UiT THE ARCTIC UNIVERSITY OF NORWAY

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Studying usage and experiences of mHealth technology for its improved usability

Mixed methods research for understanding users' long-term engagement with the Few Touch application for self-management of Type 2 diabetes mellitus

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Abstract

Type 2 diabetes mellitus (T2DM) is getting prevalent very rapidly, although it is preventable by avoiding or reducing behavioral risk factors. On the other hand, mobile phones have become so powerful that they serve as a platform for application software. With the high possession rate of such high-end mobile phones, they have been considered as an ideal terminal to provide help for self-care of chronic diseases including T2DM. This is reflected by the recent monotonic increase in the number of research studies about mobile phone use for health care (mHealth) that targets people with diabetes.

In spite of a number of studies concerning mHealth for people with diabetes, there has not yet been any clear evidence of its effect. A multitude of study designs combined with deficits in reporting details of subjects' engagement with each component of the provided mHealth technology makes it difficult to conduct a rigorous meta-analysis. Therefore the current status of studies about mHealth technology is expressed as a "black box"; many potentially effective factors are included in intervention and it is not clear which factors are important and why.

Considering that behavior change is a path of improvement in self-management of T2DM, it is crucial to investigate users' usage and experiences of mHealth technology over time: how the mHealth technology has been utilized for users to change their behaviors, otherwise why it was not used, why users stopped using it, why it was not effective in spite of usage. Furthermore, ensuring usability of a technology is essential for the initial uptake and continuous usage of it. This is especially true when a new technology is introduced.

To tackle this problem, research was conducted in three phases. In all phases, a moderate sample size was chosen to enable thorough qualitative analyses in combination with analyses on quantitative data. In Phase 1, a 1.5-year trial of a mobile phone-based self-help application "the Few Touch application" was carried out. In this trial, the application was tested by 12 people with T2DM who had been involved in the design process from an early stage. In the course of the trial period, the application design was iteratively improved based on feedback from the test participants. In Phase 2, an updated version of the Few Touch application was tested by 11 new users for five months. In both phases, actual usage of each function of the application over time by each participant was investigated together with qualitative feedback from the participants that explained their engagement with the application. In Phase 3, design of a food-information database module as a part of improvement of the information function of the Few Touch application was carried out. This was initiated after feedback received in Phase 1. The 12 participants in Trial I and other stakeholders in the project were involved in the process of requirement identification. Based on the requirements, design concepts were made and an animation based low-fidelity prototype of the design concepts was presented to the participants in Trial I. Working prototypes with different design alternatives were developed and pilot tested by 16 healthy volunteers to identify fundamental usability flaws in design of the prototypes before an actual implementation of the design in the application to be tested by people with T2DM. For this purpose, simple and non-context oriented tasks were designed.

The major contribution of this study is that it empirically showed the following:

In case of a particular personal-use based mHealth technology for self-management “the Few Touch application”, users basically used and experienced the technology as a flexible learning tool in terms of self-management of T2DM. Patterns and degrees of usage varied a lot among users and they changed over time depending on each user’s needs and background both directly and indirectly relevant to T2DM. This was because motivation for continuation of usage was a result of balancing between expected benefit and effort required to use it. Usability of the technology could be improved by designing it so that it simplifies tedious self-management activities without posing extra effort to use the technology while it enhances the learning process and maximizes its learning effect.

Testing of the technology in real-life setting of the users that had been involved in the design process revealed many usability issues that could not have been addressed in the design process. Perceived usability was generally consistent between users who had been involved in the design process and those who had not. Nevertheless, usability evaluation by users who had not been involved in the design process was more severe than those who had. Design concepts of a module for the technology were made by involving users and by incorporating stakeholders’ opinions as well as findings from relevant studies. The users involved in the design process found the user interaction of the module easy when they were shown an animation based demo. Working prototypes that implemented the design concepts were pilot tested to identify usability flaws by healthy volunteers before implementing as a module of the technology in users’ mobile phone. This pilot testing identified usability flaws of the design concepts and the reasons for them.

Preface

This doctoral research project is initiated as “User-interaction design in patient terminals” financed by Tromsø Telemedicine Laboratory (TTL) in late 2007[1]. The project had been strongly connected to another TTL research project “The Diabetes ICT Health Motivation Project (in a short name: “Lifestyle”) [1]” and a mobile-phone-based self-help application “the Few Touch application” [2], which is a “research vehicle” in Lifestyle. Lifestyle is interrelated with many relevant studies targeting people with diabetes regardless of the type (T1DM or T2DM) as well as next-to-kin to them. Thereby many Information-and-Communication-Technology (ICT) based systems are designed and developed by utilizing the Few Touch application and its components as a basis. This means that the Few Touch application, especially its main component “Diabetes Diary” (“Diabetesdagboka” in Norwegian) which is an application software running on a mobile terminal, has evolved and there are many versions and derivatives sharing the common “Few Touch” principle [3]. The versions of the Few Touch application relevant to this research are described in Chapter 4 “Materials” and two sub-sections (6.1.3 and 6.2.2).

I worked at Norwegian Centre for Integrated Care and Telemedicine (NST) in close collaboration with Lifestyle project since 6th December 2007. My main supervisor, Gunnar Hartvigsen, is a professor in the Medical Informatics and Telemedicine group at the Department of Computer Science and the scientific leader of TTL. He allowed me to study Norwegian language at university courses in order to obtain necessary skills to communicate with the participants in the study. Eirik Årsand, who developed the Few Touch application and has been the research and project leader of the Lifestyle, has been my co-supervisor since he received his Ph.D. degree in December 2009. I needed to move from Tromsø to Oslo in autumn, 2010. University of Oslo kindly offered me a place to work as a guest researcher at Design of Information Systems (DIS) Group at Department of Informatics. Simultaneously, Tone Bratteteig, who is an associate professor at the department and the leader of the group, accepted to be a co-supervisor. Since then, I have worked at DIS group. Even after moving to Oslo, I was affiliated by TTL through NST until 25th April 2013 including one month of prolongation for writing Paper 5.

All the data collection and design production for Phase 1 and 3 were done while I was located in Tromsø. Research activities for Phase 2 were mostly done after I moved to Oslo, but I travelled frequently to NST in Tromsø until March 2011 for collaboration with Motivation with Mobile project and to consult with supervisors as well as other colleagues. Most of the analysis works on obtained results were carried out in Oslo. However, I received supervision by the two supervisors in Tromsø at regular basis as well. Regarding the analysis work for writing Paper 5, Tone and I worked on it together.

Section 1.4 “Research context” provides details regarding relevance of this doctoral research to other research projects and studies.

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[1] Due to the strong relevance to the Few Touch application, the doctoral research project was merged into Lifestyle as a work package since 2012. The period for funding was originally until December 2011. This was prolonged because of my sick leave, maternal leave, and reduction of working hours.

Sub-section 1.5.2 “Included papers” provides details regarding my concrete contributions to included papers.

Acknowledgements

I gratefully acknowledge to University Hospital North-Norway, Norwegian Centre for Integrated Care and Telemedicine (NST) and Tromsø Telemedicine Laboratory (TTL) for funding this project, selecting me for this position, providing financial support for commuting from Oslo to Tromsø, and one-month prolongation of the contract for writing a paper. I would like to express my appreciation to University of Oslo, Department of Informatics (IFI), for offering me a place to work as a guest researcher for longer time than expected.

Luckily, I had three excellent supervisors; main supervisor, Gunnar Hartvigsen, and co-supervisors, Tone Bratteteig and Eirik Årsand. Their supervision from each expertise and perspective made my research balanced and solid. They always gave me critical comments but at the same time positively tackled my problems together and encouraged me to keep up my motivations. And at the end, they always respected my decision. Furthermore, I was very much supported by their constant consideration to me as a foreign student and working mother. I need to mention that Eirik provided me with great assist to my research where the participants in Trial I were involved. It was absolutely impossible to complete writing this dissertation without their supervisions and encouragements to let me work hard enough to be confident with myself. I wish to thank them sincerely.

Heidi Nilsen gave me a good support in the early phase of the study period. The professors and researchers at both NST and Design and Information Systems (DIS) group always gave me advices, inspirations, and pointers to resources when I consulted: especially, Jo Herstad and Alma Leora Culén for writing both Paper 5 and the dissertation, Maja van der Velden and Sisse Finken for qualitative analysis, Stein Olav Skrøvseth and Amela Karahasanovic for quantitative analysis. Dag Svanæs suggested me to send a position paper to a workshop "Therapeutic Strategies: A Challenge for User Involvement in Design". He also gave me insightful advices from his high expertise in Human-Computer Interaction. Taxiarchis Botsis and Ole Hejlesen gave me critical advices to the dissertation and motivated me for the very last phase of the writing. I would like to thank them for their help to assure the quality of my research.

Needless to say, this research could not be done without cooperation by all the participants in Trials I and II and the usability testing as well as the support from every aspect to this research project. Especially, Per Hasvold, the former leader of TTL and HOPE group leader; Artur Serano, the former HOPE group leader; Sture Pettersen, leader of TTL; Geir Østengen, the first project leader of Lifestyle and Motivation with Mobile; Hilde Gaard, the former leader of Motivation with Mobile; John-Fredrik Grøttem Solberg, a master student of Business Creation and Entrepreneurship who did a thorough proof reading of the questionnaire used in Trial II; Ragnhild Varmedal, Thomas Samuelsen, Niklas Andersson, Taridzo Chomutare and Jonas Lauritzen, system developers involved in the development of the Few Touch application; and Morten Devold, a master student of Gjøvik University College who worked together with me for much of the works in Phase 3. I am deeply grateful to them all.

Antidiabetic Food Center at Lund University let me stay there for two weeks to prepare information to implement in a food-information database module as a part of the Few Touch application. It was a big shame that the implementation of the food-information database module in the Few Touch application and its test by users of the application were not realized in this study. However, I thank a lot to Inger Björck, professor in Food Related Nutrition and Elin Östman, associate professor (docent) in Applied Nutrition Department of Food Technology, Engineering and Nutrition, Lund University. I sincerely hope that the knowledge I summarized thanks to the support by Elin to be implemented in new versions of the Few Touch application.

My life as a Ph.D. student was enjoyable thanks to my colleagues and good friends who shared experiences and encouraged each other: All the Ph.D. students at TTL, especially Monika Johansen, Terje Solvoll, Rune Pedersen, Jörn Schulz as my room-mates in a "semi-quiet room" at NST and Torbjørg Meum as my neighbor at an island near the open space; All the Ph.D. students at the 7th floor of IFI2, especially Guri Verne for much help in interpretation of Norwegian language and Aga Skorupka for working together towards the end of writing the dissertation; Makoto Inami and Jalena Mirkovic as post-docs who listened to me and encouraged me to keep positive attitudes in the struggling days.

Last but not least, I am the most grateful to my family: My family in Japan, my family-in-law in Oslo, and my father-in-law in heaven. My greatest thanks go to my husband, Hans Kristian, for his understanding, patience and invaluable support to me at all times. I am the happiest wife in the world to have you as my partner for life and to be blessed with a wonderful boy, Lars Naoki.

Contents

Abbreviations

DB	Decisional Balance
FBM	Fogg's Behavior Model
GDAs	Guideline Daily Amounts
GUI	Graphical User Interface
HbA1c	Glycosylated Hemoglobin
HBT	Health Behavior Theory
HCD	Human-Centered Design
HCI	Human Computer Interaction
IBCT	Interactive Behavior Change Technology
ICT	Information and Communication Technology
IDF	International Diabetes Federation
NST	Norwegian Centre for Integrated Care and Telemedicine
OS	Operating System
PC	Personal Computer
PDA	Personal Digital Assistant
PSD	Persuasive Systems Design (used in the form of "PSD model")
RCT	Randomized Controlled Trial
SCT	Social Cognitive Theory
SD	Standard Deviation
SE	Self Efficacy
SMS	Short Message Service
SUS	System Usability Scale
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus

TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TTL	Tromsø Telemedicine Laboratory
TTM	Transtheoretical Model
UCD	User-Centered Design
UNN	University hospital of North-Norway
VAS	Visual Analogue Scale
WHO	World Health Organization
ZUI	Zoomable User Interface

Part I: Summary of the dissertation

1 Introduction

1.1 Background for the research

1.1.1 Prevalence of Type 2 Diabetes Mellitus (T2DM)

The International Diabetes Federation (IDF) DIABETES ATLAS was updated in 2012 and according to it more than 371 million people have diabetes worldwide [4]. This number accounts for 8.3% of world population. Given that the previous edition of IDF DIABETES ATLAS estimated that 285 and 439 million people would have diabetes in 2010 and 2030, respectively, the pace of prevalence is rapidly increasing. Among the three types of diabetes; Type 1 diabetes mellitus (T1DM), Type 2 diabetes mellitus (T2DM) and gestational diabetes, T2DM accounts for 90% of all diabetes worldwide [5]. The risk factors for T2DM include unhealthy dietary habits and low level of physical activity. Such behavioral risk factors are associated with metabolic and physiological changes that have multiple effects leading to T2DM, hypertension, hyperlipidemia, and obesity. This means that poor management of diabetes leads to serious complications and potentially other conditions, such as cardiovascular diseases. These conditions account for 50-80% of deaths in people suffering from diabetes [6].

1.1.2 Market growth of high-end mobile phone and use of mobile terminals for health care (mHealth)

A recent report from World Bank stated that there are over six billion mobile subscriptions worldwide and 75% of the world population has access to a mobile phone [7]. With technological evolution, mobile phones have become powerful. They are typically called “smartphones”. Smartphones offer a variety of functions in addition to serve as a platform for application software, which are typically called “apps”. Application development for smartphones was boosted by well-prepared developmental environment for each operating system and infrastructure that enable easy entry to the app-market. Due to the ubiquity and personal use of a mobile phone compared to PCs, mobile phones have been considered as a good platform of personal health care. This has led to a number of mobile applications developed for health care purposes. “mHealth” is defined as “the use of mobile computing and communication technologies in health care and public health” [8] including use of such applications. The market growth of mHealth applications is extremely rapid: Only in the U.S., it was 718 million USD in 2011 and based on estimations, 1.3 billion USD in 2012 [7]. The number of the available mHealth applications from Apple’s App Store reached 15,000 in September 2011, a significant increase from the 4,000 in February 2010 [7]. However, a survey by Consumer Health Information Corporation revealed that “26% of apps are downloaded and used only once. Of the people who confirm using their apps, 74% drop out by the 10th use”. The reasons for stopping using apps were explained as “inaccurate (10.2%)”, “not engaging (15.8%)”, “not user friendly (32.6%)”, and “found a better one (34.4%)” [9].

1.1.3Research on mHealth for diabetes and research gaps

Reflecting the high prevalence of T2DM and penetration of high-end mobile phones, the number of scientific research works on mHealth is rapidly increasing as well. A very recent review by Fiordelli et al. [10] clearly showed this trend: the number of mHealth research articles published between 2002 and 2007 was only 23 whereas the number of those published between 2008 and 2012 was 94. The number of publications has been increasing monotonically since 2005. They also revealed that "diabetes has received a great deal of attention" among the other health conditions studied [10].

In spite of the number of mHealth research for diabetes, there is no clear evidence of benefit of mHealth due to difficulties in conducting a rigorous meta-analysis of the findings [11,12]. This is mainly due to considerable differences in the research design and the overall methodology in studies where mHealth was used for intervention purposes. Other literature reviews [13–15] identified the weaknesses of previous studies addressing topics related to the use of a mobile device as an intervention terminal for the management of diabetes. The primary problem has been the obscurity of participants' long-term engagement with the intervention tools. Mulvaney et al. [14] argue that "studies should report engagement data overtime and with different components of the intervention". The same problem is also pointed out in a recent Cochrane review "Computer-based diabetes self-management interventions for adults with T2DM" that also included studies employing mobile devices as a patient terminal [16]. Such problem makes it difficult to understand "how they (interventions) work": what components or behavior change techniques are most effective to achieve the desired impact.

Attrition of patient's engagement with eHealth intervention is the norm when it is carried out through Internet and typically using computers as a patient terminal [17]. Thus, it is critical to adequately analyze patients' engagement with intervention over time to identify the necessary components for; initial uptake, on-going use of an intervention tool, and achievement of desired impact. Piette [18] also insists that development research should "insure that new technologies[2] are designed in ways that are acceptable and accessible to patients and are sufficiently engaging so that patients will continue to use them over time". Especially for the initial uptake and ongoing use of an intervention tool, achievement of high usability is considered to be both key and challenge [19]. Quoting words by Klasnja et al. [20], "a deep understanding of how technology interacts with other important factors that affect behavior change – people's attitudes and preferences, their relationships, the context in which they live and work, etc. – is critical for the development of effective tools" and "thus, during the initial evaluation of a novel system, investigation of patterns of use and users' experiences with the system should be seen as a primary evaluation goal" [20]. Summarizing, to ensure the achievement of sustainably usable technologies for self-management of chronic disease, research within Human-Computer-Interaction (HCI) should focus on understanding use and uncovering potential problems that stem from design of an employed ICT system for intervention.

[2] Here "technology" means "interactive behavior change technology".

1.1.4 The case: A mobile phone-based self-help application: “the Few Touch application”

The Few Touch application [2] is a mobile-phone-based self-help application developed at Norwegian Centre for Integrated Care and Telemedicine (NST). It was designed for continuous use with the purpose of improving users’ blood glucose management by increasing physical activity and encouraging a healthier diet. The fundamental policy in designing the application has been the achievement of unobtrusiveness in patients’ daily life and simplicity for ease of use. This is because ”people with chronic diseases have more than enough additional disease related issues to consider and manage on a daily basis”, as explained in a section ”Few-Touch” concept [2]. In the discipline of HCI, User-Centered Design (UCD) is a fundamental principle. Design and development of the Few Touch application therefore involved patients with diabetes as potential users in the initial steps of the design process [2,21].

From September 2008, the application was tested for its feasibility by 12 people with T2DM that had been already involved in the design process. The user-involvement in the design process turned out effective and successful: initial analysis of the results showed that the tested application was highly appreciated in general despite some design issues that were found rather unsatisfactory [2,22]. The patients showed their interest in extending the use of the application beyond the originally planned 6-month period and in further participating in the research program. Nevertheless, a generally decreasing trend in usage of the application functionalities was observed [2,22].

Self-management of a chronic disease such as T2DM is a daily issue requiring sustainable engagement by people with T2DM at a certain level. Considering the employed UCD approach in its development, the Few Touch application would have a great potential to be well accepted and actively used by people with T2DM in general. If this were the case, the testing of the application would provide rich information about users’ engagement with the application. Analyses of such information would then provide “a deep understanding of how technology interacts with other important factors that affect behavior change [20]”, as described in the previous sub-section. In addition, continuous design iteration of the Few Touch application based on users’ feedback would not only improve the quality of the application but also give implication regarding how target users should be involved in the design process. The negative user experience of a technology in the real-life setting would reflect the issues that had not been addressed in the designing phase.

1.2 Research problem and questions

The main issue in the current mHealth research for the self-management of diabetes can be summarized as follows: in many studies, it is unclear how and why an mHealth technology and its components actually have or have not been used for users’ self-management. In order to disentangle causality of effect by an mHealth technology, research within HCI should focus on understanding usage and experience of the technology in users’ self-management and uncovering potential problems that stem from its design.

Therefore, the primary research problem in this doctoral research is:

"How do users use and experience a personal-use based mHealth technology for self-management of T2DM, and how can its usability be improved?"

"Personal-use" here means that the application is used and managed solely by the user: no other people such as patient-peers, health care providers or next-of-kins use the application.

In this dissertation, I follow the definition of usability by ISO13407 [23]: "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [ISO 9241-11: 1998, definition 3.1]". It also defines: effectiveness as "accuracy and completeness with which users achieve specified goals [ISO 9241-11: 1998, definition 3.2]"; efficiency as "resources expended in relation to the accuracy and completeness with which users achieve goals [ISO 9241-11: 1998, definition 3.3]"; satisfaction as "freedom from discomfort, and positive attitudes to the use of the product [ISO 9241-11: 1998, definition 3.4]"; context of use as "users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used [ISO 9241-11: 1998, definition 3.5]"; and user as "individual interacting with the system [ISO 9241-10: 1996, definition 2.2]".

To address this research problem, in this dissertation I studied a particular personal-use based mHealth technology for self-management of T2DM; the Few Touch application. I discuss two cases where the Few Touch application was tested by different small groups of users. One is by 12 people with T2DM who were involved in the design process of the application and testing lasted totally 1.5 years where design of the application iteratively improved. The other is a 5-month trial of the application by 11 people with and at high risk of T2DM who were not involved in the design process. I also discuss an iterative design process of the application for further improvement where both users and non-users were involved, with a particular focus on design of a new module as a part of the application. More specifically I studied the following four research questions:

R1: How do users use the Few Touch application over time?

This question is essential to address the primary research problem. Self-management of T2DM is not a single event but a daily issue, it is therefore also important to investigate actual usage over time.

R2: What are users' motivations for usage of the Few Touch application for their self-management?

By investigating users' motivations for usage of the Few Touch application for their self-management, the reasons of users' usage and experience of the Few Touch application will be explained. Thereby the actual role that the Few Touch application played in users' self-management will be explained.

R3: What are the factors that contribute to the usability of the Few Touch application?

This question addresses practical issues that are associated with the usability of the Few Touch application. Answers to this question will therefore contribute toward accumulating knowledge about usability of the Few Touch application.

R4: In which ways can users be involved in evaluation and design of the Few Touch application to ensure its usability?

The latter part of the primary research problem, "how can its usability be improved", can be addressed in many ways. In this dissertation, I focus on user-involvement by looking at how users and non-users were involved in evaluation and design of the Few Touch application. Through this process, I study how these contributed to improved usability of the application and to identification of usability flaws. Taking the answers to the four research questions, I will draw implications for user-involvement in evaluation and design of a personal-use based mHealth technology for self-management of T2DM that utilizes a smartphone with a small screen.

R1 directly covers the "use" part of the primary research problem, while answers to R2 and R3 will explain reasons for the "use and experience" part. The answers to R2 and R3 will also identify the goals that the Few Touch application should aim in terms of usability. R4 addresses the latter part of the primary research problem with a specific focus on user-involvement in evaluation and design as a part of the process to improve usability of the Few Touch application. Therefore answering to these four research questions will address the primary research problem to a certain extent. The cases that I take in this dissertation are limited to evaluation and design of one particular technology; the Few Touch application. Specifications of the application need to be taken into account as a part of limitation in terms of transferability of the results. The specifications include; choice of a smartphone as a patient terminal, choice of a particular model of a smartphone and its specifications, choice of functions that the application offers, and design of each function. Nevertheless, the Few Touch application is designed to support daily self-management of T2DM. The Few Touch application is therefore equipped with fundamental functions to serve as a personal-use based mHealth technology for self-management of T2DM. Therefore, in this sense the findings and the implications of this research contribute to accumulating knowledge for evaluation and design of a personal-use based mHealth technology for self-management of T2DM using a similar smartphone.

