a self-help tool, and not a tool you can work together with others with?
13. Would you like to cooperate with someone with this system?
14. Should there in an ideal service – be something or someone that supports you?
15. Which suggestions do you have for improvements of the system?
16. Which possibilities do you foresee – based on a system like this?
17. Which expectations do you have for the step counter application?
18. Do you have some final comments?

Interview Guide 1, original Norwegian version:

Intervjuguide – i møte med deltakerne en-og-en, før de får utdelt stegteller (etter ca. 4 mnd. Intervjuene avholdt 18. desember 2008 og 15, 16, 20., 21. og 23. januar 2009)

NB: forut for dette korte intervjuet – ca 15 min. per person – har brukerne fylt ut spørreskjemaet.

(Les inn dato og ID først på audio-opptaket først.)

Spørsmål:

1. I tillegg til det du har fylt ut på spørreskjemaet, er det noe du vil kommentere generelt med hensyn på bruken av systemet, dvs. blodsukkermålersystemet, matvaneregistreringen, tipsene.
2. Hvor ofte bruker du systemet?
3. Hva synes du om tipsfunksjonen, som du fikk installert forrige gang?
4. Hvordan fungerer tipsene i dag? Burde de vært knyttet opp til hvordan du mestrer diabetes'en din?
5. Hvordan virker blodsukker delen?
6. Hvor ofte måler du blodsukkeret per dag?
7. Hvordan virker matvaneregistrerings delen?
8. Hvor ofte bruker du den?
9. For systemet som helhet - hva fungerer bra? (Hvis de svarer "alt fungerer bra" – Spør "hva vil du fremheve?")
10. Hva fungerer ikke, eller fungerer mindre bra?
11. Burde systemet være mer avansert, inneholde muligheter for flere registreringer – eller er det tilstrekkelig mange muligheter?
12. Er det tilstrekkelig at systemet er et selvhjelps-verktøy – og ikke et verktøy der du samarbeider med andre om sykdommen?
13. Kunne du tenke deg å jobbe sammen med noen med systemet?
14. Bør det i en ideell tjeneste - være noe eller noen som følger deg opp?
15. Hvilke tips har du til forbedringer av systemet basert på slik det er nå?
16. Hvilke muligheter ser du framover - basert på systemet?
17. Hvilke forventninger har du til skrittelleren som du nå får utdelt?
18. Noe du vil si til slutt?

Interview Guide 2 – Added question to the 2007 survey on eHealth trends

English Summary of Interview Guide 2:

The main themes and questions for this interview guide were:
In this EU- and WHO-funded survey [14], 1001 informants were interviewed by telephone (CATI), as part of another survey. The following questions and alternatives were designed by colleagues and me in order to obtain an updated reference on the use of step counters and other health monitoring devices in Norway:

- I will list some devices that may be used to access personal health-related information – please indicate whether you have used these the last half year, and if "yes" – please indicate it whether you use them daily, weekly, monthly, or more seldom.
    1. Step counter / pedometer
    2. Heart rate monitor
    3. Blood pressure monitor
    4. Blood glucose monitor

Interview Guide 2, original Norwegian version:

Intervjuer:
”Jeg skal nå lese opp noen apparater som kan brukes til å skaffe informasjon om helsetilstanden din. Jeg vil gjerne vite om du har benyttet disse det siste halve året, og i så fall om det er daglig, ukentlig, månedlig eller sjeldnere enn månedlig.”

(INTERVJUER: VED IRREGULÆR ADFERD, SPØR OM HVOR MANGE GANGER BRUKT SISTE ÅR, OG FINN RIKTIG KATEGORI)

	(LES OPP)	Daglig	Ukentlig	Månedlig	Sjeldnere enn månedlig	Ikke brukt siste halvår	Vet ikke /Ubesvart (ikke les opp)
1	Skritteller / pedometer	1	2	3	4	5	6
2	Pulsmåler	1	2	3	4	5	6
3	Blodtrykksmåler	1	2	3	4	5	6
4	Blodsukkermåler	1	2	3	4	5	6

Appendix 18: Requirements specification - for the Few Touch diabetes diary system 2008 - Type 2 diabetes

Requirements specification for the Few Touch diabetes diary system 2008 - Type 2 diabetes

Authors:

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Norwegian Centre for Telemedicine, UNN, Tromsø.