1.3 Research approach

1.3.1 Mixed methods research

The research problem and the research questions require understanding of relevant phenomena and processes to address each of them. For R1, regarding usage of the Few Touch application over time, it is essential to acquire precise data that represent actual usage and to quantitatively analyze how the usage changed or did not change over time for each user. In order to understand the reasons for usage, qualitative information was collected from users that explain their experience from usage of the application. Qualitative analysis of the qualitative information can be strengthened by corroborating with the results of the quantitative analyses. As written in the previous section, I follow the definition of usability by ISO13407. When "specified goals" are simple and direct goals of certain operations of a specific function, efficiency of the functions can be evaluated both qualitatively and quantitatively. "Resources expended" can be for example represented by time spent on certain operations but also represented by users' subjective assessment regarding for example mental and/or physical effort. In the research part where a new module for the Few Touch application was designed, I compared two prototypes with regard to usability. Here, specified goals were simple and specific functions were tested. In order to better understand results of evaluation and to identify problems of designs with the two prototypes, efficiency was studied both quantitatively and qualitatively. In addition, satisfaction of each prototype with regard to specific functions and as a whole module was both qualitatively and quantitatively assessed. Qualitative assessment was done by collecting users' opinions, while quantitative assessment was done by asking them to give scores to each prototype by using specific tools and compared the difference in scores between the two prototypes. Therefore we used both qualitative and quantitative methods for both data collection and analysis, and synthesized results of both types of analysis to answer addressed question(s). This type of research is categorized as mixed methods research.

Johnson et al. [24] analyzed 19 definitions of mixed methods research and concluded to give a comprehensive definition of it as follows:

> "Mixed methods research is an intellectual and practical synthesis based on qualitative and quantitative research: it is the third methodological or research paradigm (along with qualitative and quantitative research)".(p. 129)

In their analysis, they identified five themes of mixed methods research: "*what* is mixed", "*when or where* in the design mixing is carried out (i.e., the *mixing stage*)", "*breadth* (of mixed methods research)", "*why* mixing is carried out in research", and "the *orientation* of the mixed methods research". The theme that is most relevant and important to this research is the theme of "*why*". As they describe, the key purpose of the mixed-method research is "breadth and/or corroboration". Quoting their words, breadth for this context means "(a) providing better understanding, (b) providing a fuller picture and deeper understanding, and (c) enhancing description and understanding" while corroboration is reflected by the focus on triangulation of findings.

In terms of the theme of "*why*", advantages of qualitative research over quantitative research include the ability to provide rich insight into human behavior and to explore and discover dimensions that quantitative research does not cover with its a priori hypotheses. On the other hand, due to its nature, the results of qualitative research are in all cases human constructions. By borrowing quotes by Guba and Lincoln [25], "(human constructions) are all inventions of the human mind and hence subject to human error. No construction is or can be incontrovertibly right; advocates of any particular construction must rely on persuasiveness and utility rather than proof in arguing their position" (p. 108). Qualitative research is different by nature from quantitative research, and terms such as reliability, validity and generalization are not appropriate to demonstrate robustness. Tobin and Begley [26] argue the importance of triangulation to establish completeness and "goodness" to ensure the quality of the research. The concept of goodness is to locate situatedness, trustworthiness and authenticity; to provide clear and adequate information about the research for readers to judge the quality. This is especially important due to the nature of qualitative study which is not linear but dynamic and interactive regarding design and implementation of methods.

As described, mixed methods research approach was taken in this research. However, due to the nature of the research problem and the research questions, the objective of the research corresponds to that of qualitative research. Therefore, I report this research as in detail as possible to follow the concept of goodness.

1.3.2 Research phases

This research was conducted in three phases:

Phase 1: Trial I - A long-term testing of the Few Touch application by users that were involved in the design process – and design iteration

Phase 2: Trial II - A long-term testing of the Few Touch application by users that were NOT involved in the design process

Phase 3: Design and pilot testing of a food-information database module as a part of the information function of the Few Touch application

R1-R3 are mainly addressed by the results from the two trials in Phase 1 and 2. On the other hand, R4 is addressed by all the phases. Below, I will explain the three phases.

1.3.2.1 Phases 1 and 2

Phases 1 and 2 involved a long-term testing of the Few Touch application to address R1-R3 described in 1.2.

Figure 1.1 in the next page illustrates the relationship between; the participants in each phase (rectangles with round corners), tested applications, testing (pentagon), collected and analyzed data (questionnaire results, interviews and recorded data on Diabetes Diary) and the resulted designs and identification of needs for a new design process (big arrows).

Items in blue color are related to Phase 1 while those in yellow color are related to Phase 2. In the course of the trial, we collected both qualitative and quantitative data to analyze their usage of the application and their experiences. Qualitative data were obtained by questionnaires and interviews. Quantitative data were usage data recorded on Diabetes Diary of the Few Touch application.

The participants in Trial I and II are different groups of people. The participants in Trial I were involved in the design process of the Few Touch application, expressed in items in black color in Figure 1.1, from its early stage. On the other hand, the participants in Trial II were those who were neither involved in the design process nor had previous knowledge about the Few Touch application.

Design of the Few Touch application was iteratively improved in Phase 1 based on feedback from the participants. The first version of the Few Touch application was improved with two minor updates before the major update of the Few Touch application with Diabetes Diary version 2. Based on feedback from the testing of the Few Touch application with Diabetes Diary version 2, Diabetes Diary version 3 was designed and developed. This version was tested in Trial II.

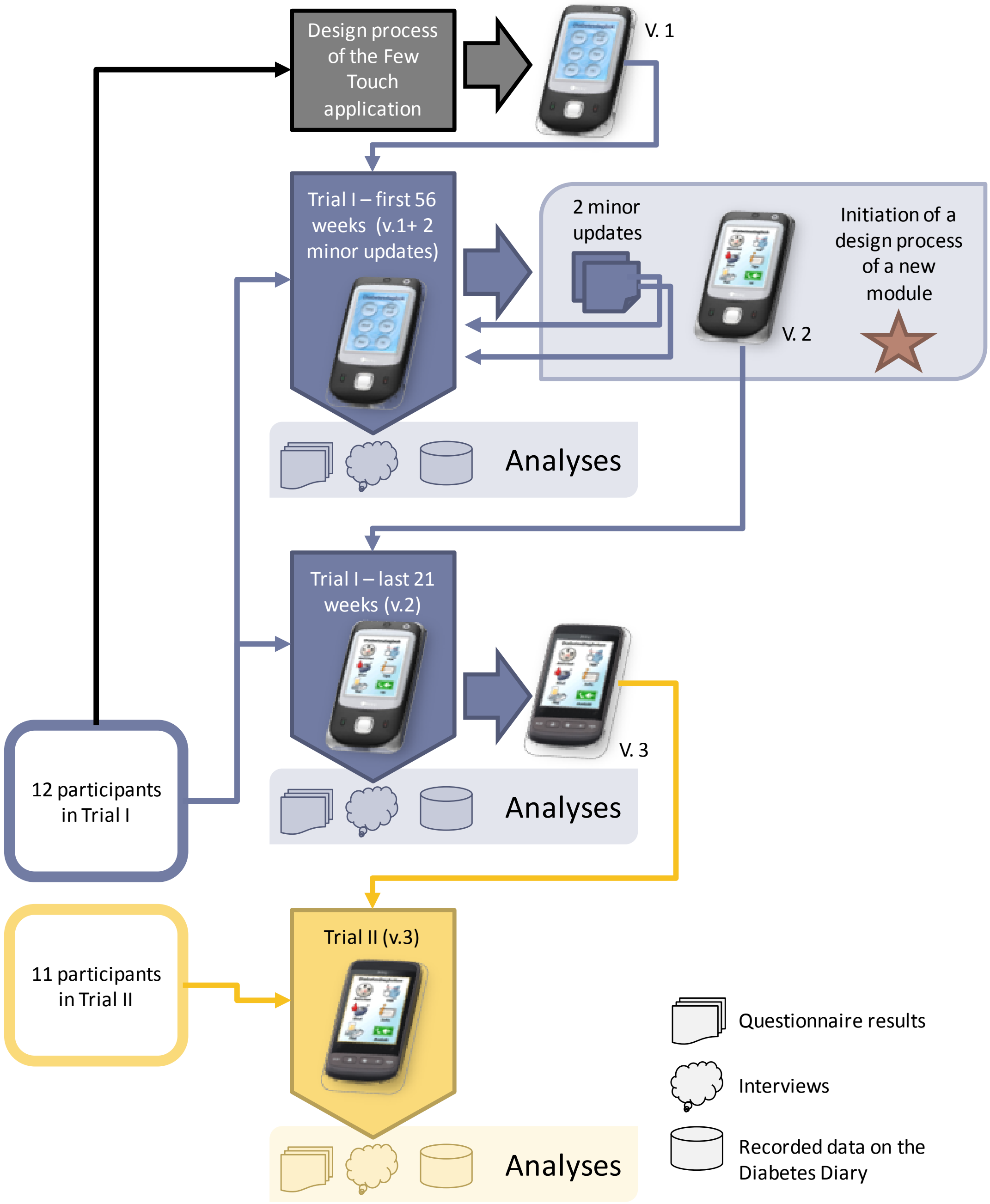


Figure 1.1 Phase 1 (in blue) and Phase 2 (in yellow)

1.3.2.2 Phase 3

Phase 3 focuses on a specific function of the Few Touch application: the information function. This phase was initiated by feedback obtained in Trial I that identified a need for a separate design process to implement a food-information database module as a part of the information function, expressed by a star in Figure 1.1. In the course of Trial I, the participants' needs for an instant access to food-information relevant to their self-management were identified. Figure 1.2 illustrates the relationship between; the people involved in Phase 3 (rectangles with round corners), design process (rectangle), the resulted designs (big arrows), pilot usability testing (rhombus), and collected and analyzed data.

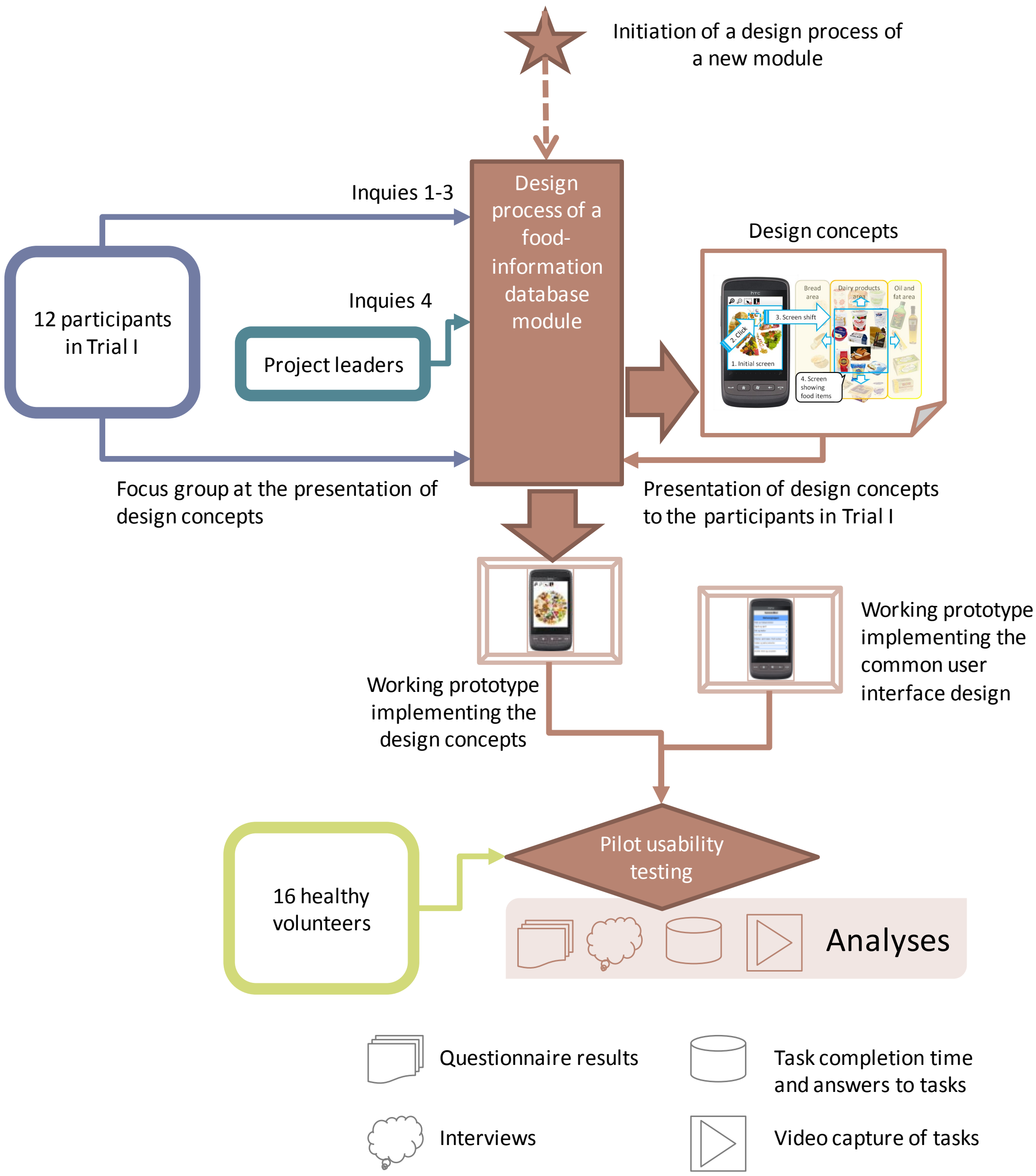


Figure 1.2 Phase 3

Three inquiries were made to the participants in Trial I to specify the context of use and the user requirements. For these inquiries, mainly questionnaire was used as a data collection method. Based on findings from the three inquiries and relevant literature, an inquiry was also made to the two project leaders of Lifestyle project [1] who also were users of the Few Touch application due to their T1DM. Lifestyle project is where iteration of design, development and testing of the Few Touch application was carried out involving mainly the participants in Trial I. This inquiry was made to identify requirements of user interaction design of the food-information database module from an educational point of view and to identify usage scenarios for design of test tasks. These inquiries were made in the form of individual unstructured interview.

Referring to relevant research results and design principles for user interaction of ICT artifacts as well as the identified requirements, design concepts of a food-information database module were developed with focus on functions for search and comparison of food items. The design concepts were presented by a low-fidelity prototype using animation function of presentation software to the participants in Trial I. They showed generally positive responses to the design concepts. From their responses to the presented concepts, we also gained further understanding about the context of use and the information needed to specify user requirements.

As a very early stage of the design process, two working prototypes were made and pilot tested regarding two functions. The purpose of this pilot usability testing was to find out any usability flaws in design of prototypes before taking a further step in development for actual implementation to real-users' application to be tested. The testing was therefore done with simple and non-context oriented tasks by recruiting convenient sample of 16 healthy volunteers. With the pilot usability testing, we also aimed to examine whether or not the proposed design concepts solve the reported problems with traditional and common user interfaces. The following data were collected for analysis: task completion rates, error rates, task completion time, pre- and post-test questionnaires, post-test interview and video capture of screen on which tasks were carried out.

1.3.3Limitations of the research approach

Foremost, this research is not a medical study. This research was carried out from a perspective within HCI to address the research problem concerning clear understanding about usage and experiences of a particular mHealth technology, the Few Touch application, over time and for improved usability of it. Although this research involves long-term trials of the Few Touch application, this research is not a medical study where clinical outcomes are the main concern. Use of long-term trial as a method is solely the design of the study and I argue a long-term trial of a resulted design of a personal-use based mHealth technology for self-management of T2DM is necessary before conducting a clinical study of it. However, this study design and relevant conditions in this study cause the following limitations.

First, all the phases in this research are very early to middle stage of design process of an mHealth technology as an ICT artifact. All the involved participant groups in this study were therefore relatively in small size. This is also partly relevant to the difficulty in recruitment of people with T2DM who voluntarily participate in research due to both small population in towns of North Norway and inconvenience in transportation due to geography. Naturally, the number of participants is small and they are highly motivated. Small size of participant groups is appropriate for research projects like this study where both thorough qualitative analysis and analysis using large quantitative data sets are required. In addition, a certain level of motivation for self-management of T2DM is important in the early design process, because if design is not successful with those with high motivation, it will never succeed with those with low motivation. As a case study, this research would generate knowledge about usage and experiences of a particular mHealth technology and thereby yield implications for improved usability of similar mHealth technologies. However, the degree of transferability may be limited due to the characteristics of the samples. In addition, the small sample size poses a limitation at interpretation of results of quantitative analyses which compared different design ideas (Inquiry 3) and two prototypes (pilot usability testing) in Phase 3. The comparison was done in terms of subjective evaluations and expended time to complete simple tasks. In both cases, the quantitative analyses were used to corroborate the results of qualitative data and its analysis. I should clearly elaborate here that the purpose of these two are not to assess absolute advantages and disadvantages of target objects for generalization.

Second, although the trials in Phase 1 and 2 are "long-term" trials, the trial periods are 1.5 year and five months, respectively. As a research within HCI, these periods are reasonably long enough to address the research problem and the research questions. However, considering the period that people with T2DM need to tackle T2DM, the extent to which this research can address about usage and experience of mHealth technology "over time" will be limited.

Third, we did not evaluate any clinical data at pre- and post-trial as well as in the course of the trial period of the application. Here, clinical data means any types of medically meaningful data for T2DM such as glycosylated hemoglobin (HbA1c), blood glucose values, accurate records about diet and physical activity as a part of health behavior. This is firstly because this research is not a clinical study. Second, recorded data on Diabetes Diary are not appropriate enough to use to evaluate effects of the Few Touch application on blood glucose control, nutrition habits and physical activity level. This is because the way to use the application was totally up to the participants. Blood glucose values surely reflect the blood glucose level at the moment of measurement. However, it changes depending on relational time to meals, physical activity and other health conditions. Not all the participants regularly measured blood glucose level at a regular time with respect to meals and physical activities. Self-management behavior is a direct and sole predictor of health outcomes. I strongly argue that mHealth technology should be designed to be used for improving self-management and/or for keeping good behaviors, and it is important that research within HCI field should focus on usage and experiences of mHealth technology in the context of self-management. Nevertheless, given that mHealth is use of mobile technology for *health care*, the study design of Phases 1 and 2 without evaluating impact of the Few Touch application regarding clinical outcome certainly limits what this research can address.

Last, Convenient sample of healthy volunteers participated in pilot testing of working prototypes in Phase 3. People with T2DM are difficult to recruit and therefore they are scarce and precious resources. This is especially true in the condition stated above: small population and difficulties with transportation. Furthermore, considering that an artifact is designed for them to use in their self-management of diabetes, it is very critical to find out any possible usability flaws and fix them before testing with those with diabetes in any settings. On the other hand, the people with T2DM, at least those we included in the studies, were not suffering from any severe cognitive problems or sensory paralysis at all: they were general citizens in the sense of daily ICT-use. These two are the main reasons why we carried out pilot testing with healthy volunteers.

1.4 Research context

As described above, we conducted trials of the Few Touch application for people with T2DM and performed iterative design and development. The context of self-management is considerably different between T1DM and T2DM [27]. Our initial literature review did not limit including studies to ones that targeted only people suffering from T2DM. However, this research basically focuses on people with T2DM and the self-management of their condition.

This doctoral research project is strongly connected to other research projects where "the Few Touch application" [2] has been used as the "research vehicle". Trial I addressed in Phase 1 is strongly interrelated with Årsand's doctoral research project [2]; Trial I was initiated in the city of Tromsø in northern Norway under the umbrella of this project. The results from the first six months of Trial I were presented in Årsand's dissertation [2] but also in a journal paper [22] and I am the second author of this paper. I contributed to works relevant to evaluation of usability of the Few Touch application as a part of my doctoral research. In the journal paper and Årsand's dissertation, the focus is given to evaluation of effect of the Few Touch application, while the focus in this study is particularly given to daily use and experiences of the application and design improvement for daily use. Furthermore, this research also investigated the data obtained from the extended period which included design iteration and implementation. In this sense, although the same case is used, the view point of this research is different from Årsand's doctoral research project.

Trial II addressed in Phase 2 was conducted as a part of the "Motivation with Mobile project[3]" held in the city of Harstad[4] in northern Norway. The participants had no previous knowledge about the Few Touch application. The project was administered by NST in collaboration with Norwegian Diabetes Union. The union promotes a patient-oriented learning course called "Motivation Group[5]". Motivation Group is a patient-oriented learning course organized locally gathering people with T2DM or at high risk of T2DM. A group activity is led by a representative person with T2DM. The participants meet regularly (typically once a week) to help each other to improve their lifestyle. Motivation with Mobile project aimed to strengthen Motivation Group course held in Harstad by introducing the Few Touch application.

In Phase 3, all the inquiries to people with T2DM as potential users involved the participants in Trial I. For the presentation of design concepts of Food Browser and the pilot usability testing in Phase 3, a master student at Department of Computer Science and Media Technology of Gjøvik University College participated in and we collaborated. Although quite much work was done in a good collaboration, most of the necessary works were divided among us. What I was mainly responsible for were:

- Planning the pilot usability testing
    - Design of test tasks
    - Design of a test procedure and arrangement (the number of participants, instructions to participants, experimental design, and other practical miscellaneous)
    - Choice of data to collect and methods for it (questionnaires and quantitative measures)
    - Arrangement of test participants
- Technical development of a Food Map search function
- Decision on food items to include in the prototypes
- Preparation of images of food items to be used
- Debugging and modification of a Scatter Plot comparison function

[3] http://www.telemed.no/motivasjon-med-mobil.5037834-247951.html. (Available only in Norwegian)

[4] The quickest transportation between Tromsø and Harstad is by an express boat and it takes four hours.