A scenario – describing the use of the Few Touch application

Petra retired recently at the age of 63. She was diagnosed with Type 2 diabetes last year and recently received the Few Touch application from the NST. She uses the new mobile phone both as her ordinary phone and as an interface for improving her diabetes management. She tries to wear the step counter and to use the blood glucose monitor every day. Each morning she measures her blood glucose value. This Sunday morning it was rather high: 9.5 mmol/l. She wonders why. Then she remembers the features of the Few Touch application features, and fetches the phone. The phone's screen displays the last seven measured values, with her recent 9.5 mmol/l measurement highlighted at the top of the list. Now, she notices that she also had a high measurement at the bottom of the list. Since she measures once a day, she understands that this was last Saturday. Hmm, high during weekends, can this be a general pattern, she wonders. She presses the graph button, which shows her the last 50 measurements. Yes, as she suspected, the reading has generally been higher every weekend for the last seven weeks. She now decides to change her physical activity goal, to see if this can improve the blood glucose readings for the next weekend. She presses the menu button and then the set-goal button, and increases her recent aim of walking 6000 steps per day to 8000 steps per day. She also sets a reminder so that the Few Touch application will send her a reminder at 16:00, so that she can still work on improving this number in the afternoon.

1.1 General specifications for all the applications

1.1.1. The user should use as few touches as possible to access each functionality, using a finger (i.e. without needing to use the stylus). Note: the current calendar functionality (September 2008) is difficult to use with a finger, and should be improved in future.

1.1.2. "One day" (from 0:00-24:00) and "one week" shall be the two main overview periods for the patient. Here, one week means "today and the previous six days".

1.1.3. Present the data as visual feedback without any interpretation.

1.1.4. It shall be possible to search for a specified period to display data for.

1.2. Blood glucose measurement application

1.2.1. Shall transfer measured blood glucose data from the blood glucose monitor OneTouch Ultra 2 from LifeScan to the touch-sensitive smartphone wirelessly and automatically when the measurement strip is removed from the meter after each measurement. The data shall be displayed as the top value in the list of the last seven measurements as described in 1.2.2, and shall be highlighted.

1.2.2. With one finger touch from the main menu, it shall be possible to display the last seven measurements of the blood glucose values and the actual time that the measurements were taken, in text on the smartphone. This screen shall be called "7 Siste målinger". The application shall have two buttons at the bottom of the screen, named "Meny" ["Menu"] and "Vis Graf" ["View Graph"]. Pressing "Graf" will bring you to the screen described in 1.2.3.

1.2.3. Shall display a graph on the smartphone showing the last 50 blood glucose measurements, with one (clearly visible) mark per measurement. There shall be no lines connecting the marks. Shall display two horizontal lines to indicate measurements that are too low or too high, crossing the y-axis at 4 and 8 mmol/l. These lines will divide the screen in three colours, from the top: yellow, then green and under the lowest line: red. The y-axis shall be fixed from 0 to 14 mmol/l, presenting labels for every second value (0, 2, 4, 6, etc.). The screen shall be called "Siste 50 målinger" ["Last 50 measurements"]. There shall be two buttons at the bottom of the screen, named "Meny" and "Angi Tidsrom" ["Specify Period"]. Pressing "Angi Tidsrom" brings you to the screen described in 1.2.4.

1.2.4. Shall display two active fields called "Fra dato" ["From date"] and "Til dato" ["To date"] where you are able to enter dates, e.g. in the form: 20.03.08 or from a calendar, preferably using a finger (a future design wish: make the selection arrow for entering the calendar bigger). This screen shall be named "Angi tidsrom for blodsukkergraf" ["Specify period for blood glucose graph"]. There shall be two buttons at the bottom of the screen, named "Meny" and "Vis Graf". Pressing "Vis Graf" will bring you to the screen described in 1.2.5.