[5] http://www.diabetes.no/?module=Articles;action=Article.publicShow;ID=1924 (Available only in Norwegian)

1.5 Claimed contributions and included papers

1.5.1 Contribution of dissertation

By mixed methods research with focus on individual users, basic mechanism of users' engagement with a personal-use based mHealth application for self-management of T2DM, the Few Touch application, was explained. Engagement here means actual usage of the application by recording relevant data to self-management, and utilization of both the recorded data and the application in the context of self-management. The Few Touch application served as a flexible learning tool for users to instantly confirm how their self-management activities and/or health status influenced their blood glucose levels. While the common mechanism was explained, heterogeneity of patterns and level of engagement both among users and over time was also confirmed. Various factors associated with usability of such application were identified. The study also indicated that users' backgrounds both directly and indirectly relevant to the problem domain have a strong influence on the usability. Thereby this study contributed to fields where personal-use based mHealth technologies for self-management of T2DM using a similar smartphone are designed, developed and used, by providing the following implications:

- Importance of clarification of users' engagement with mHealth technology regarding its difference among users and its change over time.
- Importance of involving people with T2DM that have different needs and background both directly and indirectly relevant to the problem domain, namely self-management of T2DM in a design process. The involvement should be throughout design and development process until a long-term testing of a working prototype to discover latent problems that could otherwise not be manifested.
- Potential of efficient and effective discovery of usability flaws stemming from design of a mHealth application by including healthy volunteers in pilot usability testing. This is due to their low or no motivation for use of tested mHealth application. Such testing should focus on very fundamental simple tasks requiring no experience as being diagnosed as T2DM or relevant knowledge to self-management of T2DM. Testers should however have various backgrounds as people with T2DM.

Table 1.1 presents details of contribution of dissertation in the form of a list of key findings, phases where the findings were led from, and associated research questions.

Table 1.1 Details of contribution of dissertation: how key findings are associated with research question(s) and where the findings are addressed

#	Findings	Addressed in Phase(s) and paper(s)	Research question
F1	There were considerable differences in usage of the Few Touch application in terms of usage pattern and level of engagement, and in addition they changed over time	Phase 1, 2 (Paper 2, 3)	R1
F2	Motivation to use the application is a result of balancing between the expected effort required to use it and the expected benefit, mainly learning about user's T2DM,	Phase 1, 2 (Paper 2, 3)	R2

	by using the application.		
F3	Factors that reduced effort required for self-management of T2DM while enhancing learning about a user's T2DM seemed positively associated with usability of the Few Touch application.	Phase 1, 2 (Paper 2)	R3
F4	Usability of the Few Touch application is strongly influenced by individual user's needs and various types of backgrounds both directly and indirectly relevant to the problem domain that the application addresses.	Phase 1-3 (Paper 2, 3, 4, 5)	R4

1.5.2 Included papers

Literature review of related works and Phase 1 and 2 resulted in published papers through peer-review process. Major findings in Phase 3 are summarized into a manuscript which is under review process when this dissertation is submitted. Therefore, including this manuscript by calling it Paper 5 for convenience, I will include five papers listed in Table 1.2

Table 1.2 List of included papers

#	**Paper title, forum and authors**
Paper 1	"A Review of Mobile Terminal-Based Applications for Self-Management of Patients with Diabetes", eTELEMED'09 (Tatara N, Årsand E, Nilsen H, Hartvigsen G)
Paper 2	"Long-Term Engagement with a Mobile Self-Management System for People with Type 2 Diabetes", JMIR Mhealth Uhealth (Tatara N, Årsand E, Skrøvseth SO, Hartvigsen G)
Paper 3	"Usage and Perceptions of a Mobile Self-Management Application for People with Type 2 Diabetes: Qualitative Study of 5-month Trial", Studies in Health Technology and Informatics. 2013;192:127-31 (Tatara N, Årsand E, Bratteteig T, Hartvigsen G)
Paper 4	"Patient-user involvement for designing a self-help tool for Type 2 diabetes", Therapeutic Strategies A Challenge for User Involvement in Design: Workshop in conjunction with NordiCHI2010 (Tatara N, Årsand E, Hartvigsen G)
Paper 5	"Making it Easy is not so Easy: Interaction Design with Text and Image on a Small Screen" submitted to CHI 2014 (Tatara N, Bratteteig T)

Below is the description of each paper with its relevance to this dissertation and my contribution.

Paper 1: **Tatara N**, Årsand E, Nilsen H, Hartvigsen G. A Review of Mobile Terminal-Based Applications for Self-Management of Patients with Diabetes. Proceedings of International Conference on eHealth, Telemedicine, and Social Medicine, 2009. (eTELEMED '09), Page(s): 166 – 175, 2009

Relevance to this dissertation: This paper presents the literature review of related works and summary of findings at the time of summer 2008. The review provides a broad overview of the research works in terms of; target users, use of technologies, design of mHealth, and study designs such as methods of intervention and other types of evaluation of mHealth. The summary of findings became the basis of evaluation and design improvement of the Few Touch application, as used in Phase 1 and 2.

My contribution: I conducted all the works and wrote the manuscript by consulting to the co-authors regarding interpretation of findings in collected papers for a synthesis.

Paper 2: **Tatara N**, Årsand E, Skrøvseth SO, Hartvigsen G. Long-Term Engagement with a Mobile Self-Management System for People with Type 2 Diabetes. JMIR Mhealth Uhealth 2013;1(1):e1

> **Relevance to this dissertation:** This paper presents mechanism of participants' engagement with the Few Touch application by analyzing data from the first 56 weeks of Trial I. It also presents design factors associated with long-term usage and usability of the application. Therefore, the paper has the major relevance to the dissertation. Details of results are presented in the paper and its appendices.
>
> **My contribution:** I am a main contributor in writing the paper and in revision based on comments and questions given by the reviewers for the first round of the reviewing process. As written in "Authors' contributions" section in this paper, I contributed in: "conception and design of the present work, namely analysis of the results from the long-term trial"; "developing protocols for data collection"; "data collection"; and "data analysis" in addition to writing and revision.

Paper 3: **Tatara N**, Årsand E, Bratteteig T, Hartvigsen G. Usage and Perceptions of a Mobile Self-Management Application for People with Type 2 Diabetes: Qualitative Study of 5-month Trial. Studies in Health Technology and Informatics. 2013;192:127-31.

> **Relevance to this dissertation:** This paper presents a summary of the results of analyses of data from the Trial II. Due to the limited space of this conference paper, extended summary of results are presented in chapter 7.
>
> **My contribution:** I wrote the paper and revised based on comments and questions given by the scientific program committee for the reviewing process. I am also a main contributor in designing the questionnaire, data collection and analysis.

Paper 4: **Tatara N**, Årsand E, Hartvigsen G. Patient-user involvement for designing a self-help tool for Type 2 diabetes. Proceedings of Therapeutic Strategies A Challenge for User Involvement in Design: Workshop in conjunction with NordiCHI2010, ISSN 0105-8517, Pages: 53-55, 2010

> **Relevance to this dissertation:** This position paper is a short description about Trial I, but it provides with discussion which is very much relevant with Finding 4. The discussion was very much inspired by results of the workshop.
>
> **My contribution:** I participated in the workshop by presenting this position paper. I wrote and revised the paper.

Paper 5: **Tatara N**, Bratteteig T. Making it Easy is not so Easy: Interaction Design with Text and Image on a Small Screen. Submitted to CHI 2014.

> **Relevance to this dissertation:** This paper reports from most of the results in Phase 3: Inquiries 3 and 4, concept design, working prototypes and the pilot usability testing. Due to the limited space of this conference paper, extended summary of results are presented in chapter 8. It has therefore foci on the Finding 4.
>
> **My contribution:** I contributed to planning and conducting all the works described in the paper. For the works done in collaboration with others, the published works are referred. The ones who did the works described in collaboration with me are

acknowledged. However, due to the anonymization policy of the conference, their names are anonymized in the submitted version. Formulation of the whole paper and each chapter, especially introduction, discussion and conclusion, was done in collaboration with the co-author. Both authors wrote and revised the manuscript.

1.6 Dissertation structure

The remainder of this dissertation consists of three parts: Summary of the dissertation, Collection of papers, and Appendices.

PART 1 – Summary of the dissertation

Table 1.3 Dissertation structure

Chapter	Content
2 – Background	This chapter first introduces basic knowledge and facts about T2DM with focus on self-management. Second, principles and frameworks in HCI that are strongly related to the research problem are introduced. At last, current situation of mHealth research is summarized with focus on mHealth for self-management of diabetes.
3 – Related works	Summary of related works with focus on users' engagement with mHealth technology is presented.
4 – Materials – the Few Touch application	I present the first version of the Few Touch application used in Trial I, mainly with focus on screen designs and menu structure of the Diabetes Diary version 1.
5 – Methods	Due to the similar nature of the studies, methods for Phases 1 and 2 are presented together in the first section. Methods for Phase 3 are presented in the second section. Due to the nature of qualitative study as explained in 1.3.1, methods presented in the second section are limited to overall explanation of employed methods and rationale. Interpretation of subjective scores obtained by questionnaires in this study follows. In the last section, I provide with information about ethics with regard to involving people with T2DM as users of the Few Touch application and involving healthy volunteers in the pilot usability testing.
6 – Phase 1	Results of Phase 1 are presented.
7 – Phase 2	Results of Phase 2 are presented.
8 – Phase 3	Results of Phase 3 are presented.
9 – Discussion	I discuss the results according to the findings in association with research questions and reservations of this study.

10 – Conclusion	I conclude the research in the form of answering research questions and addressing the primary research problem.

PART 2 – Collection of papers

PART 3 – Appendices

During my PhD study period, in addition to the included papers in this dissertation, I contributed to other papers from the project as well. I would include a list of them as **APPENDIX 1** due to either marginal relevance to this dissertation or marginal contribution to a paper. The rest of appendices provide details of backgrounds, methods and results.

2 Background

2.1 Type 2 Diabetes Mellitus (T2DM)

2.1.1 Definition, symptoms and treatment

Diabetes is distinguished into three types: Type 1 (T1DM), Type 2 (T2DM), and gestational. Among them, T2DM is most rapidly getting pervasive, and this is often associated with unhealthy lifestyle [27,28]. Dam [29] presented a brief overview of studies on lifestyle and the development of T2DM and concluded that dietary changes and increased physical activity with weight loss would lower risk of T2DM. While in T1DM pancreas produces very little or no insulin, in T2DM either/both insulin production is insufficient or/and insulin resistance is so high that blood glucose is inefficiently used by cells as an energy resource. This status leads to higher blood glucose level than normal and causes damages to the peripheral blood vessels over time. Often, T2DM develops without being diagnosed, because people sometimes don't experience symptoms or signs before T2DM have gotten so serious that complications have already arisen. Typically symptoms and signs include excessive thirsts, fatigues, loss of interests and concentration, frequent urination, weight loss without intention, frequent infections [30]. Treatment of T2DM primarily involves dietary regulations and regular physical activities, but oral medications can also be used. Although T2DM used to be called non-insulin dependent diabetes mellitus, depending on the condition, insulin injection is also prescribed [31]. Self-monitoring of blood glucose combined with lifestyle-change is shown to be associated with persistent improvement of blood glucose control [32]. However, its frequency depends on the clinical necessity as well as other factors including patient's knowledge, skills and willingness to incorporate it into one's care plan [33]. HbA1c is generally used as an indicator of an averaged blood glucose level for the preceding 3-month period. IDF recommends that patients with T2DM should be advised to maintain HbA1c under 7.0% to avoid developing complications [34]

2.1.2 Importance of self-management

IDF's global guideline for T2DM states that "self-management refers to the individual's ability to manage the symptoms, treatment, physical and psychosocial consequences and lifestyle changes inherent in living with a chronic condition" [34]. Although care plan including lifestyle management must be designed for each individual with T2DM, three activities are essential: regular physical activities, healthy diet, and maintaining blood glucose level within target range in conjunction with blood glucose monitoring [35]. Self-management behavior is a direct and sole predictor of health outcomes, such as HbA1c, unless other factors affect the patient's health [36]. On top of that, self-management behavior in diabetes is strongly connected with quality of life [37].

In chronic diseases, responsibilities of the daily care lie heavily in the patients themselves. Collaborative management between patients, health care providers, and their families enhances the effectiveness of care only when adequate self-care is conducted by the patients. Key principles of the theories on which successful interventions have been developed on, include the idea that "illness management skills are learned and behavior is self-directed" [38].

As Mamykina et al [39] also concluded in their observation study, patients obtain skills in self-management by being a “detective” on and by negotiating with him/herself to establish their own reasoning process. Family physicians also point out that facilitators in management of T2DM that resides in patients are their ability to assume responsibility and control over their diabetes [40]. By reflecting these above, Wagner [41] describes that in order to improve outcomes the patient-provider interactions 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”. These all imply the importance on focusing more on patients rather than on only healthcare providers’ perspective. IDF’s global guideline for T2DM clearly reflects this by stating “make patient-centered, structured self-management education an integral part of the care” as well as “adopt a whole-person approach and respect that person[6]’s central role in their care” [34].

2.1.3 Adherence and barriers to self-management

The word “adherence” is explained in the report “Adherence to long-term therapies” by World Health Organization (WHO) [42] as follows: “conceptualized as the active, voluntary involvement of the patient in the management of his or her disease, by following a mutually agreed course of treatment and sharing responsibility between the patient and health care providers”. As described previously, self-management of T2DM involves behavior change especially about dietary habit and physical activities. Certain barriers to self-management activities are reported, and they include; lack of knowledge and understanding, limited or inaccessible resources, limited social support, environmental issues including time constraint, emotional difficulties such as frustration, and inadequate or non-individualized care [40,43–45]. Numerous Health Behavior Theories (HBTs) are proposed to explain health behavior change. However, many of them are similar with regard to important elements in spite of using different terminologies. Due to very few studies comparing HBTs, it is not clear which HBT best explains a certain health behavior [46].

Hereafter, I will focus the issue around diet because of the strong relevance to Phase 3.

2.1.3.1 Importance of knowledge and understanding about diet for diabetes care

Relevant research studies report their findings that diet is the most challenging aspect of diabetes care. Nagelklerk et al. [43] conducted three focus group sessions with 24 patients with T2DM in Chicago in 2002 in order to describe perceived barriers to self-management of T2DM. They found that the highest ranked barrier was lack of knowledge and understanding the diet plan despite the fact that the participants had at least one consultation with a dietician. Ahlgren et al. [47] found a positive relationships between having a meal plan and satisfaction with diabetes dietary lifestyle. However they also found that “respondents were overall less satisfied with their ability to follow their meal plan” compared to their satisfaction with the meal plan itself.

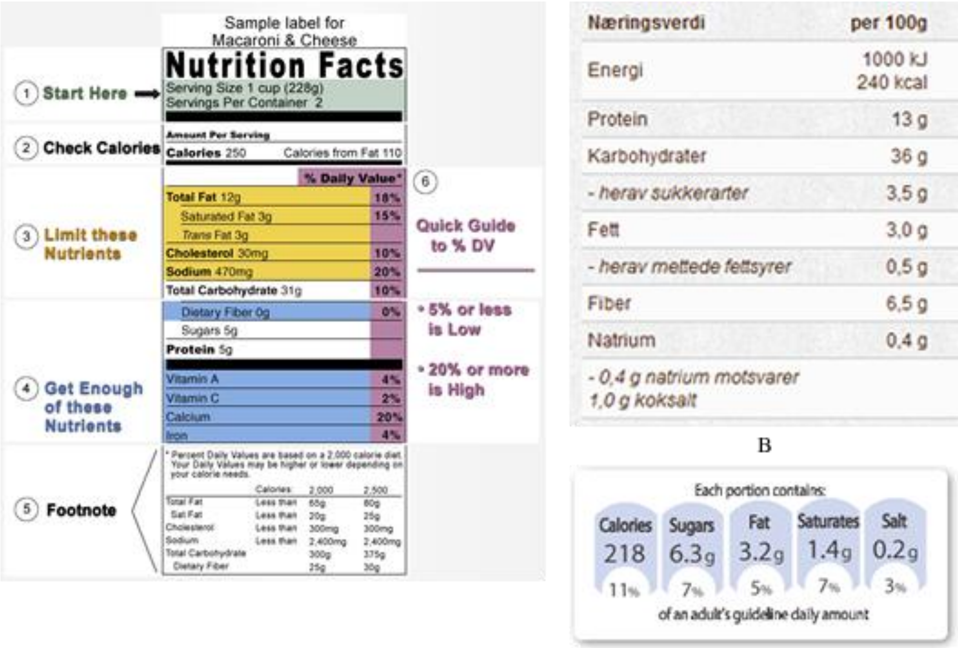
Even though a variety of internal and external factors are associated with difficulty in changing dietary habits [44,47,48], knowledge regarding “what, when, how much to eat” is among others especially important to foster strategies and skills of: food selection, preparing;

[6] In this context, that person refers to “a person with diabetes”.

meal planning; and dining out [44]. Kanstrup et al. [49] investigated everyday life with diabetes in a study where eight families including members with diabetes were involved. In this study, they identified archetypical activities that were divided into "action-based" and "location-based". "Action-based" activities are related to calculating, co-operating and remembering, and need to be done anytime, anywhere and by anybody. On the other hand, "location-based" activities are related to planning, finding and informing, and need to provide "right information to right person at right time". All the families that participated in their study clearly stated their needs for "access to information about particular things of importance e.g. the ingredients in food to make more qualified decisions" rather than specifically prepared information relevant to diabetes.

2.1.3.2 Current status of nutrition-fact label design

Information about foods should be provided in the form that is interpretable and useful. Chhabra et al. reported difficulties in comprehending nutrition information due to the format in which information is provided to users [50]. Nutrition facts of food items are shown in different manner depending on a country as shown in Figure 2.1. For example nutrition contents are shown in the unit of "per serving" in the U.S. [51] (Figure 2.1, A), while in Norway 100 gram is used as the unit [52] (Figure 2.1, B). Another type of formats is Guideline Daily Amounts (GDAs) [53] (Figure 2.1, C). This format shows "how much energy and nutrients are present in a portion of a food or beverage and what each amount represents as a percentage of a person's daily dietary needs". GDAs are used for major food company products mainly in European countries. Studies however show contradictive results in terms of ease of interpreting information given in GDAs format. A study by the European Food Information Council [54] presents that most consumers in targeted six European countries have reasonable knowledge and were able to make correct health inferences from nutrition labels with no major differences between the labeling systems (Traffic Lights, GDAs and color-coded GDAs). On the other hand, a recent systematic literature review [55] indicates no particular advantages of the GDAs in terms of consumers' interpretation of nutrition information and selection of healthier products. However, the authors call for readers' attention to the only limited number of studies conducted to assess the influence of nutrition labels on consumers' purchase.



A C

Figure 2.1 A variety of nutrition labels (A: nutrition label format used in the U.S., B: one type of nutrition label used in Norway, and C:nutrition label in GDA format)

2.2 HCI for engaging ICT

According to Association for Computing Machinery Special Interest Group on Computer-Human Interaction (ACM SIGCHI), "HCI is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [56].

HCI is multidisciplinary itself. It concerns ergonomics, informatics, industrial engineering, psychology, social sciences, cognitive science, graphic design, and so forth. From HCI-relevant resources, we can find and learn basic principles, theories, and established methods from these disciplines that are employed in HCI research field.

In this section, I will describe the two most relevant topics to this research.

2.2.1 Usability

As I wrote in 1.2, ISO13407 [23] defines usability[7] as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and

[7] There are different definitions of usability. For example, Sharp et al. [57] sharp states that "usability is generally regarded as ensuring that interactive products are easy to learn, effective to use, and enjoyable from user's perspective." (p. 20) and they elaborate the usability goals as "effective to use (effectiveness)", "efficient to use (efficiency)", "safe to use (safety)", "having good utility (utility)", "easy to learn (learnability)", and "easy to remember how to use (memorability)". In this dissertation however, I follow the definition of ISO13407 as I stated in 1.2.

satisfaction in a specified context of use [ISO 9241-11: 1998, definition 3.1]". Usability matters not only for users' acceptance or preference of a product but also for proper use of a product and consequence of using a product [58]. Therefore, usability is an essential quality factor with regard to a personal-use based mHealth technology for self-management of T2DM.

Goals of usability evaluation can vary depending on the purpose; for example, comparison of several products to make a choice, evaluation of revised design, comparison by different types of users such as novice users and experienced users, finding problems that affect usability, and so forth. Effectiveness is defined as the "accuracy and completeness with which users achieve specified goals" and efficiency is defined as "resources expended in relation to the accuracy and completeness with which users achieve goals" [23]. Thus they can be objectively and quantitatively measured by conducting usability testing of a product regarding certain tasks with certain goals. Concrete measure is decided up to the usability goals and purposes of an evaluation. On the other hand, satisfaction is defined as "freedom from discomfort, and positive attitudes to the use of the product" [23]. Therefore, measuring satisfaction requires self-reporting by users. Satisfaction could be asked either or both per task, per function or / and as overall perception of the whole product. Often times, semantic differential methods, Likert-scale and preference of compared products are used as well as established questionnaires such as; System Usability Scale (SUS) [59], AttrakDiff™ [60] and those discussed in [58] or listed in Common Industry Format for Usability Test Reports [61][8].

To achieve high usability, it is essential that a product is easy to use. Krug explains ease of use as "self-explanatory, obvious and self-evident regarding what it is and how to use it" [62]. Series of design principles and guidelines are proposed to achieve ease of use, but there are a lot of similarities [63]. Design principles are also used for evaluation of usability, and when used in evaluation they are called heuristics [57]. Nielsen conducted a factor analysis to synthesize different usability heuristics and revealed that the identified top 10 heuristics can explain 95% of serious usability problems in total [64].

As its definition describes, usability of a product is determined both by the three factors and by relationship between those factors and context of use. "Context of use" is defined as "users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used" [23]. This implies that there are lots of factors that would influence usability. Considerable difference in context of use between handheld terminals and desktop computers called for: research on usability factors specific to mobile terminals with different size of screen and input methods from desktop computers [65–71]; usability testing in field settings [72–74]; and development of new heuristics [75], satisfaction measure [76], check list [77] and cognitive model [78] that are specific to mobile[9].

In addition, technology development of handheld devices is so rapid that specification changes dramatically within a few years. By following such changes, factors determining usability need to be revisited for investigation. This is argued by Fling in his book "Mobile Design and Development" issued in 2009 [79], saying like: "Don't trust any report, fact, or

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[8] Here I refer to the Common Industry Format version 2.0 published at http://zing.ncsl.nist.gov/iusr/ but cite ISO standard ISO/IEC 25062:2006 because the format is not anymore available at the website of National Institute of Standards and Technology.

[9] Tremendous amount of research works can be found in relevant journals and conferences, but I listed up ones whose findings are relevant to this dissertation.

figure that is more than a year or two old. It is most likely wrong (p. 61)", "Don't try to simply apply the same rationale to your mobile strategy as you would your web or print strategy (p. 67)" and "Don't forget to innovate. Try new things, be bold, and don't be afraid to fail (p. 61)". Nevertheless, very general principles still need to be consulted at designing and evaluation before user testing. For example, "keep it simple" remains important in design for mobile device, as Fling also provides relevant principles in the same book [79].

ISO13407 [23] also defines the Human-Centred Design (HCD) process for interactive system. UCD yields huge benefit in terms of: efficiency, satisfaction, productivity (or effectiveness) by using the system, and quality of the developed system. Careful consideration on selection of the potential users and degree of involvement in design process is the first key issue, because user-involvement must be as effective as possible. The second key issue would be how early and how often user could be involved. One of the characteristics of human-centered approach that ISO13407 defines is "the active involvement of users and a clear understanding of user and task requirements". This advocates the importance of the close and frequent interaction in order to enhance the effectiveness of user involvement. HCD process is required exactly because of the facts that design principles and usability heuristics cannot be simply implemented and that especially for mobile "context (of use) is king" [80].

For any ICT-based systems, usability is essential to ensure good user experience. User experience can be conceptualized as an overall impression of a product around use [57]. Thus, user experience goals could vary depending on the purpose of an ICT system. User experience is influenced by more factors than components of usability, although satisfaction is very much relevant. The most relevant user experience goal to this research is that a system feels engaging to a user in a sense that it helps self-management of T2DM. As explained previously, self-management involves behavior change which is often times challenging to people with T2DM. In the next sub-section, I will describe a discipline that is specific to design of ICT systems for behavior change.

2.2.2Persuasive technology

Persuasive technology is briefly explained as technology that is designed or used with "intent" that a user would change his/her behaviors voluntarily by using the technology. This means that persuasive technology affects on a user with intention but does not affect by unintentional side-effect. Following to the definition, persuasion requires an "intentionality" to change both/ either attitudes and/or behaviors [81,82].

A number of frameworks[10], models, strategies, principles, propositions for design and analysis of persuasive technology are proposed [81–90]. Although proposed frameworks use different terminologies, there are many commonalities among them. For example, Fogg's conceptualization of sources of intention [81]; endogenous, exogenous and autogenous, is used for the argument for clarification of persuader in the Persuasive System Design (PSD) model [86]. Three approaches to influencing behavior in Design with Intent [88] can be translated into motivation and ability in Fogg's Behavior Model (FBM) [83], because

[10] For convenience, I use the word "framework" as a generic name for frameworks, models, strategies, principles, and propositions in this sub-section.

constraining behavior is reducing ability and motivation. Fogg's Behavior Grid[11] [85,91] and categorization used in Oinas-Kukkonen's Behavior Change Support System are similar in terms of what type of behavior change is targeted. Especially the foci on relapse in behavior change are also common to propositions presented by Kraft et al. [89]. Twenty-eight design principles in the PSD model [86] include the seven strategies proposed by Fogg [82]. They have also commonalities with "Design Strategies for Lifestyle Behavior Change Technologies" proposed by Consolvo et al. [90]. But the Design Strategies for Lifestyle Behavior Change Technologies provide more concrete arguments especially for design principle: "self-monitoring", which needs to be "abstract and reflective", "unobtrusive", and "trending / historical".

As persuasive technology should focus on users' behavior change by interaction with it [82], various relevant psychological theories are incorporated in the proposed frameworks. For example, theories about rather intuitive judgments, such as "heuristics and biases" [92] or "framing" [93] are explicitly used in Design with Intent methods [88]. Theories about longitudinal behavior change are also referred in several frameworks in common especially for lifestyle change to improve health condition [85,86,90]. Such theories include trans-theoretical model (TTM) [94] and goal-setting theory [95]. Theories from social psychology are also drawn and resulting in similar design strategies or principles in spite of different theories referred [86,90,96].

Ethics is an important perspective of persuasive technology from views of both persuasion and technology that raises ethical questions by nature in its use [81]. However, in a review of publications in a series of "Persuasive conferences", Torning et al. [97] found that ethics was addressed at length as the topic in only three out of 51 reviewed papers. The authors criticize the current situation as "ethics being largely unaddressed might in itself be considered unethical" and advocate the importance of responsibility of designers and researchers on ethical aspects. To solve such situation, Karppinen and Oinas-Kukkonen [98] proposed a framework of ethical approaches in persuasive technology design, which provides pointers to ethical principles according to approaches categorized into; guideline, stakeholder analysis and user involvement. The third approach highlights the ethical issues more effectively and efficiently in designing and development process. By its nature that users who are direct stakeholders are participating as a member of design team, especially participatory design has a strong advantage in reducing potential ethical problems.

The frameworks described above can be applied to any domain as long as it concerns persuasive technology. There have been several review or viewpoint papers discussing the current situation and challenges of research on persuasive technology for health [99–101]. However, some of the review papers [97,102] pointed out that the methodologies taken are still described in vague manner in most of the reviewed studies and the authors advocate the needs for concrete design methods for successful development of persuasive technology. Andrew et al. [103] pointed out that tactics to realize the strategies are missing. They found that the "suggestion" technologies had been relatively unexplored so far. They argue that suggestion technology would be important along the evolution of technology to provide suggestion with another important principle "kairos". "Kairos" means to provide right information at right timing when it is most effective. They analyzed relevant literatures

[11] Fogg's Behavior Grid in [85] is a revised version of that proposed in [91] and the number of classified behaviors is reduced from 35 to 15.

aiming to improve health behavior with various design strategies, and identified a list of dimensions that describe the design space of suggestion tactics in two categories: technological dimensions and content dimensions. The proposed dimensions can be used for both designing and evaluating systems that employ the suggestion strategy as persuasive technology. Unfortunately, the process of identification of the dimensions is not described in the publication. However, the direction of their research suits the fifth and sixth steps of the Fogg's eight design steps [84], which are "find relevant examples of persuasive technology" and "imitate successful example", respectively. This research by Andrew et al. is a good example of making a framework for identification of design requirements specification.

2.3 mHealth

This section consists of two subsections. In the first section, I will explain mHealth, starting with definition, continuing to a brief overview of the current situation of mHealth in view of application area and trend. Then I will describe research gaps and challenges in mHealth. This is followed by introduction of research agenda proposals by researchers.

2.3.1Definition

As written in Introduction chapter, mHealth is defined as "the use of mobile computing and communication technologies in health care and public health" [8]. The Global Observatory for eHealth at WHO defines "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices" [104]. This definition indicates communication technologies are not necessarily used in mHealth but the point is that the device is mobile so that it is portable and has a feature of "always on a user". mHealth is considered to be a part of eHealth [104,105]. Gemert-Pijnen et al. found that eHealth was differently defined in their review of eHealth frameworks [105]. In their proposal of a holistic framework, "CeHRes roadmap", they define eHealth as "all kinds of information and communication technology used for supporting health care and promoting a sense of well-being" [105]. Thus, in the following sub-sections, I will describe relevant research works in eHealth as well as mHealth to cover common topics and challenges.

2.3.2Application area and trend

A survey by WHO revealed that mHealth is emerging through experimentation rather than strategic implementation in many WHO member countries [104]. In their categorization, mHealth includes mere use of mobile phone line between citizens and health care providers, which in fact is frequently reported. On the other hand, mHealth taking advantage of mobile computing, such as patient monitoring or decision support systems, is much less frequently reported and very few countries reported that such initiatives were established. Possible reasons for low implementation of monitoring are lack of sensors at reasonable costs [104] and very limited compatibility with external sensors for tracking health information [106,107] This is somehow contradictive to strong user needs for tracking function on mHealth applications on smartphones [106].

As scientific research, a recent review by Fiordelli et al. [10] gives a very good overview of application area and trend of mHealth research including study designs and technologies used. They found that major application area of mHealth research is chronic conditions among which diabetes leads in the number of studies. Diabetes is targeted in a great deal of studies with mHealth interventions as well [108]. Fiordelli et al. also found the shift of study interest in the last five years; from split interests in evaluation of technology itself and of impact on health outcomes to mostly evaluation of the impact of mobile technology on health outcomes [10]. Given that a review was conducted in 2012, it is surprising that they found that few studies applied native mobile-phone applications created ad hoc for research purpose. On top of that, none of the reviewed studies applied already existing and publicly available smartphone applications [10]. The major technology used in mHealth intervention research is still short message service (SMS) [10,108].

Incorporation of HBTs and of strategies employed in persuasive technology into eHealth including mHealth intervention is considered to be beneficial. This is not only for intervention using messaging service as its delivery channel but also in technology design and development [90,99,109–113]. This notion is reflecting the growing recognition that knowledge alone is insufficient to produce significant changes in behavior and that psychological and behavioral intervention is necessary [42,114]. However, Chomutale et al. found that still only a small number of smartphone-based mHealth applications for self-management of diabetes are equipped with personal education features and social network features [115].

2.3.3 Research gaps and challenges

The biggest research gap is that there is very limited clear evidence of effects by mHealth. It is not only in the domain of diabetes as described in Introduction chapter but also other purposes within domains of disease management and health behavior change.

mHealth intervention with SMS or other types of messaging seems to have positive effects on improvement in self-management skills, behavior change or health outcome measures [116–119]. However, the strength of evidence is fairly limited. This is because of heterogeneity of study design. Few studies are with high quality of evidence while many studies suffer from lack of reporting of process measure, demonstrated causality, and risk of bias [116,118,120]. The word ”black box” is used to express the current situation of studies with many potentially effective factors included in intervention [121,122]. This is not only limited to mHealth research but applicable to a part of eHealth research. Morrison et al. [123] found that studies of eHealth intervention with self-management features, activity planning and self-monitoring, often lacks specifications regarding how activity was planned, what behaviors were monitored, or how behavior was monitored. In their review of Web 2.0 self-management intervention for older adults, Stellefson et al. [124] also point out that "impact evaluations assessing Web 2.0 engagement were lacking". Although almost all reviewed studies monitored web log activity, they did not take advantage of the information to assess users' usage. Lehto and Oinas-Kukkonen [125] also revealed that program utilization was rarely assessed (3 out of 23 reviewed articles). They also revealed that incorporated persuasive features were not explicitly tested in Web-based smoking and alcohol intervention studies [125]. Effect of incorporation of HBTs in ICT-based intervention is not clearly shown either, because of the considerable variety in the effectiveness and study designs [126–128]. Evidence of tailoring intervention is also unclear for long-term effects on adherence to medication because of low-quality adherence measurement [129]. In Web-intervention studies for weight-management [130] and for people with mild and moderate depressive symptoms [131], it was found that participants did not read tailored message. They suppose that lack of trigger to let a user visit the web site and lengthy contents were the possible reasons for that the users did not read tailored messages.

Lack of information and lack of clear organization of results make it difficult to conduct rigorous review. The current status provides very limited clear evidence regarding effects of mHealth in terms of not only health outcome but also cost effectiveness. This is considered to be the major barrier to the implementation of mHealth in the health care setting [104].

Another great challenge in mHealth is the "law of attrition", which was defined by Eysenbach [17] as "the phenomenon of participants stopping usage and/or being lost to follow-up, as one of the fundamental characteristics and methodological challenges in the evaluation of eHealth applications". As the factors influencing attrition, Eysenbach listed up the followings: relative advantage, compatibility, complexity, trialability, observability [17]. Additionally, he listed up hypothetical factors of usage attrition such as; ease of drop out, ease of stopping using an application, usability and interface issues, and lack of "push" factors such as reminders [17]. It is implied that tailoring message [116,132] and more extensive employment of dialogue support such as reminders and suggestions [133] have a potential effect on users' retention, but the evidence is not yet strong enough to be generalized [122]. Another issue about attrition is that more engagement with program does not automatically mean more improved outcome. A part of participants benefit from a brief exposure to Web-based interventions. However such participants are likely to be included among dropouts [134] or if not, they will decrease usage of or be less engaged with eHealth program. This is due to "ceiling effect", which illustrates the status that a participant finds no more effect by further engagement with the program [135].

2.3.4Research agenda

In order to overcome the barrier against implementation of mHealth, one way of potential approaches is to employ rigorous research methods such as Randomized Controlled Trial (RCT) to provide with high-quality evidence on efficacy of mHealth [112,118,121,136]. However, there are opinions that research methods such as RCT are not necessarily appropriate considering rapid evolution of mobile technology and too many uncontrollable confounding factors that cannot be anticipated [105,137,138]. Regardless of the types of evaluation, the most essential requirement throughout the course of design, development and evaluation is to clearly and thoroughly describe information so that the results can be comparable with others [12,14,139]. CONSORT-EHEALTH [140] offers a solid guideline to follow when planning, conducting and reporting eHealth interventions. This guideline clearly states the necessity of detailed description about intervention and patients' utilization of the program. As described previously, non-usage of or drop outs from eHealth program are inevitable, and thus it is important to report non-usage and drop-outs over time [17]. Kelders states "understanding how the content, system and service of an intervention are used and experienced, may be the key to understanding why eHealth technologies suffer from large non-adherence rates" [122]. Whittaker et al. argue that qualitative investigation should be carried out to the participants of RCTs in order to obtain more in-detail understanding about how participants experienced the intervention tool [136]. Mixed methods research is considered having a high potential to understand user experience in relation to how actual usage influenced the outcome [105]. It is also important to investigate what level of engagement is necessary to benefit from the investigations and how it varies among users [112].

Taking multidisciplinary approach is also considered essential. In CeHRes Roadmap, integrating persuasive technology, UCD and business modeling is considered necessary to give theoretical background for the development process [105]. However, in eHealth and mHealth research in general, there is a certain gap between domains - HCI and healthcare - in terms of focus and thereby study design and reporting styles. This gap is confirmed by the finding of a review of Web-based dietary interventions [141]. Another review of Web-based intervention programs for diabetes revealed that only six percent of tools were free of usability errors [142]. As a matter of fact, it is considered a great challenge to realize patient-participation in design from an early stage [143]. Based on actual experiences, many researchers recently presented practical guidelines or implications about UCD when users are patients and/or how to involve healthcare consumers, such as patients as users [21,144–149]. However, most of them are published within HCI domain. In order to fill this gap, a research team should be consisting of members with multidisciplinary backgrounds including ones from HCI domain [150]. Especially for ensuring usability of a mHealth application, which is considered to be one of factors of attrition or low uptake [17,135,151], UCD is essential [19,104]. The importance of UCD is illustrated by successful experiences in developing engaging mHealth tools by implementing UCD from an early phase and thereby being able to identify a number of key system requirements [152]. It is also illustrated by lessons that usability problems with an mHealth application were found when tested by people who were novice to the application and without technical background [153]: When the same mHealth application had been tested for three months by users with technological background and with previous experience of using the same type of the mobile phone, the usage remained high over time and users' impression on the usability was also good [154].

As described in Introduction chapter, evaluation of mHealth from HCI perspective should therefore focus on understanding usage and uncovering potential problems that stem from design of an employed mHealth or eHealth technology for intervention [20]. And again, evaluation of usability and of how design features influence effects should be made publicly available [137]. With regard to integrating persuasive technology, it is a challenge to ensure that a user would use the program with a positive attitude. For example, Crutzen et al. [155] found that although participants appreciated having control on web sites so that a user could skip pages, the knowledge obtained and exposure to pages were higher among those who used pages with less user-control. Together with ethical issues of persuasive technology described in the previous section, such challenges should be tackled with active involvement of stakeholders, especially the end users.

3 Related Works

3.1 Users' engagement with mHealth for their self-management of diabetes

Paper 1 covers research works on mHealth for self-management of diabetes published by the time of July 2008. The paper gives a broad overview of reviewed works in terms of study design and findings. Many review papers of mHealth for diabetes were published after Paper 1. The foci of the review papers could be divide into: efficacy of mHealth [12,13,15,16,108,117,156][12]; design of interventions [14]; design of technologies [107,157]; and design of smartphone applications [115], especially focusing on evaluation of applications available on market [107,158–160]. Because this dissertation focuses on users' usage and experience of a personal-use based mHealth technology for self-management of T2DM, in this section, I will review related works from this point of view.

Table 3.1, Table 3.2 and Table 3.3 summarize characteristics of research articles about mHealth for people with diabetes published by the time of June 2013 depending on the targeted type of diabetes; non-specific types, T1DM, and T2DM, respectively[13]. The tables include only articles that report level of users' actual engagement with the provided mHealth technology at least in a sentence or in the form of a table or a figure[14]. Hereafter, the word "a participant" is going to be used as an individual who actually was provided with an mHealth technology in a study to use it in his/her self-management of diabetes. The tables are summarized with regard to how participants' engagement was reported. Special attention was given to whether or not an article reports anything about difference in engagement among participants and its change over time. In the Tables, if the cells for "individual difference in engagement level" and "change in engagement level over time" are both blank, the article reports level of engagement typically in the form of total and/or average (mean) of usage by all the participants for the whole period. **APPENDIX 2** provides more details about each article.

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[12] A review by Krishna et al. and a review by Free et al. are not exclusively targeting diabetes but also other diseases and a review by Pal et al. includes mHealth as a part of "computer-based" intervention.

[13] I did not include articles which I am an author (or co-author) of.

[14] [161] shows information about proportion of received logbook by physicians, but from the description in MATERIALS AND METHODS on p. 162, it is unclear whether or not the logbooks of the participants in the intervention group were sent regardless of data entry. Due to this, this study is not included in

Table 3.3

Table 3.1 Characteristics of mHealth study for people with diabetes (type not specified) with focus on report about participants' engagement

Study (Authors and year of publication)	**Population**	**Sample size, Drop outs**	**Intervention Period**	**Individual difference in engagement level (1-5) [a]**	**Change in engagement level over time (1-3)[b]**
Tsang et al., 2001 [162]		20, 1	3 months	2[c]	3
Ferrer-Roca et al., 2004 [163]		12,4[d]	9 months [e]	2[f]	1: Monthly [f] 3
Ferrer-Roca et al., 2004 [164]		23, No info.	8 months		3
Larizza et al., 2006 [165]		38, 8	12 months	1	
Mamykina et al., 2008 [166]	Newly diagnosed	25, 1	5 months	2, 4 (unclear)	
Lee et al., 2009 [167]		20, 3	3 months		
Hanauer et al., 2009 [168]	Young adult treated with insulin	22, 4	3 months	2, 3, 5	1: Monthly 3
Istepanian et al., 2009 [169]		72, No info.	Unclear		
Rotheram-Borus et al., 2012 [170]	Woman	22, 0	3 months	2, 4, 5	

[a] 1: Differences between pre-defined arms are reported, 2: Differences among individuals are reported (not predefined arms), 3: Results of statistical analysis of the difference are reported, 4: Reasons of the difference are qualitatively reported, and 5: Potential factors associated with level of engagement are investigated.

[b] 1: Granularity of reported change in engagement level (when not described, data are given only for the whole period of intervention), 2: Results of statistical analysis of the change are reported, and 3: Reasons of the change are qualitatively reported.

[c] Data is based on answers given to a questionnaire

[d] Four participants could not be contacted for the exit interview

[e] Not all the participants used the system for 9 months due to gradual recruitment

[f] Only regarding use of PC (mobile terminal for this intervention was not used at all))

Table 3.2 Characteristics of mHealth study for people with T1DM with focus on report about participants' engagement

Study (Authors and year of publication)	Population	Sample size, Drop outs	Intervention Period	Individual difference in engagement level (1-5) [a]	Change in engagement level over time (1-3) [b]
Kumar et al., 2004 [171]	Child, Adolescent	40 (19 with game use), 3[c]	1 month	1, 2, 3, 4	
Vähätalo et al., 2004 [172]		102, Unclear [d]	12 months	2, 3, 5	
Gibson et al., 2005 [173]	Young adult	93, No info.	9 months	1, 3, 4	1: Weekly 3
Farmer et al., 2005 [174]	Young adult	93, 12	9 months	1, 3, 4	1: Weekly
Rami et al., 2006 [175]	Adolescent	36, 0	3 months	2, 4	
Benhamou et al., 2007 [176]	Adults Treated with continuous subcutaneous insulin infusion	30, 2	12 months (Cross over)	1, 2, 3	1: At frequency of clinical visit which is unclear 2
Jensen and Larsen, 2007 [177]		1	3 months e		1: Daily
Kollman et al., 2007 [178]		10, 0	3 months		
Franklin et al., 2008 [179]	Young adult	64, 4[f]	12 months	2, 3, 5	
Gomez et al., 2008 [180]	Treated with continuous subcutaneous insulin infusion	4, 0	6 months	2	1: Qualitative description only
García-Sáez et al., 2008 [181]	Treated with continuous subcutaneous insulin infusion	10, 0	1 month	2	3
Rossi et al., 2009 [182]		Unclear [g]	3 months		
Rossi et al., 2010 [183]		67, 9[h]	6 months	2	
Cafazzo et	Child, Adolescent	20, 2[i]	3 months	2	

al., 2012 [184]					
Mulvaney et al., 2012 [185]	Adolescent	28, 5	3 months	2	3
Frøisland et al., 2012 [186]	Adolescent	12, 1	3 months		

[a] 1: Differences between pre-defined arms are reported, 2: Differences among individuals are reported (not predefined arms), 3: Results of statistical analysis of the difference are reported, 4: Reasons of the difference are qualitatively reported, and 5: Potential factors associated with level of engagement are investigated.

[b] 1: Granularity of reported change in engagement level (when not described, data are given only for the whole period of intervention), 2: Results of statistical analysis of the change are reported, and 3: Reasons of the change are qualitatively reported.

[c] Three participants did not transmit their data at all

[d] Dropouts might be merged into “inactive” group

[e] The participant stopped using the service after 3 months of use

[f] Four participants did not send a SMS at all

[g] Recruited individuals counted 50, but the values showing simple statistics regarding participants don't correspond to this number

[h] Data were analyzed for all the 67 originally involved participants

[i] In addition to the two dropouts, six participants who did not have sufficient baseline data from the meters for the authors to perform the analysis were excluded from the analysis

Table 3.3 Characteristics of mHealth study for people with T2DM with focus on report about participants' engagement

Study (Authors and year of publication)	Population	Sample size, Drop outs	Intervention Period	Individual difference in engagement level (1-5) [a]	Change in engagement level over time (1-3) [b]
Faridi et al., 2008 [187]	Not insulin treated	15, 5[c]	3 months	2	1: Qualitative description only 3
Forjuoh et al., 2008 [188]		43, 25[d]	6 months	2, 3, 4, 5	1: Every 3 months 2
Sevick et al., 2008 [189]		74, 22[e]	6 months	2, 4	
Cho et al., 2009 [190]		38, 3	3 months		
Turner et al., 2009 [191]	Treated with insulin	23, No info.	Unclear [f]		
Sevick et al., 2010 [192]		123, Unclear	6 months	2, 5	1: Weekly 3
Noh et al., 2010 [193]		24, 2	6 months		
Lyles et al., 2011 [194]		8, 0	3 months	2, 4	
Hussein et al., 2011 [195]		12, No info.	3 months		1: Monthly (Qualitative description only) 3
Lim et al., 2011 [196]	Elderly	51, 2	6 months		
Dick et al.,2011 [197]	African-American in urban area Treated by either insulin and/or oral medication	19, 1[g]	1 month	2	
Katz et al., 2011 [198]		32, 16	12 months	2, 4	1: The first and last 10 weeks
Nes et al., 2012 [199]		11, 4[h]	3 months	2	
Vervloet et al., 2012 [200]		56, 11	6 months	1, 2, 3, 5	1

[a] 1: Differences between pre-defined arms are reported, 2: Differences among individuals are reported (not predefined arms), 3: Results of statistical analysis of the difference are reported, 4: Reasons of the difference are qualitatively reported, and 5: Potential factors associated with level of engagement are investigated.