1.2.5. This screen is similar to the one described in 1.2.3, but the heading includes the text "XX dager - YY målinger" ["XX days - YY measurements"] (XX and YY shall be automatically calculated based on the input from the screen described in 1.2.4). The x-axis is labelled according to the time span, based on the procedure described in 1.2.6.

1.2.6. If the displayed measurements are within a week, each weekday shall be used as a label on the x-axis, with the first three letters of the day name (Man, Tir, Ons, Tor, Fre, Lør, Søn). If the data is from 1-3 weeks, only the first letter in each day name is used. If the data is from 3-7 weeks, the x-axis is labelled with the week number (e.g. "Uke 1") and a red tag at the end of the week indicating Sunday. If the data is from more than 7 weeks, but less than 7 months, the x-axis is labelled with the month name tags “Jan”, “Feb”, “Mars”, April, Mai, Juni, Juli, Aug, Sept, Okt, Nov, Des) If the data is from more than 7 months, the x-axis is labelled with the quarter name tags “1. kvartal”, “2. kvartal”, “3 kvartal”, 4. kvartal”.

1.2.7. The following requirements are postponed until after the first main user test has been performed:

1.2.7.1. Remove “kvartal” and use the year as the label for the X-axis for data spanning more than 3 quarters, for the blood glucose graph.

1.2.7.2. Implement a scroll bar in the list view, including one month of data

1.2.7.3. Highlight the most recent measurement in the list view.

1.2.7.4. Make it possible to specify a user-defined period for the list view (as has been done for the graph with the function “Angi tidsrom”).

1.2.7.5. Include the average blood glucose and your target average blood glucose set in the Goal section.

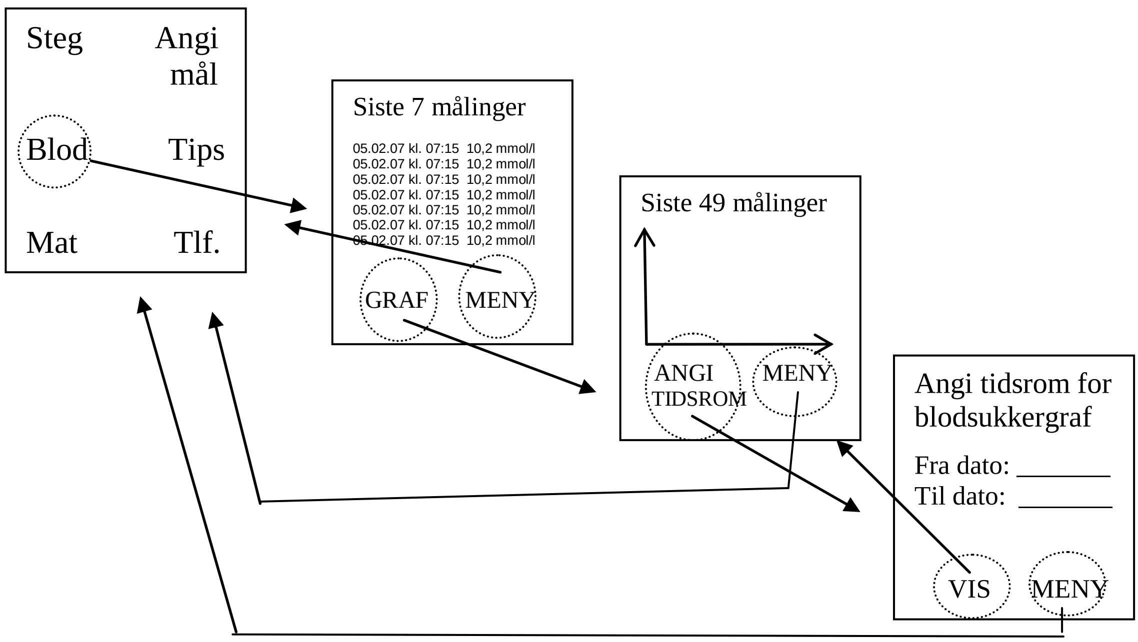


Figure A: Menus and the flow of actions upon their activation (in Norwegian).