[b] 1: Granularity of reported change in engagement level (when not described, data are given only for the whole period of intervention), 2: Results of statistical analysis of the change are reported, and 3: Reasons of the change are qualitatively reported.

[c] Five participants did not transmit information altogether

[d] Twenty-five participants did not complete the final (6-month) clinical visit

[e] This number includes dropouts from the control group (n=77)

[f] HbA1c is compared at 3 months after the start of intervention, but otherwise no information was found

[g] One participant did not complete the text messaging portion of the pilot

[h] Four dropped out after enrollment but before intervention started

As observed in Tables and **APPENDIX 2**, there is a great variation in reported contents about participants' engagement including how they dealt with data of participants who dropped out in the course of intervention. Among the 39 articles listed in the Tables, 14 articles report results of their investigations of both individual difference and longitudinal change in participants' engagement. Among the 14 articles, however, one article reports that no participants used the provided mHealth technology at all in the intervention period: An alternative access means, personal computer was used instead. In this case, the mHealth technology was an access to web-based program via Wireless Application Protocol of a mobile phone [163]. Another reports participants' usage based on self-reporting [162]. In addition, some articles don't provide clear enough information about expected engagement [162,163,180,185]. Majority of the articles describe results of inquiries to participants regarding their perceptions and/or user experience. However, relationship between actual attrition of usage or non-usage and reported usability problems often remain unclear. Introduction in Paper 2 provides a summary as well as our arguments for articulation about participants' engagement with mHealth technology, so I will not describe about it further here.

Regarding persuasive technology, "reduction" is the most frequently employed principle. Reduction principle is implemented by automatic data transmission from a meter to a mobile terminal and/or further to a data server [167,169,171,173,174,176,184,186,190,191,194,196,199] and use of customized recipes or meals for quick recording of diet [189,192]. Other principles that are often implemented include: reminder [168,172,175,178,184–187,190,194,195,197,200], suggestion [168,175,182–185], and tailoring [175,176,185,187]. Although in some studies mHealth is used as a basis for communication with health care providers [162,166,170,182,183], principles like social learning or social comparison are incorporated in fewer studies [170,179,184].

Limited number of articles describe its incorporation of HBTs or relevant grounds for design of mHealth [166,170,179,189,192,199], while one study [197] is retrospectively analyzed in comparison with established HBTs [201].

Clear incorporation of UCD for designing mHealth is also limited. One study [184] articulates the UCD process as well as evaluation of the designed mHealth technology, while most of the other cases UCD of employed mHealth is articulated in separate articles [166,173,174,177,185,186,194,199].

To sum up, being consistent with the findings by relevant review works [12–14], reporting of participants' engagement varies a lot and often times very limited. Although reduction and reminder are frequently employed design principles in mHealth technology, incorporation of persuasive technology principles is also limited as well as HBTs and UCD.

3.2 Difficulty in finding food items in a nutrition database of a handheld device-based applications

In this section, I will present a brief summary of problems reported in research studies where food-information database on a hand-held device was used. This summary complements background relevant to Phase 3. A review paper [202] I have co-authored covers the studies of mHealth technology to support diet management for people with diabetes.

ICT, especially handheld devices, have been used for research elaborating on dietary intake assessment and diet education [202–204]. Use of a hand-held device has been considered positive: Burke et al. [204] concluded its feasibility given the fact that no participants withdrew due to difficulty or burden to use; and other research works confirmed its advantages such as giving an instant access to necessary information [205] and helping users develop skills in diet planning [206]. On the other hand, research also revealed many challenges experienced by users, especially inability to find commonly eaten food items in spite of a large number of items included in the database [203–207]. A difficulty in identifying the appropriate food group to search was also reported [204]. The same study also indicated the advantage of users who have knowledge about names of food items to enable quick search by a function that immediately presents the foods beginning with letters which a user had entered. These illustrate that such database requires users to have enough literacy and knowledge about food items. In a design study on dietary monitoring application for patients with low literacy, three methods were compared in 6-week pilot testing by 18 hemodialysis patients with low literacy [208].The three methods are; using barcode and image search to find food items to record, and voice recording. The results showed that icon interface was used most frequently, at average 445 times per participants. Barcode was used at average 42 times per participant and only 71 voice recordings in total were made by six participants. This result indicates that the visual information about foods is easy to recognize. In addition, the very low usage of the voice recording implies that voice recording required knowledge about names of the food items.

4 Materials

4.1 The Few Touch application

As written in the Introduction chapter, the Few Touch application is the core material of this research. The main component of the Few Touch application is the smartphone-based "Diabetes Diary". Diabetes Diary runs on a smartphone with Windows Mobile OS. Core features of the Few Touch application are: (1) automatic wireless data transmission from sensors using Bluetooth, (2) nutrition habit recording enabled by few-touch operation on the smartphone, (3) feedback with simple analysis of three types of data shown by the Diabetes Diary, (4) goal-setting functions for physical activities and nutrition habits, and (5) information function for self-management of diabetes.

Although core features of the Few Touch application remained and a blood glucose meter, OneTouch Ultra 2 (Lifescan Inc., Milpitas, CA) and Polytel Bluetooth adapter (Polymap Wireless, LLC, Tucson, AZ) were used in both Trials I and II, the version of Diabetes Diary was updated several times within the timeframe covered in this research. These updates are a part of design iteration basically based on feedback from users of the Few Touch application. Reasons and rationale for design updates will be described in chapter 6. In this section, I introduce the versions of Diabetes Diary that were used in Phase 1, by using screen design and structure[15].

4.2 Diabetes Diary version 1

Diabetes Diary version 1 was used in the first 56 weeks of Trial I. Figure 4.1 shows the structure and screenshots of each page in version 1. The "Phone (tlf)" button switches to the default home menu of the smartphone. Tapping the button "Change Period" (in Norwegian, "Angi Tidsrom") on screen (d) displays a blood glucose measure graph showing all the data for the set duration. Tapping "low carb. (in Norwegian "lav karb.") snacks", icons for meals, or the "status" button on screen (e) displays screen (f). Tapping "high carb. (in Norwegian, "høy karb.") snacks" or icons for drinks on screen (e) displays screen (g) [209]. Details regarding each function is presented elsewhere [2,22]. A mobile phone used in Trial I was HTC Touch Dual[16].

[15] There are many other smartphone applications that are derivatives of the Few Touch application which have different functionalities in addition to common core functionalities with the versions introduced here. For more details, refer for example [3,186] .

[16] This product is not available anymore. The user manual is available at: http://dl4.htc.com/web_materials/Manual/HTC_Touch2/090901_Mega_HTC_WWE_Manual.pdf (accessed 20th August 2013)

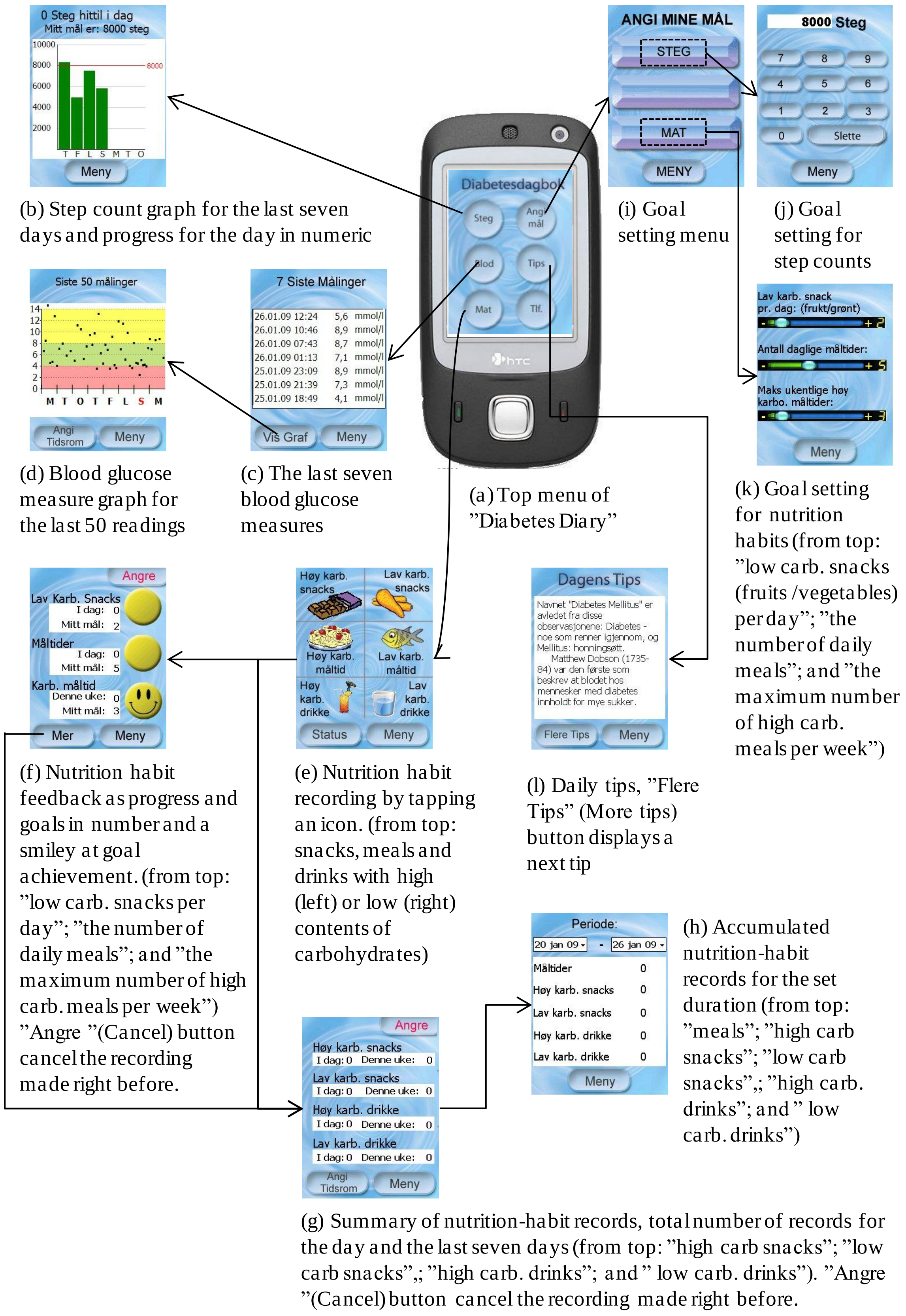


Figure 4.1 Screen design and structure of Diabetes Diary version 1 (Figure 1 of Paper 2)

5 Methods

5.1 Phases 1 and 2

5.1.1 Settings of long-term testing – Trial I and Trial II

Long-term testing is often employed in mHealth research for diabetes as described in chapter 3, as this is the most effective method to evaluate how an application works in relation to its purpose. Long-term testing is used not only for clinical trials but also for feasibility testing to gain better understanding about application use and usefulness in a more qualitative manner [73]. In both trials described below, the participants were provided with a mobile phone as a user terminal of the Few Touch application, but it was up to the participants if they would use it as their personal mobile phone or not.

Phase 1 Trial I was initiated to evaluate how the participants in the design process of the Few Touch application with Diabetes Diary version 1 would use and experience it in their daily self-management activities. The 12 participants took part in Trial I starting from September 2008 in the town of Tromsø where NST is located. The local regional ethical committee approved the study protocol in 2006 (Regional komité for medisinsk forskningsetikk Nord, Ref. No. 13/2006). The recruitment process and other details about the participants are explained elsewhere [22]. The participants were given hands-on instruction about how to use each function. They were also explained that frequency and the way to use the Few Touch application were up to them: the use was voluntary. The participants also tested the Few Touch application with Diabetes Diary version 2 for the last 21 weeks. Diabetes Diary version 2 is the results of implementation of new designs based on users' feedback we obtained in an early phase of Trial I.

Phase 2 Trial II was carried out by involving 11 people with and at risk of T2DM who had NOT been involved in the design process of the Few Touch application. The purpose of Trial II was to understand how the Few Touch application is used, experienced and perceived by target users in general, in a long-term perspective. The Few Touch application with Diabetes Diary version 3 was used. Diabetes Diary version 3 is the results of implementation of new designs based on both users' feedback we obtained in the last 21 weeks of the Trial I and new requirements that arose as prerequisites to serve as a tool for clinical intervention. As described in 1.4, the participants in Trial II were participants in Motivation Group, thus their motivation for self-management was considered as high as the participants in Trial I. The local regional ethical committee regarded Trial II as outside their scope of approval authority. The study protocol was therefore approved by the privacy officer at our local regional hospital (University hospital of North-Norway (UNN)). A mobile phone (HTC Touch 2[17]) without functions as the Few Touch application was distributed in September 2010 to familiarize the participants to the phone. A week later, Diabetes Diary version 3 was installed to the mobile phone and the participants received a blood glucose meter and a Bluetooth transmitter

[17] This product is not available anymore. The user manual is available at: http://dl4.htc.com/web_materials/Manual/HTC_Touch2/090901_Mega_HTC_WWE_Manual.pdf (accessed 20th August 2013)

attached to the sensor as a part of the blood glucose sensor system. Basic instructions about each function were given orally to the participant group. Similarly to Trial I, the participants in Trial II were also explained that the use of the application and how to use it were up to the participants.

5.1.2 Data collection and analysis

5.1.2.1 Usage trends and patterns

In Trial I and Trial II, recorded data on Diabetes Diary were collected at user meetings. One data-set comprised of a timestamp, a value, and a data id. Due to the following reasons, only timestamps were used for the further analyses. To explore usage trends over time, we defined "usage rate" as the number of days per week on which each function was used. Notes regarding reported problems from the participants [2] were used to glean data that reflect actual use as much as possible. For the physical activity sensor system in Diabetes Diary version 1, we assumed that days with step counts greater than zero were the days on which the system was used, unless participants reported any problems with it. This is because the step counter automatically transmits data once a day at a regular time, even if it has not been used on that day.

In order to explore usage trends over time, trend analysis was administered on usage rates. Because usage rates can take only integer values between 0 and 7, Mann-Kendall non-parametric trend test [210] was employed. Usage rates for weeks in which each function was accessible for all seven days were used for analyses. The null hypothesis is that the signs of single differences in target values sum to zero. The test statistic tau is a measure of the monotonicity of the trend and can take a value in range of -1 (monotonic decrease) to 1 (monotonic increase). For Mann-Kendall test, statistic software program R with `MannKendall` function in Kendall package was used.

I used 5% as a significance level simply by following tradition [211] because there is no reasons to reject this. I used 10% as marginal level of significance because of relatively small samples and to pay attention to a potential that the result would imply.

In Phase 1, pattern analyses were conducted to investigate each participant's daily usage pattern of each function for the 56 weeks of Trial I. By following the study by Skrøvseth and Godtliebsen [212], a kernel density estimator with Gaussian kernel smooth was applied on the time at which recordings were made. The analyses were done on only data for blood glucose measurements and nutrition habits, because the physical activity sensor system sent step counts at a regular time by default. Before pattern analyses were conducted, I had observed usage patterns of the two functions by plotting points on a field of date (x-axis) and time of the day (y-axis). Apparent changes over time in usage patterns of nutrition habit recording system were observed whereas the usage patterns of blood glucose sensor system remained over time (**APPENDIX 3**). Therefore, data for nutrition habit recording were divided into two-month intervals so that the analysis would highlight the change in usage pattern over time. Curves for each period are normalized according to the proportion of usage in the period against the whole period. The bandwidth was empirically decided to be one hour by trying different values. For computation of kernel density estimates and drawings of curves, statistic software program R with `density` function and `plot` function was used.

5.1.2.2 Questionnaire

Questionnaire was used with the purpose of collecting information in a comparable form, in terms of both difference among participants and change over time. Both off-the-shelf questionnaire and custom-made questionnaire were used.

System Usability Scale (SUS) questionnaire [59] is widely used questionnaire to quickly and easily assess usability of a product or service [213]. SUS comprises of 10 descriptions to rate by 5-point Likert scale which represent 1: strongly disagree and 5: strongly agree. The score takes a range of 0-100 with step of 2.5. Bangor et al. [214] showed its validity and robustness based on their accumulated SUS data obtained from over 2300 surveys from more than 200 studies. Their study also shows how to interpret absolute SUS score, because there is a negative skew in the distribution of scores. According to their study, the score of 70 or higher indicates that the system or product is acceptable. This is approximately in line with what Sauro advocates based on results from 500 studies [215].

Custom-made questionnaires were used to investigate many relevant issues that were not feasible or sensible to investigate by using standardized questionnaires, by following the results of a case study by Jokela et al. [216].

In Phase 1, SUS was conducted twice: six months and 1 year after the kick-off of Trial I. The first time was to evaluate the Diabetes Diary version 1. The second time was to evaluate Diabetes Diary version 2 which was introduced at that time.

Custom-made questionnaires were made to investigate usability in more detail based on the context of the Few Touch application. The following list shows the summary of questionnaires relevant to this study.

1. Satisfaction with 14 design elements of the Few Touch application (5-point Likert scale)
2. Agreement with motivational effect of each function on better self-management (5-point Likert scale)
3. Agreement with effect of using the Few Touch application on behavior change in activities for self-management of diabetes (5-point Likert scale)
4. Perceived usefulness of the Few Touch application. (7-point Likert scale)
5. Satisfaction level with knowledge about diabetes and with the skills in diabetes management (5-point Likert scale)
6. Expected frequency of usage of the Few Touch application in future (multiple choice from: Daily, Weekly, Monthly, or Seldom)
7. Satisfaction level with the tips function (5-point Likert scale)
8. Agreement with possible improvement of the Few Touch application by incorporating 10 potential functionalities (5-point Likert scale)
9. Agreement with actual improvement in medication, blood glucose control, physical activity level, and nutrition habits (yes/no)

Questionnaires 1 and 8 comprise particular items that had been found essential or important as a mobile terminal-based self-help tool for diabetes in our survey of other relevant studies, summarized into Paper 1 [217]. For details of each questionnaire, please refer Table 4 and Multimedia Appendix 4 of Paper 2 [209]. The participants in Trial I answered to more questionnaires than described above, because of other research activities combined to the cohort.

In Phase 2, a custom-made questionnaire was the main source to gain understanding about users' experiences of the Few Touch application in Trial II. The reason for this is twofold. Firstly, questionnaire enables an efficient and systematic comparison of results of users' experiences by the participants in Trial II with those by the participants in Trial I. Secondly, due to the setting of Trial II, data collection needed to be done within a very limited time. As described above, Trial II was administered in a setting of Motivation Group. The group organized regular meetings on every Monday in the early evening at an education room in the Harstad hospital[18]. Thus all the meetings in Trial II were arranged as a part of the regular meetings of Motivation Group. The regular meetings included other events as well, so the time that could be allocated to Motivation with Mobile project and Trial II was very limited. Due to these reasons, the questionnaire was designed mainly in the multiple-choice format with an option to add free-text comment. The questionnaire comprised of 74 major questions. English translation is attached as **APPENDIX 4**. The questions and options for answers were designed based on results of Trial I and a questionnaire that Norwegian Diabetes Union administers to participants in Motivation Groups. SUS was used as a part of the questionnaire.

5.1.2.3 Interview

Interview was used to obtain better insight of interviewees in their words so that they would account for more nuanced and precise opinions compared to a questionnaire with fixed options to answer [57].

Phase 1 Both individual interviews and focus groups were employed. These interviews were basically led by the project leaders of Lifestyle project [1] in which design and development of the Few Touch application was carried out. In order to increase the chance that all the participants could attend, most of the time two focus groups were scheduled in a week for the same purpose. Interviews were semi-structured. The questions used in the interviews were designed to identify the participants' experiences of the Few Touch application in relation to self-management activities. All interviews were audio recorded.

For analysis of the data, we employed thematic analysis. Thematic analysis is a method for identifying, analyzing and reporting patterns (themes) within data [218]. This method is also used as a method for a systematic literature review [219]. Because of the strong relevance between the questions and the aim of the analysis which addressed understanding usage and experiences of the Few Touch application, we followed the framework suggested by Braun and Clarke [218] in which codes and themes were identified at semantic level using a theoretical approach. Transcripts of focus group interviews at Meeting 4, when six months have passed since the start of Trial I, were divided into data extracts. These data extracts were sorted into pre-determined category (or categories) and simultaneously coded. The categories were combinations of topics in group A and B described in Table 5.1.

Table 5.1 Pre-determined categories for thematic analysis of interview transcripts in Phase 1

Group A	Group B
How a participant: 1. used 2. experienced (i.e., what happened or did not happen to the	With regard to: A. as a whole application or in general B. each function or component C. user interaction design (i.e., navigation

[18] http://www.unn.no/unn-harstad/category20627.html

participant by using the Few Touch application or a component of it) 3. perceived the Few Touch application	and information/menu structure) D. user interface (screen) design

This coding was done by me and the second author of Paper 2 [209] independently. In the case of conflicts, we discussed until we got agreement upon. After coding, I searched, reviewed, and revised themes. The second author of Paper 2 [209] inspected them. Again, we discussed the themes till we got agreement upon. The data sets obtained from other interviews were used to corroborate or modify the results of the analysis above. This is because Meeting 4 was the first occasion of interview after the participants obtained and used all the functions of the Few Touch application, and the information we obtained therefore was the richest. This approach was taken partly inspired by how the development of a grounded theory progresses: “first data is collected and analyzed to identify categories, then that analysis leads to the need for further data collection, which is analyzed, and more data is then collected [57]”. The findings from the thematic analysis were investigated by collating results of questionnaires and analyses of usage data. The results were used to explain mechanisms of the participants’ engagement with the Few Touch application over time and factors associated with usability of the application.

Phase 2 To supplement the answers to questions about experiences and usability of the Few Touch application usability, a focus group session was held two months after the Trial II start. This was led by the project leader of Motivation with Mobile project, in the form of semi-structured interview. Similarly to Phase 1, questions were directly relevant to experiences and usability of the Few Touch application. Therefore, their quotes were simply and semantically summarized [57].

5.2 Phase 3

Unlike Phases 1 and 2, Phase 3 is about the very early stage of a design process until the first working prototype was made and pilot tested.

The design process basically followed the HCD process defined in ISO13407 [23].

First, inquires were made to “understand and specify the context of use” and “specify the user requirements” [23]. “Producing design solutions” [23] followed. As a part of this design activity “producing design solutions”, working prototypes were made for a pilot test to find usability flaws.

At this early stage of design process, results of data collection and analysis influence the next step to take in terms of concrete methods to take for both data collection and analysis. In order to enhance readability by keeping the flow, I will describe concrete methods and materials as well as corresponding results in Chapter 8 and will introduce methods employed and the rationale in this section. Overview of research and design activities is described in 1.3.2.2.

5.2.1Initial requirement identification

Inquiries 1-3 were made to the participants in Trial I. Inquiry 4 was made to the two project leaders of Lifestyle project [1].

At Inquiry 1, a custom-made questionnaire was administered to collect user needs regarding methods for access to information relevant to T2DM and situations in which they would need the information. Four questions were made to ask the participants' needs regarding information function of the Few Touch application (**APPENDIX 5**). Questions were made in the multiple-choice format, for two questions with an option to add free-text comment as well. Intention of using multiple-choice style was to investigate whether or not user needs that only a few participants had explicitly expressed were actually common user needs. Therefore, the items in each question reflected feedback we obtained in Trial I. The results were simply summarized into a table.

At Inquiry 2, card sorting technique was used to understand users' mental model about organization of information and concepts in order to design information architecture enabling an efficient access to information [58,220]. This technique was used to redesign structure of the information function of the Diabetes Diary. In this particular case, the attention was paid to keep the "Few Touch" principle: to organize information so that users don't need to scroll the page. The intention was thus to know: what types of categories the users expect to find at the menu page (the top level) of the information function; what types of information they expect to see immediately under each category (the second level); and what types of information they would like to see or read in case they are interested in details of the topic by pressing "more info" button (the third level).

An open card sorting method [58] was employed with a modification so that the participants could make their own grouping of information and hierarchy in each group.

Results of card sorting were analyzed using Hierarchical Cluster (HC) analysis and Multi-Dimensional Scaling (MDS) [58]. Although I employed hierarchical structure for each group in this card sorting, it is still non-parametric and difficult to quantify. Thus a distance between cards was defined as follows: a distance between cards in a same group is 0, and a distance between cards in different groups is 1, regardless of a level in which each card was placed at. For HC analysis and MDS, I used the summed data of results by all the participants. Statistic software program R was used for calculation and plotting.

At Inquiry 3, paper prototyping technique was used as a basis to gather ideas and preference on information to display in a detail view of a food item as a part of food-information database module of the information function. Hand-drawn sketches were made in the actual size of the display so that the participants could visualize how reasonable the size of text and the amount of information would be [221]. Hand-drawn sketches were used instead of realistic graphics by following the strategy taken by Årsand et al. to the same participants [222]. A visual analogue scale (VAS) was used for rating of each design idea. This scale is typically using a 10 cm-long straight continuous line with two verbal descriptors at the extremes on each edge [223]. An answerer is expected to make a cross on the line where s/he considers most appropriately describing what s/he perceives about the issue in question. VAS has been historically used as a valid measure of intensity of pain [224–226], but there are some attempts to use it for evaluation of perception of object in HCI field [223,227]. The study by Van Shaik and Ling [223] concluded that 7-point Likert scale and VAS are equally good for psychometric online questionnaire. Because the participants in Trial I mentioned that it is difficult to decide on which score to rate at 7-point Likert scale, for example either 5 or 6, I decided to use VAS instead.

To compare the scores given to the four designs, Kruskal-Wallis one way analysis of variance by ranks was used. As a post-hoc test of Kruskal-Wallis, I used Bonferroni correction [228] on the results of Wilcoxon test on each pair of samples. Bonferroni correction is criticized for its main weakness explained as “the interpretation of a finding depends on the number of other tests performed” [228]. The same author [228] also states that “a final situation in which Bonferroni adjustments may be acceptable is when searching for significant associations without pre-established hypotheses”. At Inquiry 3, we did not have any pre-established hypothesis. Considering this fact and the relatively small number of total Wilcoxon test (all combination of four designs generates six pairs), we employed Bonferroni correction. Details of each test method can be found for example in a book by Wohlin et al. [229]. Software program R was used for calculation.

Focus group sessions were carried out after the participants completed the questionnaire to hear their opinions about suggested design alternatives and their needs for food-relevant information. The sessions were led by the project leaders of Lifestyle project [1], but I also asked supplemental questions accordingly. Collating audio records, their opinions written in the free form on the questionnaire, and the notes taken during the focus group sessions, their needs and opinions were categorized and summarized.

Inquiry 4 Based on findings from Inquiries 1-3 and results of relevant literature, an inquiry was made to gather requirements to design the food-information database module as an education tool. The topic was concentrated around user interaction design and usage scenario to design tasks at usability testing. Inquiry was made to the two project leaders of Lifestyle project [1] as both domain experts and stakeholders of the project. Both two leaders had been diagnosed with T1DM for more than 10 years at the time of 2010, and they were very skilled in terms of self-management. For approximately 10 years, they had been engaged in research projects focusing on patients with diabetes (both T1DM and T2DM) and people caring them. As patients with T1DM, they were also users of the Few Touch application. In all senses that they were skilled patients with T1DM, users, and research project leaders, they were regarded as domain experts. Due to an exploratory nature of the aim of this inquiry, unstructured individual interview was administered. Notes were taken and the main issues of interest were summarized, following the manner introduced by Sharp et al. [57].

5.2.2 Concept design

5.2.2.1 Conceptual model

Johnson and Henderson [230] define conceptual model as “a high-level description of how a system is organized and operates”. In the interactive system context, it shows an “idealized view of the how the system works” [230].

I developed conceptual models of user-interaction designs for functions to search and compare food items in a food-information database module by specifying and describing the followings:

- The major design metaphor (and analogy, if any)
- The concepts (task-domain data objects, attributes and operations)
- The relationships between concepts

- The mapping between the concepts and the task-domain

I followed the framework that Johnson and Henderson suggested [230].

5.2.2.2 Prototyping for presentation

Houde and Hill [231] define three types of prototypes according to the focus:

- Role: referring to "questions about the function that an artifact serves in a user's life – the way in which it is useful to them"
- Look and feel: denoting "questions about the concrete sensory experience of using an artifact – what the user looks at, feels and hears while using it"
- Implementation: referring to "questions about the techniques and components through which an artifact performs its function" – "how it actually works"

Here artifact is defined as "the interactive system being designed" [231]. Prototypes may explore design space with a single focus or more foci.

To gather opinions to the design concepts of a food-information database module from the participants in Trial I, a role prototype of the design concept with partial focus on look and feel was made and presented. It was a low-fidelity role prototype [231] with a moderate resolution. A variety of animation functions of Microsoft Office PowerPoint 2007® (PPT) were utilized to help the participants concretely visualize the design concepts for user interaction.

Focus group sessions with semi-structured interview were held after the presentation of design concepts to the participants in Trial I. Notes was taken and the sessions were audio recorded. Audio records were listened and main issues of interest were summarized.

5.2.3 Prototyping for pilot usability testing

Two interactive prototypes were made based on HTML and JavaScript for the pilot usability testing described below. For these prototypes, combination of "role" and "implementation" with partial focus on "look and feel" was used due to the aim of the testing with focus on testing fundamental functions. One was to implement the user-interaction design concepts. The other is to implement more traditional user interaction designs, i.e., text- and number-based design with hierarchical data structure using a list for the purpose of comparison.

5.2.4 Pilot usability testing

A pilot usability testing was administered to find usability flaws of the proposed design concepts as well as to examine advantages and disadvantages of it with regard to fundamental functions.

Usability testing is normally conducted in a controlled environment unlike field testing such as long-term testing described above. The purpose is typically to measure performance of certain tasks and to elicit users' opinions to make them as basis for improvement of the design [57].

Pilot study is run to make sure the proposed methods are viable before going into the main study. This enables avoiding wasting resources and time of the participants as well as avoiding frustrations of the participants. Therefore, when we found any flaws in methods, we made changes in methods accordingly. In pilot study, convenient samples such as colleagues or peers are asked to participate, if access to the real target users is limited [57].

As **data collection** methods; pre- and post-test questionnaires, automatic data recording of task completion time and task answers by implemented program in prototypes, post-test semi-structured interview were used.

For questionnaires, both custom-made questionnaires and off-the-shelf questionnaires were used.

Pre-test questionnaire was to ask participants' demographic information (gender and age-bracket [20<40, 40<60, 60+]) and the previous experiences relevant to the tested prototypes.

Post-test questionnaires (**APPENDIX 6**) included a custom-made questionnaire made to ask participant's preference on tested prototypes in terms of tested functions and as a whole system. It also asked reasons for preferences. Off-the-shelf questionnaires, SUS and pragmatic quality dimension of AttrakDiff™ [60], were also included.

AttrakDiff™ [60] "is an instrument for measuring the attractiveness of interactive products". Leuteritz et al. showed that AttrakDiff™ is a good measure of satisfaction of a system [232]. Questionnaire comprises of many items using semantic differential scale divided into seven points with range of -3 to 3. An answerer is expected to place a cross at the point which s/he thinks describes best the product or system to evaluate. Four dimension; "pragmatic quality", "hedonic quality – stimulation", "hedonic quality – identity" and "attractiveness" can be evaluated in AttrakDiff™. Due to the focus on functionality, only pragmatic quality dimension was used at the usability testing in Phase 3. This decision is supported by the study by Büring et al. [233] which evaluated functionality of zoomable user interfaces (ZUI) on a hand-held device using scatter plot concept to search films. The following shows the word pairs used to evaluate pragmatic quality dimension (left: -3, right: +3).

- Technical – Human
- Complicated – Simple
- Impractical – Practical
- Cumbersome – Straightforward
- Unpredictable – Predictable
- Confusing – clearly structured
- Unruly – Manageable

Non-parametric tests based on ranks were used to compare; scores of SUS and pragmatic quality dimension of AttrakDiff™ given to the two prototypes, and task completion time by the two prototypes. Regarding the scores given to the questionnaires, the reasons for choice of non-parametric methods are described in 5.3. Regarding direct measure, such as task completion time, normality could not be assumed in distribution of samples because many different reasons for time-loss were observed. When samples are repeated measures, such as scores of questionnaires, Wilcoxon test was used. On the other hand, when measurements in two samples could not be paired, Mann-Whitney test was employed. Such cases are typically when a participant completed a task with one prototype but did not with the other.

5.3 Interpretation of subjective scores

Not all the numerical data are in the form of ratio or interval scale [229]. For example, scores obtained by Likert-scale are in the ordinal form. In principle, ordinal scores obtained with Likert-scale should not be treated as interval scale. Jamieson [234] criticizes that this “rule” is commonly neglected even in medical education: some of them use even parametric analysis. HCI field is not an exception, because there are some studies which use parametric analysis of scores obtained with Likert-scale (for example [235,236]). On the other hand, Good [237] calculates mean and standard deviation (SD) of scores obtained with 7-point Likert scale, but analyzed with non-parametric test (Wilcoxon matched-pairs signed-rank test) because normality cannot be assumed for semantic differential scores. Confidence intervals were computed for the median rather than mean. In their attempt of meta-analysis to investigate relationship between subjective satisfaction and task performance, by using three transformations, Nielsen and Levy [238] normalized raw scores that were obtained typically using Likert-scale in the collected studies. They advocate that “it is theoretically impossible to arrive at a perfect such estimate given the nature of the original data, so one should not depend on the exact value of any single score”.

As Jamieson recommends [234], researchers ought to address appropriateness of employed methods for handling scores obtained from ordinal scale. Below, I will address rationale for choice of methods to compare results of data collected using ordinal scale.

SUS questionnaire results (Phases 1-3) According to Brooke [59], calculation of SUS score is done in the following manner:

> “To calculate the SUS score, **first sum the score contributions from each item**. Each item's score contribution will range from 0 to 4. For items 1,3,5,7,and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. **Multiply the sum of the scores by 2.5** to obtain the overall value of SU”.

The calculation includes adding up of scores obtained by using ordinal scale as well as multiplication of the sum. This fact already indicates an assumption that the SUS score is treated as interval scale. As Bangor showed in his study, the distribution of SUS scores is normally skewed and linearity of score cannot be assumed [214]. However, the very same study employs simple statistics such as measure of mean and SD of SUS scores. Moreover, the study shows how to interpret absolute value of SUS score. Based on these facts, I show results of SUS scores with mean, SD and range of scores. However, when I compare SUS scores between different designs, I use non-parametric methods.

AttrakDiff™ questionnaire results (Phase 3) AttrakDiff™ questionnaire also uses “average” measure for evaluation of a product in each dimension[19]. This indicates that “by definition”, AttrakDiff™ assumes that the scores obtained by 7-point Likert scale can be handled as values following interval scale. Therefore, I will take the same position as I did for SUS questionnaire: I show results of AttrakDiff™ questionnaire score in pragmatic quality

[19] See the demo project results at http://www.attrakdiff.de/files/demoproject_results.pdf , page 5

dimension with mean, SD and range of scores. However, when I compare AttrakDiff™ scores between different designs, I use non-parametric methods.

Custom-made questionnaires with Likert-scale (Phases 1-3) For custom made questionnaires with Likert-scale, typically with 5-point, there is no discussion to assume the scores following interval or ratio scale. Therefore, I use distribution of participants depending on the given score[20].

VAS scores (Phase 3) In studies where VAS score was used to express intensity of pain, it is shown that VAS score has property of linearity [225,226]. Therefore, I assumed that VAS scores follow interval scale and took mean and SD. For each sample (for the case of Inquiry 3 in Phase 3, each design), I tested normality of distribution by Shapiro-Wilk normality test [239] by statistic software program R with `shapiro.test` function before going to further tests.

5.4 Ethics for human-subject involvement

Following the HCD principle [23], human subjects were included in this research. The absolute ethical principle for inclusion of human-subject is to protect them and their right. The followings were particularly well explained to the potential participants as ground for making decision on participation.

- The research purpose and handling of collected data anonymously.
- Voluntary participation and right to withdraw anytime without telling the reasons.

5.4.1 People with and at high risk of T2DM as users of the Few Touch application

Declaration of Helsinki by The World Medical Association [240] prescribes “ethical principles for medical research involving human subjects, including research on identifiable human material data”. In Phase 1 and 2, people with and at high risk of T2DM participated in trials of the Few Touch application.

Phases 1 and 3 All the participants in Trial I had been participating in a design and development research of the Few Touch application and Trial I was a part of the research. Approval of the research protocol (Regional komité for medisinsk forskningsetikk Nord, Ref. No. 13/2006) and the recruitment process are well explained elsewhere [2]. Applications for prolongation of Trial I and continuation of design and development research where the same patients would be involved were approved by the local ethical committee at an appropriate timing. These applications included registration of new researchers including me who would have access to data collected from the participants. In this manner, inclusion of the participants in Phase 3 was also approved. The participants signed on information consent for further participation in the study at the end of the planned period of involvement.

[20] In Paper 2, the results of questionnaire which used Likert scale are shown in the form of mean score. By taking the position written above, I made errata for this in the end of the main body of this dissertation.

Phase 2 All of the participants in Trial II were participants in the "Motivation with Mobile project" and they started using the Few Touch application since October 2010 after signing up the informed consent to the project. Because the late decision to take advantage of the research opportunity to collect data from Motivation with Mobile project, an application for approval of research protocol for Trial II was submitted to a local regional ethical committee in December 2010 (Regional komite for medisinsk og helsefaglig forskningsetikk REK nord, 2010/3386-4). The committee however regarded Trial II as outside their scope of approval authority in January 2011. The study protocol was therefore approved by the privacy officer at our local regional hospital (UNN) in the same month. A document with explanation in detail about Trial II was given to the participants in Motivation with Mobile project on 28 February 2011. At the same time, the summary regarding difference between the Motivation with Mobile project and Trial II was presented orally. The summary points of the Trial II with regard to difference from Motivation with Mobile project are the following:

- Trial II includes collection of data recorded on the Diabetes Diary during the period that a participant used the application as a participant of Motivation with Mobile project.
- Trial II includes analysis of the collected data.
- Trial II includes use and analysis of any given feedback and suggestions they will give and have given to NST in the meetings held within Motivation with Mobile project, in the form of interview and questionnaire.
- Trial II requires participants not to have taken part in the design and development process of the Few Touch application

All the participants in Motivation with Mobile project understood the difference in the two projects, Motivation with Mobile project and Trial II, and signed the informed consent to Trial II. This procedure was taken based on advices by legal advisors at NST and UNN. It enabled us in Trial II to collect and analyze the data accumulated in the Few Touch application and to use the audio record of a focus group interview conducted in November 2010.

5.4.2 Healthy volunteer-testers in usability testing

Phase 3 Healthy volunteers were recruited to participate in the usability testing as testers. The participants were recruited among those working at the office of NST regardless of their affiliation. An invitation for usability test scheduled for one hour was sent by e-mail together with explanation about the test in English (**APPENDIX 7**). This explanation was orally given right before the testing as well, and their voluntary participation was orally confirmed. The tested prototypes are basically of no interest or relevance for the testers. In such cases, normally some rewards or incentives to the participants should be prepared at completion of testing [57]. Although no monetary compensations or extrinsic rewards could be prepared, employees at NST could register the time they spent on testing as their working hours instead.

6 Phase 1

The purpose of Trial I was to understand how a design solution developed in a user involved process was experienced by the same users, in a long-term perspective. By a thematic analysis of the collected data, we investigated mechanism of the users' engagement with the application as well as factors associated with usage of the application. Based on the feedback from the participants, design of the Few Touch application was iteratively updated and introduced to them. In this chapter, I report the results by dividing the trial period into two: the first 56 weeks with Diabetes Diary version 1 and the last 21 weeks with Diabetes Diary version 2.

6.1 Trial I – the first 56 weeks

Twelve patients with T2DM, who had been involved in the design process of the Few Touch application [2,222,241,242], took part in a long-term testing of the Few Touch application (Trial I) with Diabetes Diary version 1 from September 2008. The participants were 4 men and 8 women, age ranged from 44 to 70 with a mean age of 55.1 (SD: 9.6) and mean disease duration was 8.1 (SD 3.8) years at the beginning of the trial [209]. Hereafter, participants in Trial I are expressed by the code "Pxx" whereas "xx" indicates the participant's ID number. Table 6.1 shows a chronological table of events in the first year of Trial I.

Table 6.1 Time chart of Trial I (first 56 weeks)

Meetings	**Time (month, year) and the number of elapsed weeks**	**Events**
1	September 2008 [a],(Week 0)	Introduction of the Few Touch application (except physical activity sensor system and tips function)
		Questionnaire 5
2	October 2008, 7 weeks	Introduction of the information (tips) function
		Focus group sessions
3	December 2008 [b] - January 2009 [c] (13, 17 and 18 weeks)	Introduction of physical activity sensor system
		Individual semi-structured interview
		Questionnaire 4 and 7
4	March 2009, 26 weeks	Focus group sessions (the participants were

		divided into two groups)
		Questionnaire 1, 2, 4-8
		SUS questionnaire
5	June 2009, 38 weeks	Focus group session [d]
		Updating of Diabetes Diary with new user-interaction designs of tips function and nutrition habit recording function
		Inquiry 1 and 2 in Phase 3 (8.1.1, 8.1.2)
6	October 2009, 56 weeks	Focus group sessions (the participants were divided into two groups) [e]
		Questionnaire 3-7, 9

a. For P07 and P11, the application was introduced on 1 and 7 October 2008, respectively
b. Two participants attended an individual meeting
c. Ten participants attended an individual meeting
d. Ten participants attended the focus group session.
e. 11 participants attended the focus group session.

The participants started using the Few Touch application only with the blood glucose sensor system and the nutrition habit recording system. The information (tips) function and the physical activity sensor system with a step counter were introduced at Meeting 2 and 3, respectively (Table 6.1). Trial I was originally planned to last six months. The participants voluntarily continued participation in the study after the first six months. In the course of Trial I, the participants frequently attended meetings as shown in Table 6.1. We collected data regarding experiences of the Few Touch application in the forms of interviews, questionnaires and recorded data in the Diabetes Diary. Recorded data were collected at all the meetings. For details of original questionnaires administered in Trial I, please refer Multimedia Appendix 4 of Paper 2 [209].

Reflecting feedback from the participants as well as the results of a heuristic evaluation, user-interaction designs were updated at Meetings 4, 5 and 6, as introduced in 6.1.3 and 6.2.2. In addition, inquiries for Phase 3 were also carried out since Meeting 5[21]. Therefore, Trial I can be considered as a part of an iterative design process rather than a mere testing of an application.

[21] Table 4.1includes only relevant inquiries to the studies included in this dissertation, however, inquiries for other studies were also carried out.

6.1.1 Results of data collection and analyses

6.1.1.1 Questionnaire

Figure 6.1 shows the distribution of the answers to a questionnaire about perceived usefulness of the Few Touch application in the course of the first 56 weeks. As it shows, their perceived usefulness of the application remained considerably high for over a year.

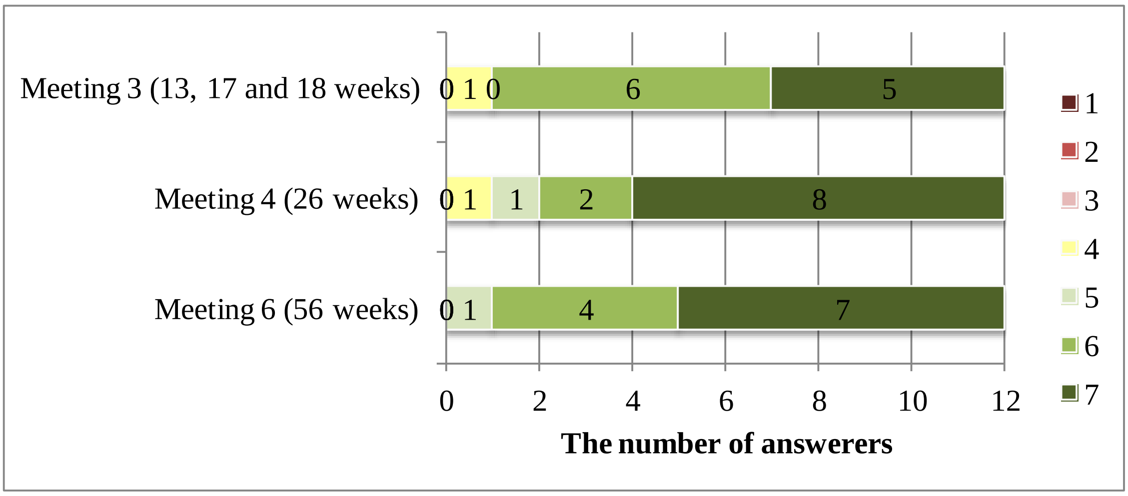


Figure 6.1 Distribution of the answers to Questionnaire 4 about perceived usefulness of the Few Touch application (1: Not useful at all, 7: Very useful).