1.3. Nutrition habits application

1.3.1. The user shall be able to record food habits with a two finger touch operation from the main menu, first by selecting the choice “Mat” [“Food”] from the main menu, and shall then be able to select from the following six categories: “Høy karb. snacks” [“High carb. snack”], “Lav karb. snacks” [“Low carb. snack”], “Høy karb. måltid" [“High carb. meal”], “Lav karb. måltid" [“Low carb. meal”], “Høy karb. drikke” [“High carb. drink”]og “Lav karb. drikke” [“Low carb. drink”], accompanied by the six symbols/pictures shown in Figure B.

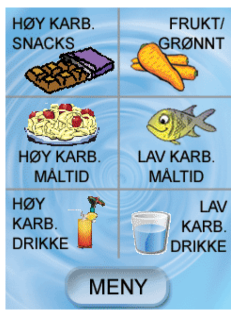


Figure B. Food data entry screen.

1.3.2. It shall be possible to cancel the last entry by touching the red “Angre” [“Cancel”] button in the Feedback screen. After having pressed this “Angre” button, the user shall again be presented with the data entry screen with six categories.

1.3.3. When the user chooses “Lav karb. Snacks”, “Høy karb. måltid", or “Lav karb. måltid", the system shall automatically display an information screen that reflects the data entry and how this relates to the user’s goal of “Lav karb. snack pr. dag” [“Low carb. snacks per day”], “Antall daglige måltider” [“Number of meals per day”] og “Maks ukentlige høy karbo. måltider” [“Maximum weekly high carb. meals”], see Figure C. The text of the category entered last shall be highlighted (green text).

1.3.4. When the user chooses “Høy karb. snacks”, “Høy karb. drikke” or “Lav karb. drikke”, the system shall automatically display an information screen that presents the number of high carb. snacks today and this week, the number of low carb. snacks today and this week, the number of high carb. drinks today and this week, and the number of low carb. drinks today and this week. The last category entered shall be highlighted (green text), see Figure D.

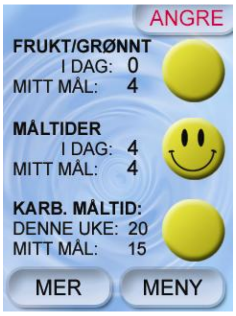


Figure C. Food data entry feedback screen 1.

1.3.5. It shall be possible to set the user’s goal for “Lav karb. snacks pr. dag”, “Antall daglige måltider” og “Maks ukentlige høy karbo. måltider” from the main menu, see Figure F.

1.3.6. It shall be possible to search for a specified period to display, using the “Angi tidsrom” button. The phone shall then display a summary screen with:
The specified period (labelled “Periode”)
Number of meals (labelled “Måltider”)
Number of high carb. snacks (labelled “Høy karb. snacks”)
Number of low carb. snacks (labelled “Frukt/grønt”) [“Fruit/vegetables”]
Number of low carb. snacks (labelled “Lav karb. snacks”)
Number of high carb. drinks (labelled “Høy karb. drikke”)
Number of low carb. drinks (labelled “Lav karb. drikke”)
There shall be one button at the bottom of this screen: “Meny”

Figure D. Food data entry feedback screen 2.

1.4. Step counter application

1.4.1. The step counter shall transfer the measured number of steps to the mobile phone, wirelessly and automatically at a given time. At present, this time is given by restarting the step counter at the desired time. In future, it shall be possible to enter the desired time from the Goals menu (Angi mål) on the phone.

1.4.2. As a general rule, data shall be transferred between 22:00 and 24:00 daily.

1.4.3. In addition, it shall be possible to transfer the number of steps to the mobile phone on user demand, i.e. when the user presses the button on the step counter.

Figure E. Step count feedback screen.

1.4.4. The application shall store the transferred number of steps on the mobile phone, for a period of at least one year.

1.4.5. This application shall show the step counter screen when the “Steg” [“Step”] button on the main menu is pressed, and shall use the latest transferred data as the current day graph bar (light green), see Figure E.

1.4.6. Shall display a bar graph on the mobile phone screen, showing the user's physical activity for the last seven days, with one bar per day (green colour) and today's bar in light green, see Figure E.

1.4.7. Shall display the number of steps today in text on the same screen as the bar graph, see Figure E.

1.4.8. Shall allow the user to enter (via the "Angi mål" menu) a number that represents the user's goal for number of steps per day, and display it as a red line, as shown in Figure 4.1.

1.4.9. When data transfer is initiated by the user (when the button on the step counter is pressed), the mobile phone shall display the same screen as Figure E, besides the heading shall be: the number of steps accumulated from yesterday at e.g. 22:00, followed by "Steg hittil i dag" ["Steps so far today"], (E.g. "3424 Steg hittil i dag").

1.4.10. When data transfer is initiated by the timer, e.g. at 22:00, the mobile phone shall show the bar graph described (Figure E) with the same text as described above in 1.4.9.

1.4.11. All screen displays shall have a button that the user can press to return to the main menu, see Figure E.

1.4.12. When the mobile phone displays the step screen after data is transferred, this screen shall remain open until explicitly closed by the user. However, the phone is allowed to return to "sleep mode" as set up in "Innstillinger" + "System" + "Strøm" + "Avansert" + "Slå av enheten hvis inaktiv i X minutter" ["Settings" + "System" + "Power" + "Advanced" + "Switch off unit if inactive for X minutes"]. (X is set in cooperation with the user during the delivery of the system to the user.) When the phone is wakened from the sleep mode, it shall display the same screen as was active when it went into the sleep mode.

1.4.13. This application shall not send step counter data to a server in this first implementation.

1.4.14. This application shall not delete step counter data unless there is limited space in the phone's memory.

1.4.15. This application shall delete the oldest step counter data if there is limited space in the phone's memory.

1.4.16. Postponed requirement: When a "Kommentar" button is pressed, the phone shall display a blank note where the user may write a comment. This note shall be stored by date and time, and be possible to retrieve by software described in a future application. When the note is closed, the user shall return to the step screen.

1.5. Set-goals application

1.5.1. The application shall show the Goal screen, see Figure F, when the "Angi mål" button on the main menu is pressed.

1.5.2. Step goals: The number entered after the user presses the "Angi mål" + "Steg" buttons will be used to draw the red line in Figure E. A keypad shall be implemented for entering step count

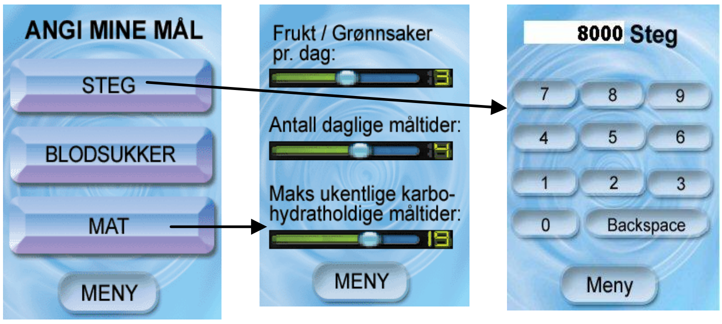


Figure F. Setting food habit goals and step count goals.

goals, as shown in the rightmost screen in Figure F.

1.5.3. Food goals: see central screen in Figure F. Touching on the right side of the blue bullet increases the figure for the goal; touching on the left side decreases it.

1.5.4. Postponed requirement: setting a goal for average blood glucose has been put on hold for now. The “Blodsukker” [“Blood Glucose”] button shall be without text.

1.5.5. Future suggestion for a requirement: The “Blodsukker” button in Figure F could be replaced by a button named “Tips”. By pressing this button, the user shall be able to specify at which times in the day one or more tips will be presented to the user automatically. By default, a tip shall be displayed once a day at 18:00, and the user can also turn off the automatic tip display.