Questionnaire 1 comprised items that had been essential or important as a mobile terminal-based self-help tool in the literature review. Results of this part of the questionnaire (Figure 6.2) show that the participants were generally satisfied with design elements of the Few Touch application with one exception of the size of the mobile phone.

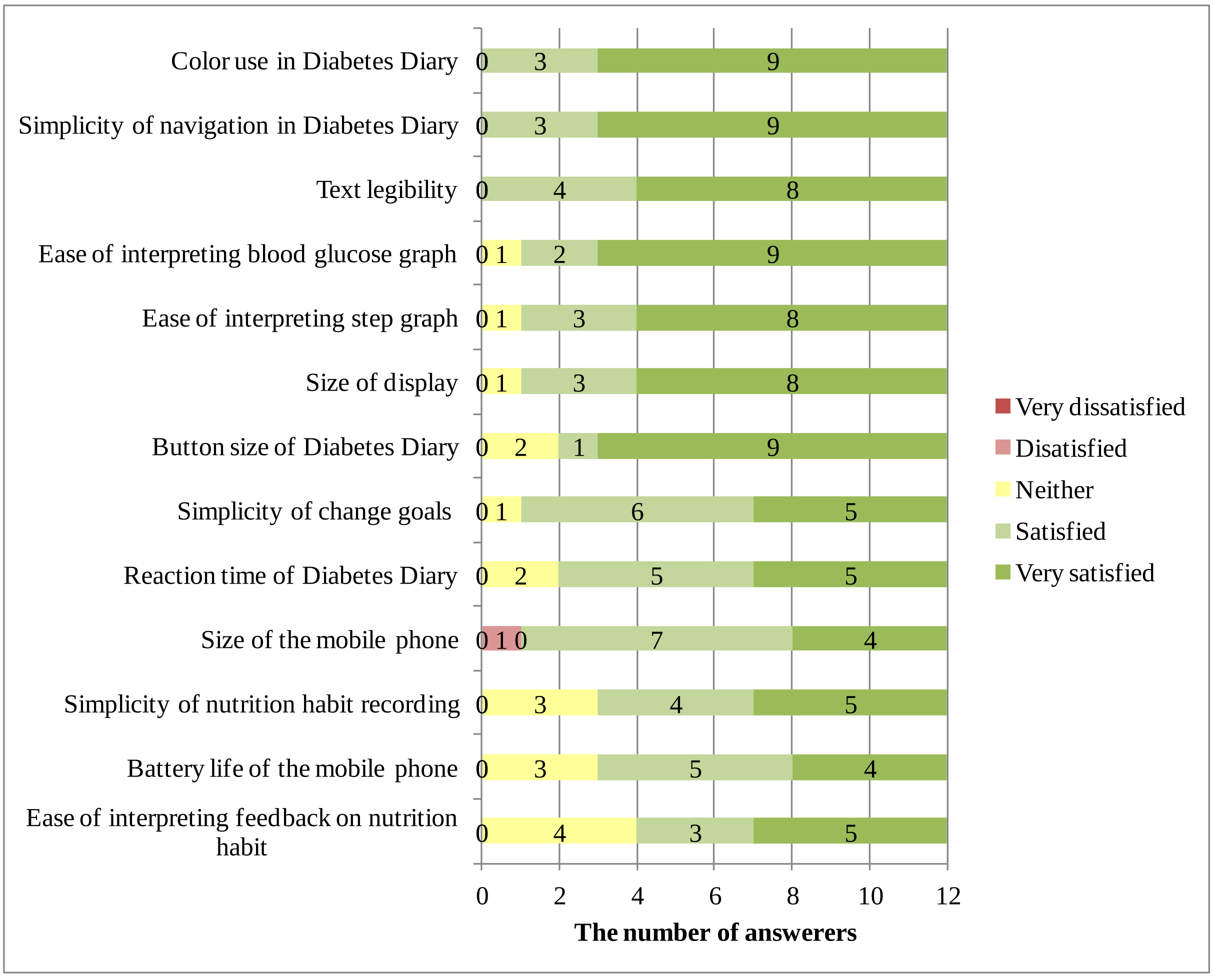


Figure 6.2 Distribution of the answers to Questionnaire 1 about satisfaction with elements of the Few Touch application[22]

Results of Questionnaires 2 (Figure 6.3) show that the participants generally agreed with each function's motivational effect on better self-management. The exception was that two participants disagreed with motivational effect of the nutrition habit recording system. Considering the high agreement level with the motivational effect, results of Questionnaire 3 (Figure 6.4) indicate lukewarm agreement level with effect of using the application on actual behavior change in self-management.

[22] The same results are summarized into Table 9 in Årsand's dissertation [2] and Questionnaire 1 in Multimedia Appendix 4 in Paper 2. In the dissertation, my name is acknowledged as an author of the questionnaire (p. 347) In Paper 2, it is annotated that the table is adopted from [2].

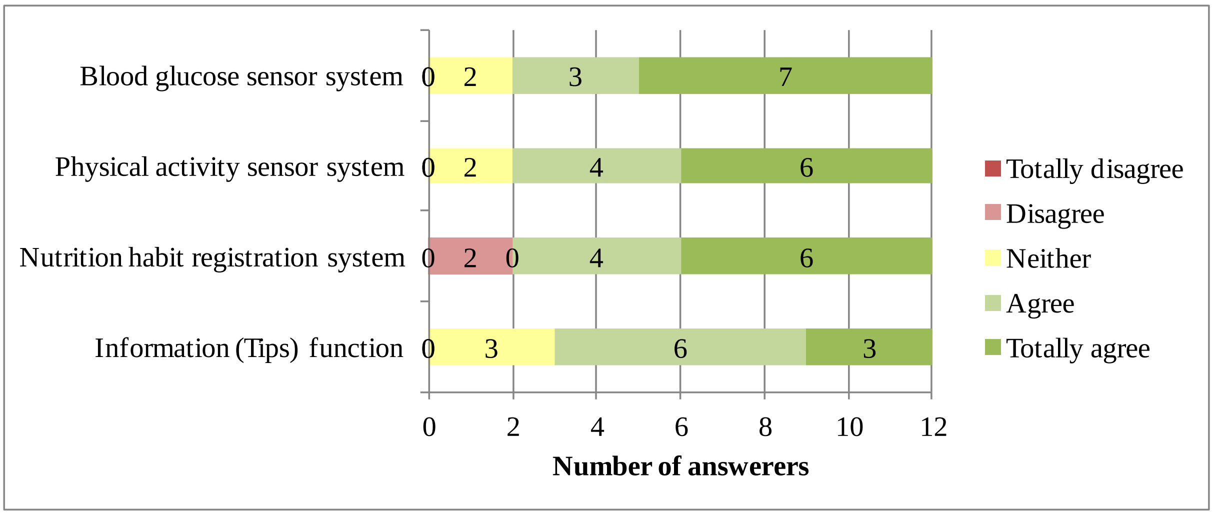


Figure 6.3 Distribution of the answers to Questionnaire 2 about agreement with motivational effect of each function on better self-management

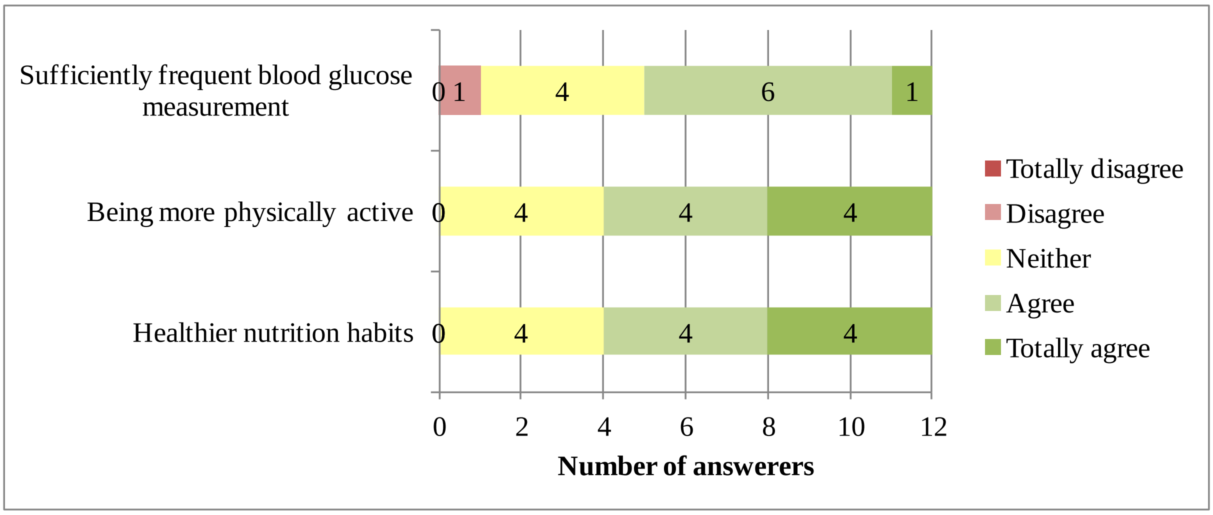


Figure 6.4 Distribution of the answers to Questionnaire 3 about agreement with effect of usage of the Few Touch application on behavior change in activities for self-management of diabetes

The results of Questionnaire 5 about satisfaction level with knowledge about diabetes and with skills in diabetes management did not show drastic change in the course of the first year (Multimedia Appendix 4 in Paper 2). Satisfaction level with the information function showed decreasing tendency over a year as well. (Multimedia Appendix 4 in Paper 2, Questionnaire 7). All of the results to Questionnaires 2-5 and 7 are reflected by the results of Questionnaire 9 asking about any improvement in the course of the trial where eight, seven and six participants answered “yes” to level of physical activity, nutrition habits and blood glucose control, respectively.

The results of Questionnaire 8 (Figure 6.5) show their preference on a smaller step counter and most of the automatic functions. On the other hand, the features that involve other people to use the application were less appreciated. This indicates that the participants were mostly satisfied with using the application for self-help purpose.

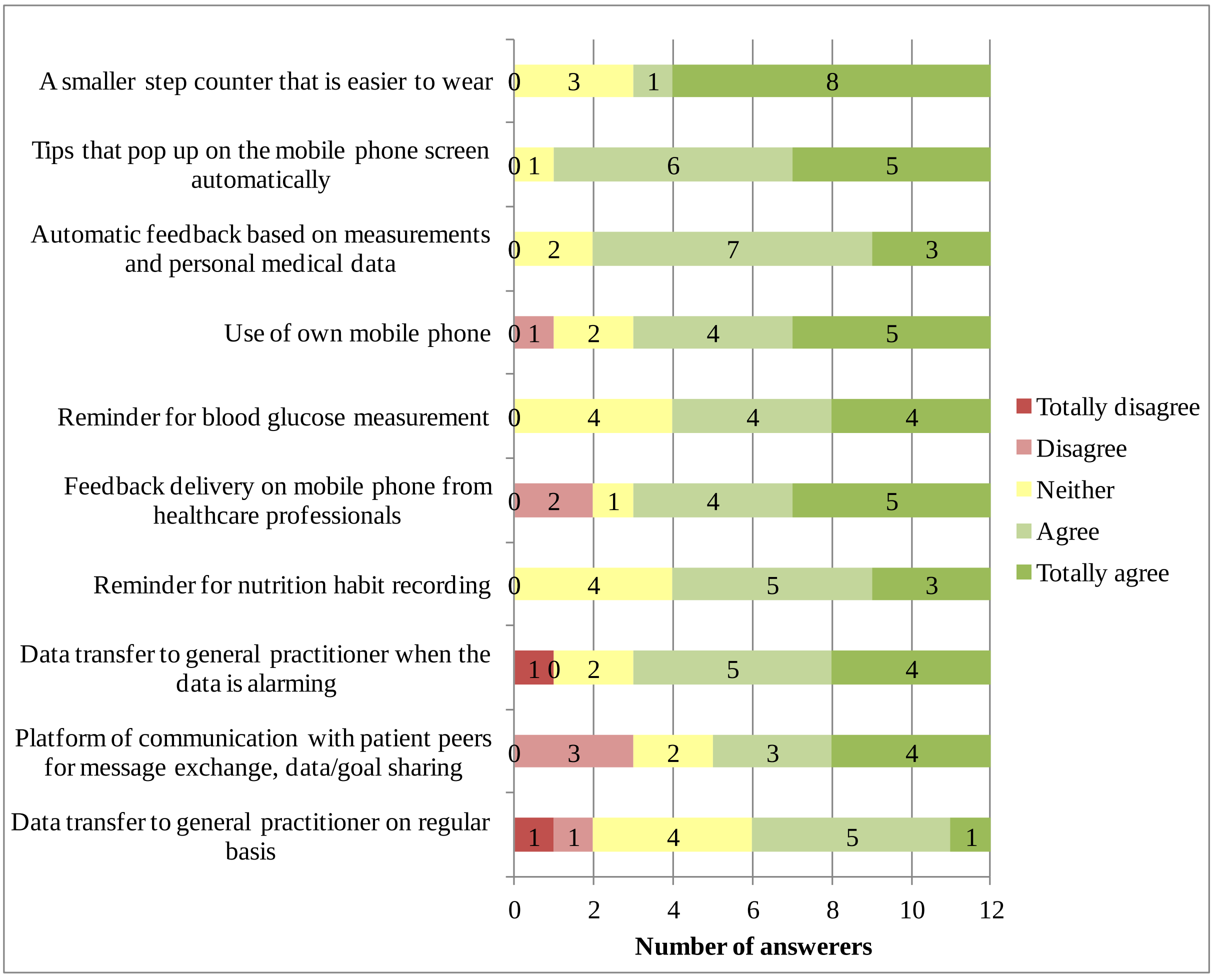


Figure 6.5 Distribution of the answers to questionnaire 8 about whether or not the participants wish to have specific elements in the Few Touch application[23]

Ten out of the 12 participants answered that they would use the Few Touch application daily in future at Meeting 4 while the rest (two) answered "weekly" to Questionnaire 6. However, at Meeting 6, the number of the participants who answered "daily" decreased to seven, and four and one answered "weekly" and "monthly", respectively.

6.1.1.2 Usage trends and patterns

Table 6.2 shows the results of Mann-Kendall trend test on usage rate of each function by each participant.

[23] The same results are summarized into Table 10 in Årsand's dissertation [2] and Questionnaire 8 in Multimedia Appendix 4 in Paper 2. In the dissertation, my name is acknowledged as an author of the questionnaire (p. 347) In Paper 2, it is annotated that the table is adopted from [2].

Table 6.2 Results from Mann-Kendall trend test on usage rate for the first 56 weeks (Table 2 in Paper 2[209])

Participant	**Blood glucose sensor system**		**Nutrition habit recording system**		**Physical activity sensor system**	
	Tau-value	*P*-value	Tau-value	*P*-value	Tau-value	*P*-value
P01	-0.19	.06	-0.58	<.001	-0.57	<.001
P02	0.22	.03	-0.01	.91	-0.10	.46
P03	-0.01	.96	0.16	.14	0.21	.16
P04	-0.35	.002	-0.37	<.001	-0.62	<.001
P05	-0.41	<.001	-0.18	.07	-0.16	.18
P06	-0.31	.003	-0.39	<.001	-0.43	.001
P07	-0.11	.33	-0.58	<.001	-0.58	<.001
P08	-0.06	.56	-0.34	.002	0.12	.47
P09[a]	-0.05	.70	-0.37	.002	-0.35	.08
P10	-0.54	<.001	-0.42	<.001	-0.35	.01
P11	-0.45	<.001	-0.71	<.001	-0.27	.05
P12	-0.63	<.001	-0.61	<.001	-0.07	.69

[a] All the recorded data on P09's smartphone were accidentally deleted at Meeting 2, and only data recorded after Meeting 2 were used for analyses.

The test results confirmed a significantly decreasing usage trend among10 out of 12 participants. This is in line with the decreasing tendency in measurement frequency observed in statistical analysis of aggregated blood glucose readings by all the participants for one year [212]. Due to the late start of using the physical activity sensor system and battery attrition for the step counter, the period that the system was available (range: 132-265 days, median: 199.5 days) was much shorter than the other two systems (range: 352 (P09, see the annotation "a" at Table 6.2) -393 days, median: 393 days). This fact requires readers' attention in interpreting the results.

Figure 6.6 summarizes the degree of usage of each function for the period in which each function was available. Degree of usage is expressed as a percentage of the number of days on which a function was used against the period which each function was available. In the figure, BG, NH and PA stand for the blood glucose sensor system, the nutrition habit recording system and the physical activity sensor system, respectively.

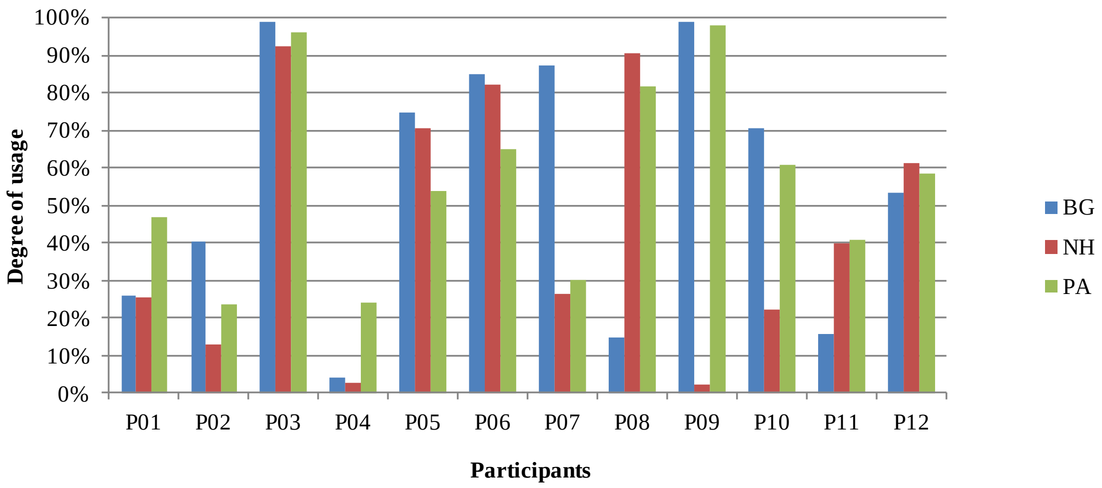


Figure 6.6 Degree of usage of three functions

As shown in Table 6.2 and Figure 6.6, analysis of data by each individual participant revealed the diversity in usage of the application: degree of usage is different among the participants, degree of usage changed over time, and the degree of change in the level of usage varied among the participants. The trends in usage rates shown in Multimedia Appendix 1 in Paper 2 also visually illustrate the diversity.

Figure 6.7 shows the distribution of blood-glucose measurement frequency among days on which any blood glucose measurement was performed.

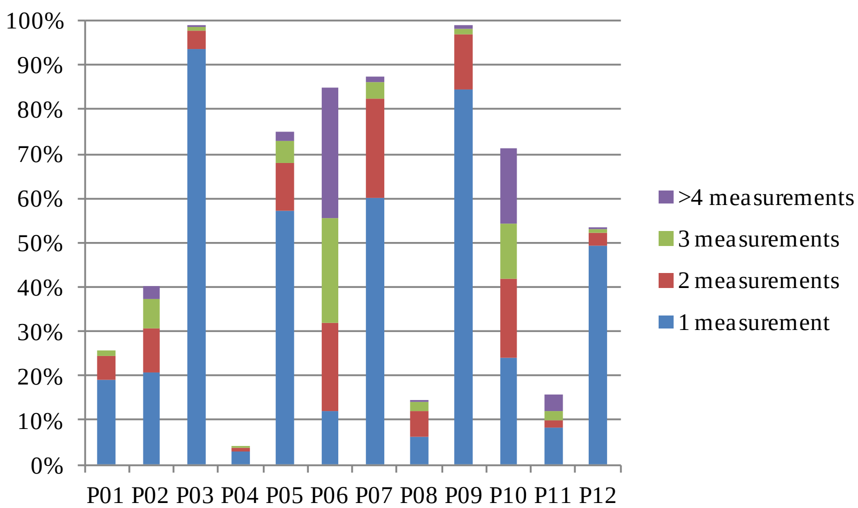


Figure 6.7 Distribution of blood glucose measurement frequency among days on which any blood glucose measurement was performed (Figure 2 in Paper 2[209])

Figure 6.8 shows the results of kernel density estimates on distribution of time points at which blood glucose measurement occurred during the day along the trial duration for each participant. “N” at the right shoulder of each diagram is the total number of data for each participant. The figure clearly illustrates the difference in their needs for blood glucose measurements in terms of timing and frequency. From Figure 6.7 and Figure 6.8, it is very clear that P03 and P09 are habituated to measure blood glucose level in the morning daily.