1.6. Tips application

1.6.1. When the user presses the “Tips” button from the main menu, the next unvisited tip shall be presented to the user as exemplified in Figure G, i.e. the system shall keep track of the ID numbers of tips visited previously and present the next tip in line, e.g. if tip no. 32 was displayed last time, tip no. 33 shall be displayed next time.

1.6.2. Approximately 80 of the information tips from the DigitalTV-CD (one of our previous projects) shall be converted into usable tips for our current Type 2 diabetes cohort and suitable for display on the mobile phone screen of 240 x 320 pixels. (These tips have been quality assured by Dr. Stein Vaaler.)

1.6.3. Future suggestion for a requirement: From the “Angi mål” button, it shall be possible to specify at which times daily one or more tips shall be presented to the user automatically (the phone shall be wakened from sleep mode and the Few Touch application shall be launched – displaying the next tip in line).

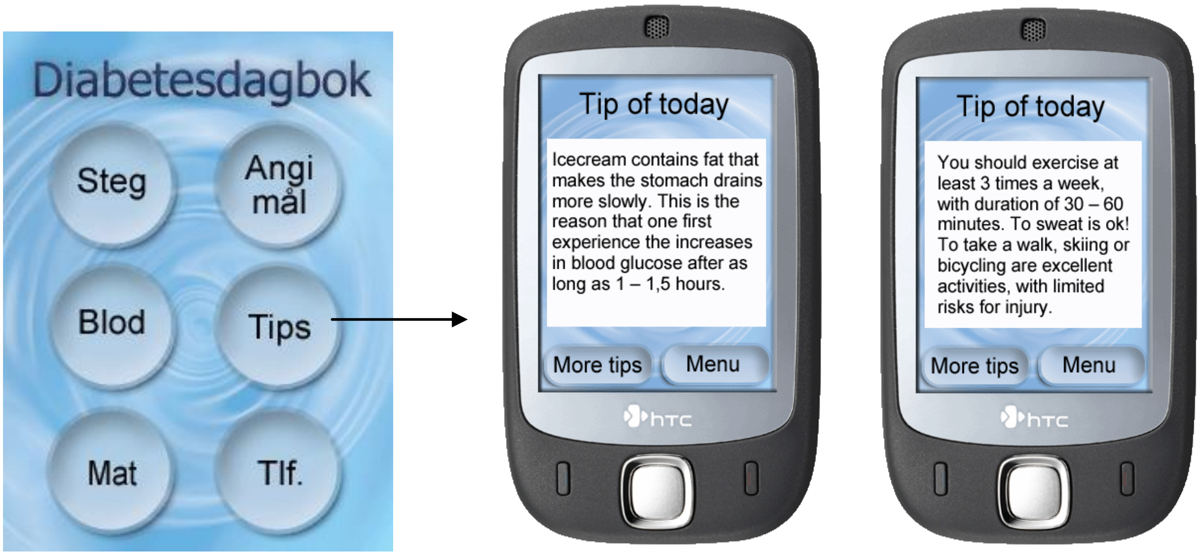
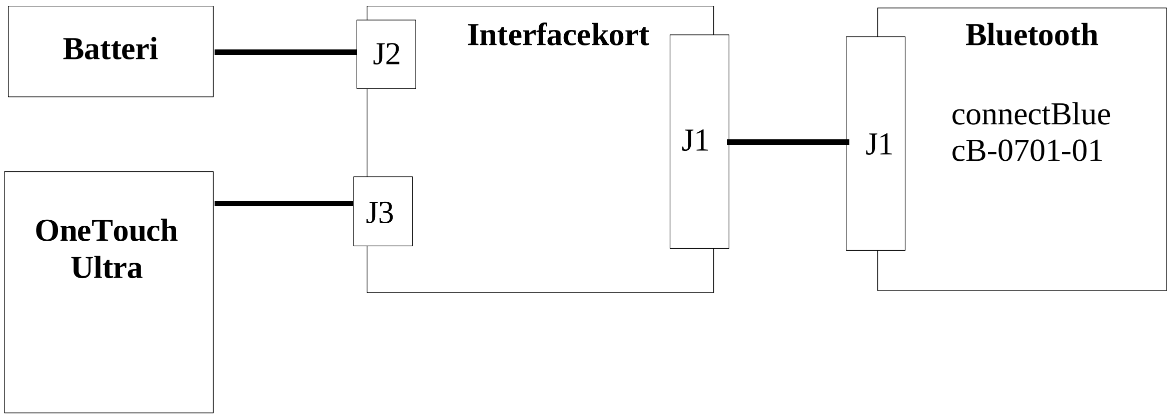


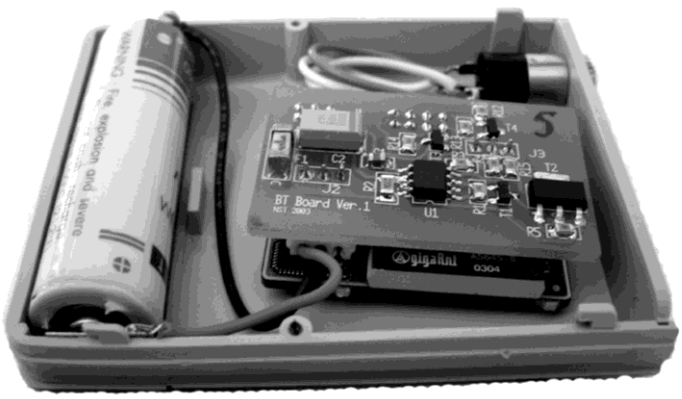
Figure G. Examples of daily tips, accessed from the main menu button “Tips”.

Appendix 19: Specifications for the Bluetooth adapter for the blood glucose sensors system

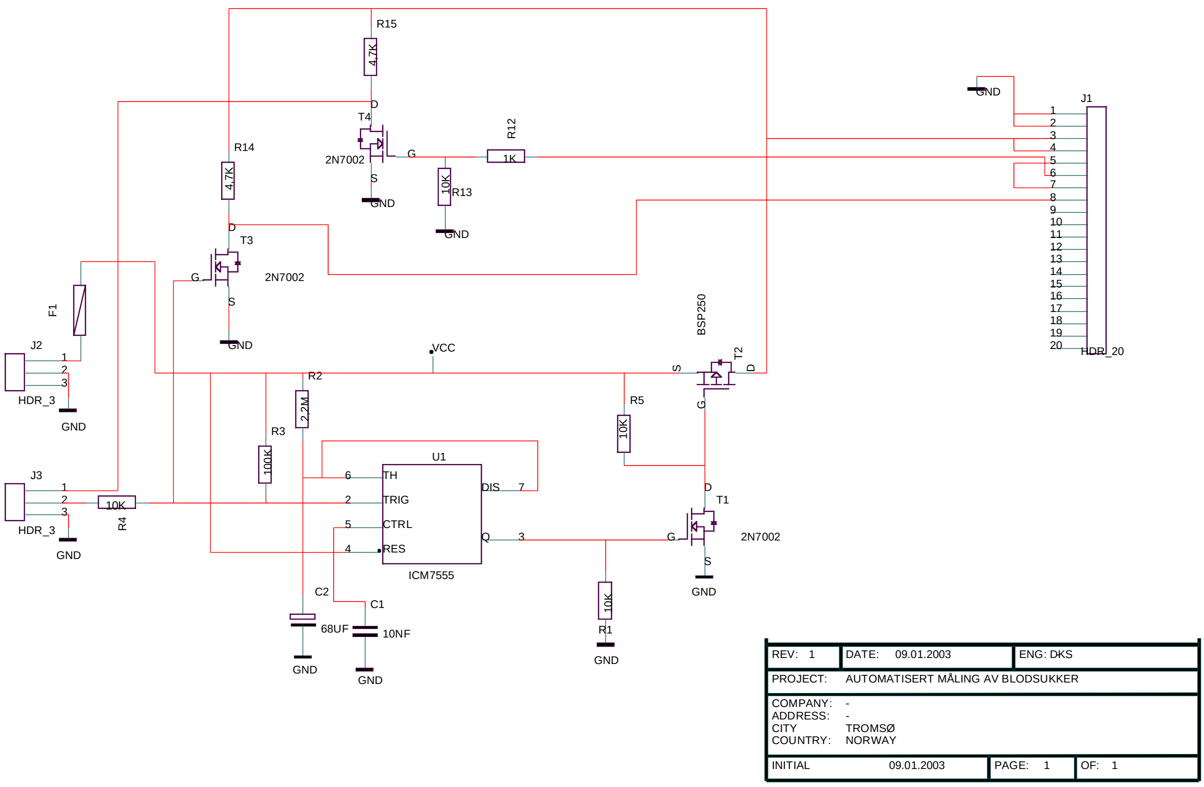
System Diagram



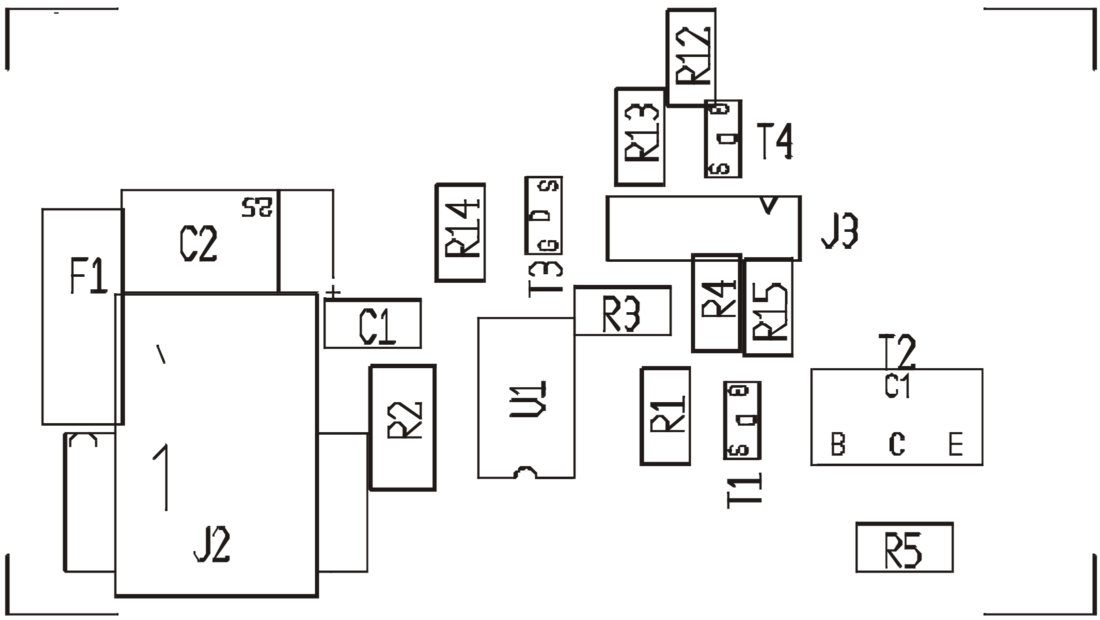
Physical Implementation



Components Layout



Printboard Layout



Components Details

#	DEVICE	VALUE	TYPE	ID
1	7555	7555	SO8	U1
1	BSP250	BSP250	SOT223	T2
1	CAPACITOR	10NF	0805	C1
1	TANTALCON.	68UF/10V	7343	C2
1	FUSE	250mA	SIL2	F1
1	HDR_20	HDR_20	HEADER2X10	J1
1	RESISTOR	100K	0805	R3
1	RESISTOR	1K	0805	R12
1	RESISTOR	2,2M	1206	R2
2	HDR_3	HDR_3	HEADER2	J2,J3
2	RESISTOR	4,7K	0805	R14,R15
3	2N7002	2N7002	SOT23	T3,T4,T1
4	RESISTOR	10K	0805	R1,R4,R5,R13
2	HYLSDON	CT 3-POL	Kontakt for ledning	
1	Jack for panel 3,5mm 3-pol			
1	LS14500 Lithium batt. 3,6V			

Appendix 19: Specifications for the Bluetooth adapter for the blood glucose sensors system