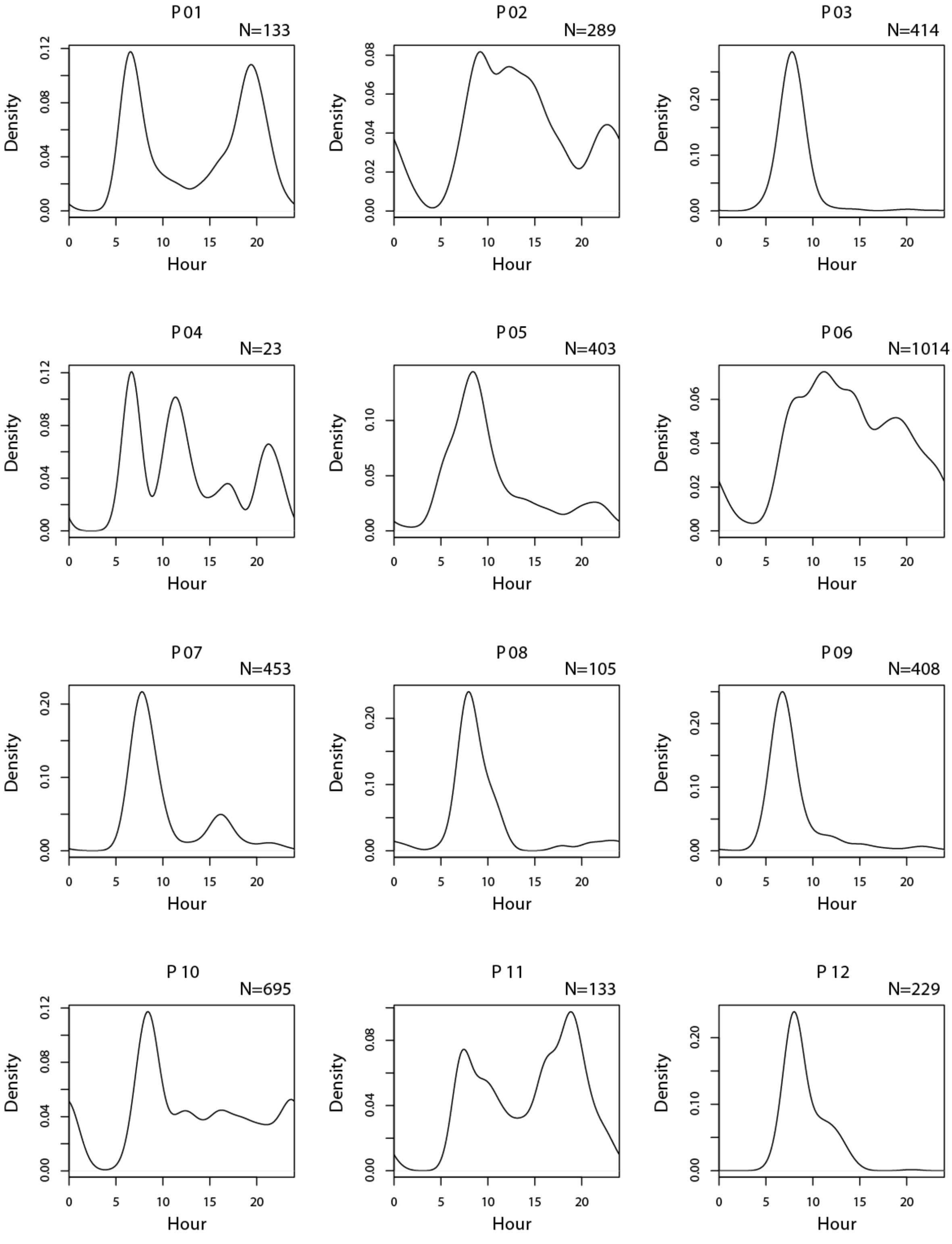


Figure 6.8 Kernel density estimates on distribution of time points at which blood glucose measurement occurred during the day along the trial duration. (Multimedia Appendix 2 in Paper 2)

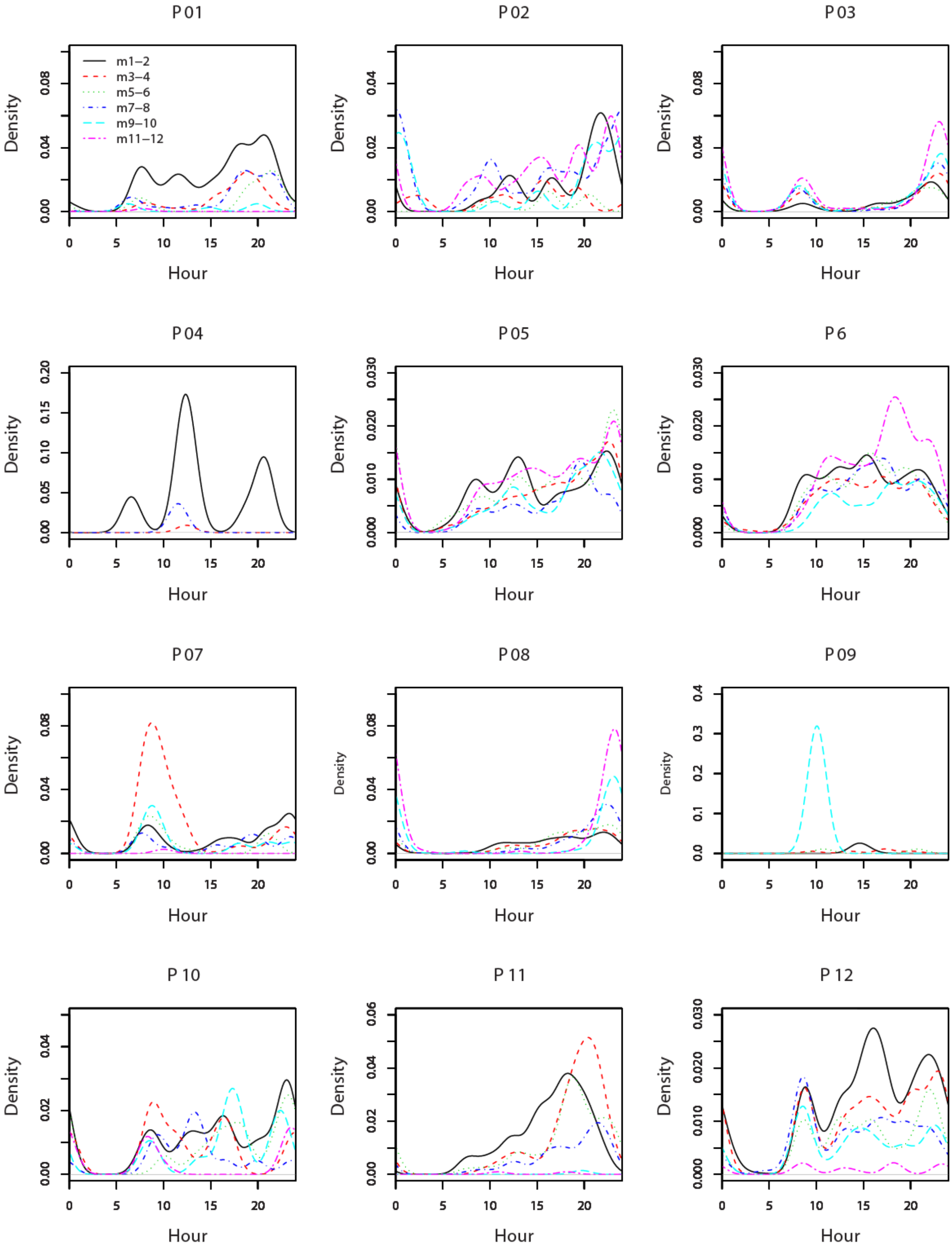


Figure 6.9 Kernel density estimates on distribution of time points at which nutrition habit recordings occurred during the day along the trial duration. (Multimedia Appendix 3 in Paper 2)

Figure 6.9 shows the results of kernel density estimates on distribution of time points at which nutrition habit recording occurred during the day for each participant. The legend title “mx-y” means the data from the x-th month to the y-th month. Each density has been adjusted by multiplying it by the proportion of the data amount recorded in the corresponding period in relation to the whole trial period. Because of the limited space, Table 6.3 shows the numbers of nutrition habit records in each period and proportion of the number against the total number of the recording during the whole period for each participant.

Table 6.3 Number of nutrition habit recordings (N) in each period and proportion of data amount

Period	m1-2		m3-4		m5-6		m7-8		m9-10		m11-12	
Participant	N		N		N		N		N		N	
P01	316	48.5%	96	14.7%	91	14.0%	126	19.3%	20	3.1%	3	0.5%
P02	68	18.2%	33	8.8%	15	4.0%	98	26.3%	63	16.9%	96	25.7%
P03	522	10.9%	682	14.3%	646	13.5%	771	16.1%	924	19.3%	1240	25.9%
P04	39	88.6%	1	2.3%	0	0.0%	4	9.1%	0	0.0%	0	0.0%
P05	351	18.1%	312	16.0%	384	19.8%	210	10.8%	267	13.7%	420	21.6%
P06	558	18.4%	425	14.0%	502	16.5%	481	15.8%	331	10.9%	741	24.4%
P07	153	20.3%	309	41.1%	91	12.1%	91	12.1%	103	13.7%	5	0.7%
P08	668	13.4%	663	13.3%	754	15.1%	804	16.1%	796	16.0%	1298	26.0%
P09	5	7.0%	5	7.0%	4	5.6%	0	0.0%	57	80.3%	0	0.0%
P10	141	25.6%	103	18.7%	100	18.1%	68	12.3%	98	17.8%	41	7.4%
P11	257	31.7%	243	30.0%	195	24.1%	108	13.3%	3	0.4%	4	0.5%
P12	553	30.5%	416	22.9%	280	15.4%	304	16.8%	225	12.4%	36	2.0%

m1-2 (September 16 2008 – November 15 2008)
m3-4 (November 16 2008 – January 15 2009)
m5-6 (January 16 2009 – March 15 2009)
m7-8 (March 16 2009 – May15 2009)
m9-10 (May 16 2009 – July 16 2009)
m11-12 (July 16 2009 –)

As Figure 6.9 illustrates, usage pattern analysis of nutrition habit recordings revealed change in patterns of recording timings in the course of the trial. The change can be described as a shift from “recording of each food/drink intake” to “recording a summary of intakes for the day”. Participants’ feedback in both interviews and questionnaires revealed that this was partly due to attrition of enthusiasm to record right after food/drink intake. This shift changed the context of nutrition habit recording, which led to a consequence that the participants became dissatisfied due to cumbersomeness of the nutrition habit recording with the design shown Figure 4.1 (e). This consequence was contradictory to the original design concept. An improved user-interaction design described later (6.1.3) reduced the necessary steps to take for recording of more than one drink/food intakes (Figure 6.11, left). Interestingly, this “improvement” changed pattern of recording timings from “recording of each food/drink intake” to “recording a summary” for one participant (P08) (Figure 6.9).

6.1.1.3 Interviews and thematic analysis of collected data

Figure 6.10 illustrates mechanism of participants' long-term engagement with the Few Touch application as a result derived from a thematic analysis.

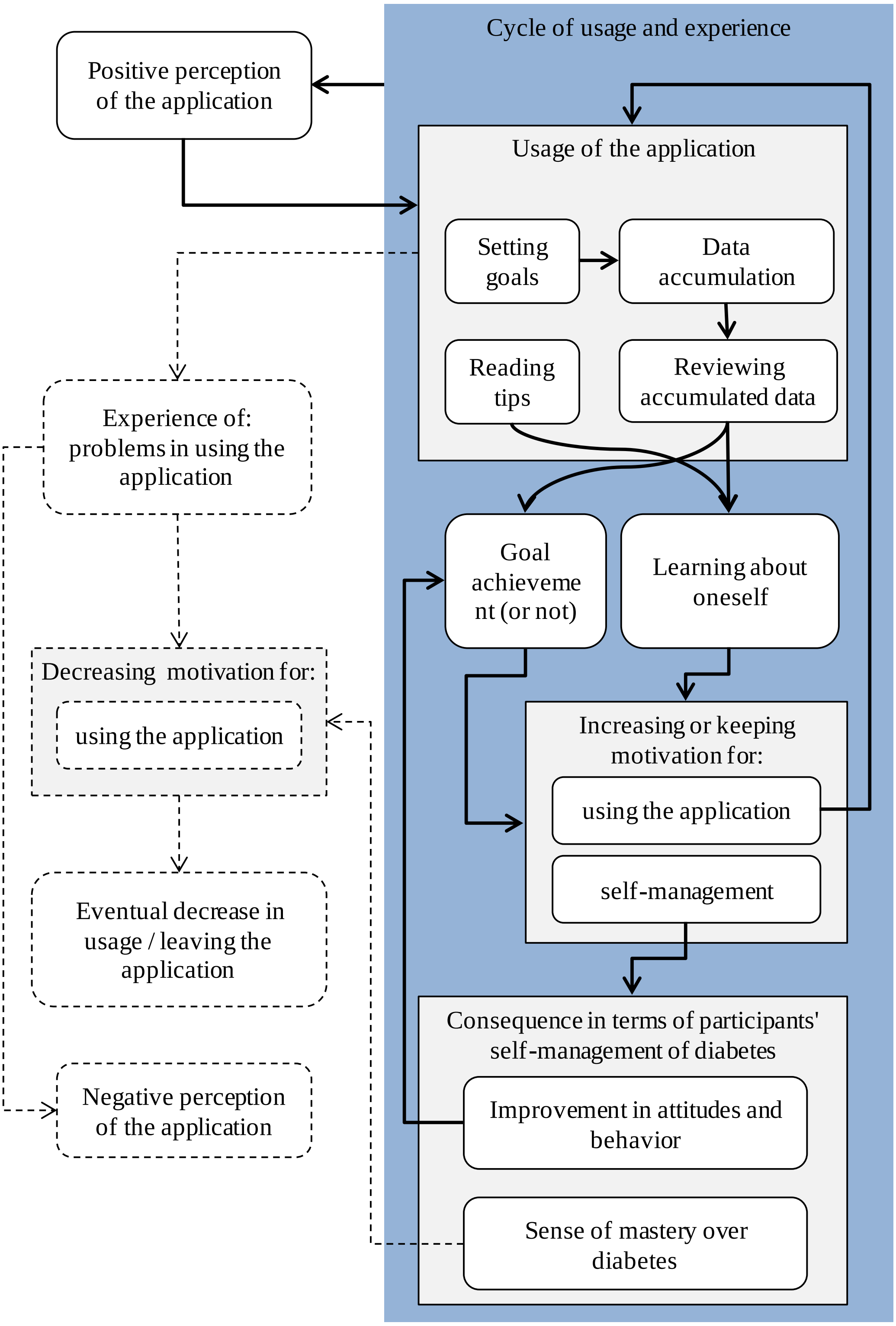


Figure 6.10 Mechanism of participants' long-term engagement with the Few Touch application. (Figure 3 in Paper 2 [209])

The Few Touch application served as a flexible learning tool for the participants by which they could instantly confirm how their self-management activities and/or health status influenced their blood glucose levels. Their usage, not only patterns or frequency but also purposes varied a lot. The bold lines in Figure 6.10 express the cycle of usage of the application, what they experienced as a result of using the application, and what they perceived about the application. This cycle explains the long-term engagement with the application. On the other hand, elements with dash lines illustrate reasons for decrease in usage. Decrease in usage was explained by two reasons. The first reason was attrition of motivation to use after obtaining sense of mastery over diabetes; users felt no more need to continue using for learning. The other reason was experience of problems in using the application. The problems identified were divided into ones stemming from outside the design concepts and ones stemming from mismatch between design concepts and reality, as listed in Table 6.4.

Table 6.4 Functions and features that caused deteriorated usability of the Few Touch application (Table 5 in Paper 2)

Function and feature	**Design concept**	**Reality**	**Affected components in usability**
User interaction design enabling nutrition habit recording completed by just one press on the appropriate category. The design that nutrition habits can be recorded only on the day	Users would record each meal, snack and drink immediately. Users could record food or drink intake with minimum effort	Participants made several records at a time or recorded nutrition habits at the end of the day to summarize their food intake so that they needed more operations at a time. (P01, P03, P05, P06, P08, P10 and P12, Meeting 2) It was not always possible to record right after eating or drinking, or due to constraints of time and place. (P07, Meeting 6) Participants sometimes needed to record nutrition habits	Efficiency, flexibility

		for past dates (P12, Meeting 2; P01, P08, Meeting5)	
Categorization of nutrition habit recording	Categories would correspond to types of eating habits that should be improved in context of T2DM, so that it encourages users to have a healthier diet.	The categorization was not precise enough for their reflective thinking, or it did not match the participants' individual preferences based on their accumulated personal experiences. (P01, P02, P08, P11 and P012, Meeting 4)	Effectiveness, flexibility
Step counter attached on belt	A physical-activity sensor should be integrated with their daily tools and outfits.	One participant (P06) did not use a belt normally. P06 had used it in a bag, but it was easy for P06 to forget about using the step counter on the next day. (Meeting 6)	Satisfaction
Step counter as a physical activity sensor	Physical activity sensor system should provide easily interpretable values to motivate a user to monitor.	The fact that other types of sports (skiing) or physical activities were not measured was disappointing. (P11, Meeting 4; [41,42] P12, Meeting 6)	Effectiveness, satisfaction
User interface of the information (tips) function and its contents	The information (tips) function would provide a user with concise information that can be shown on a screen without necessity of scrolling or more manual operation than one button press to access to a "tip of the day".	Participants wanted better access to information that they want to read (P05, P08 and P09, Meeting 5)	Efficiency, satisfaction

		Participants wanted more and richer information (P01, P03, P09 and P12, Meeting 4), preferably delivered by SMS with tailored contents based on user's profile (P12 [42])	Satisfaction
Diabetes Diary as a software on a smartphone	Users would easily access to their records and information relevant to self-management of diabetes by integrating necessary functionalities into a software application running on their personal mobile phone.	A participant (P04) stopped using the smartphone as his/her personal mobile phone, because it had problems as a mobile phone (Meeting 6)	Effectiveness, efficiency, satisfaction

Although not all of the issues listed in Table 6.4 were not identified as direct reasons for decrease in usage or the cases for all the participants, but they apparently degraded usability of the application to some extent.

From data extracts and results of the questionnaires, the following five factors were identified as associated with usability and/or usage over time: (1) integration with everyday life, (2) automation, (3) balance between accuracy and meaningfulness of data with manual entry, (4) intuitive and informative feedback, and (5) rich learning materials, especially about foods. These are explained in detail as Finding 3 in section 9.3. In the following sub-section, I will describe more in detail about the factor (5), because this is the motivation of Phase 3.

6.1.2Identification of a need for a new HCD process

At Meeting 4 the participants were asked in a questionnaire about which type of tips they regarded as the most useful. The answers were given in the free-form writing and all the 12 participants answered tips relevant to food were the most useful. Five participants described in a concrete way; "what I can/should eat, cannot/should not eat" (P07, P12), "about food to achieve low carbohydrates" (P01), "type of sugar" (P02), "glycemic index" (P09). In the same questionnaire, they were asked to write suggestions to improve the information (tips) function. Although eight participants did not write any concrete suggestion or wrote that the version they had been provided was satisfactory, the other four expressed their needs for richer information. They were "with pictures of food and fruits" (P03), "possibility to set link to the page with more detail on the interesting topic" (P05), "expanded facts about sugar amount in food" (P09), "a more active service, such as tips sent by SMS about food and training to help changing lifestyle or function to build up users' own profile" (P12). In the focus group interview, P09 expressed his/her needs for glycemic indices for more types of food items, which was agreed by the other participants as well. P09 continued in the following manner:

> P09: “Suddenly you see a new exotic fruit coming here [imported to this country], right? Then you cannot guess how much sugar it has at all. Then this is what you [researchers] could have worked on for users[24] to eat more fruits, because it is clear that I am a bit away from fruits”

Although P09 told that s/he had a good nutrition habit and ate very balanced diet with low contents of carbohydrates, s/he thought that such information would help him/her to eat more fruits.

In the other focus group session at Meeting 4, in association with the discussion about potential improvement of the nutrition habit recording system by enabling more detailed recordings, P12 expressed his/her opinion in the following manner:

> P12: “This is where the tips bank can do something. When we go to a shop and read something cryptic on the food, ‘what does it mean?’ Perhaps, there could be a kind of calculator – how much of this contains this and that, so it would be a help for the food part.”

The discussion continued as follows:

> P04: ”That’s true, it is not always so easy to understand”
>
> P12: ”Right? The more one learns, the more one gets to know that one doesn’t know. One [doctor] means one thing, and another means another thing. One gets confused.”
>
> P08: ”Yes, it is really like that when I record food, then I am not 100% sure about what is ’carbohydrate rich’ and what is not. Low and high carb. food.”
>
> P04: ”One must not always trust the sales copy.”
>
> P01: ”He [Årsand] has however illustrated it with a figure of a cake[25] for high-carb. dish and fish for low-carb. dish.”
>
> P08: ”But how about slices of bread with ordinary spread then?”
>
> P01: ”Well, there have been of course such things, so yes, it is obvious that, if it is possible [to register more in detail], it would be even a better help.”
>
> P04: ”[For better] Motivation as well”
>
> P12: ”Well, it is the matter of finding out what raises blood glucose level. There are some things that we should avoid, that always give a rise in blood sugar level. Then one can find a key, in a simple manner.”

---

[24] It was very unclear from the voice record if P09 meant “for users” or “for P09”.

[25] It is actually a spaghetti dish

This conversation illustrates that the use of the Few Touch application manifested their needs to learn more about foods. They encountered situations in which they did not know how the food in front of them would influence their blood glucose level. As P12 described, they needed an instantly accessible "fact sheet" of food items they wonder about so that they can gain objective and quantitative information as a basis to examine how they are related to increase of "their" blood glucose level.

Improvement of the information function was therefore initiated with a special focus on making it an educational reference resource, based on feedback above. Details of works for inclusion of food-information database module are described in Chapter 8.

6.1.3 Resulted design – Diabetes Diary version 2

In the course of Trial I, especially between Meeting 4 and 6, the Lifestyle project team worked a lot on upgrading the Few Touch application. This included the improvement of screen designs, part of which was already implemented at Meeting 4 and 5 as minor updates (described below). In this process, there were conversations between system developers, project leaders of Lifestyle and researchers including me. Table 6.5 shows a timeline of decision making and documentation making for upgrading the Few Touch application.

Table 6.5 Timeline of decision making and documentation making for upgrading design of the Few Touch application

Date	Description of document / meeting	Writer / presenter
10 March 2009	Overview of GUI design for Diabetes Diary to implement at Meeting 5	A system developer
11 March 2009	Suggestions for improvement of the GUI designs including concrete screen designs based on heuristic evaluation	Tatara, N
20 April 2009	A meeting with all members of Lifestyle project to discuss GUI design for Diabetes Diary to implement at Meeting 5, reflecting the suggestions given on 11th March	A system developer
20 April 2009	Quick heuristic evaluation on the presented GUI designs	Tatara, N
5 May 2009	Design guideline for the Few Touch application version 0.1 was made based on discussion with a system developer and a research leader.	Tatara, N
13 May 2009	A discussion with all members of Lifestyle project to decide which items in the design guideline to prioritize for redesigning	
14 May 2009	Design guideline for the Few Touch application version 0.1.1 was made based on the discussion on 13 May.	Tatara, N
5 June 2009	Draft of Design profile for the Few Touch application (version 0) was made.	Tatara, N

15 June 2009	Design profile for the Few Touch application version 1.0 (**APPENDIX 8**) was made	Tatara, N
2 September 2009	Design guideline for the Few Touch application version 0.2 (**APPENDIX 9**) was made.	Tatara, N

In the process described in Table 6.5, I made suggestions based on design principles in HCI and users' feedback we received by the end of Meeting 4 in Trial I. The "design guideline" was defined in May 2009 and formed the basis for designing the new version of the Few Touch application. The "design guideline" was used as a tool to determine the upgrade of the Few Touch application as well as to decide the design and development priorities. On the other hand, the "design profile[26]" gives concrete design rules and specifications of screen designs for Diabetes Diary[27] rather than requirements. Both the design guideline and the design profile were made reflecting user interaction design principles in HCI and users' feedback we obtained in Trial I.

Diabetes Diary version 1 had two minor updates shown in Table 6.4 before it was updated to version 2, as quick fixes responding to user needs in Trial I.

At Meeting 4, screen (e) in Figure 4.1 (image shown on the left-hand side of Figure 6.11) was replaced with the design shown on the right-hand side of Figure 6.11 to enable entry of more than one eating or drinking record at a time.

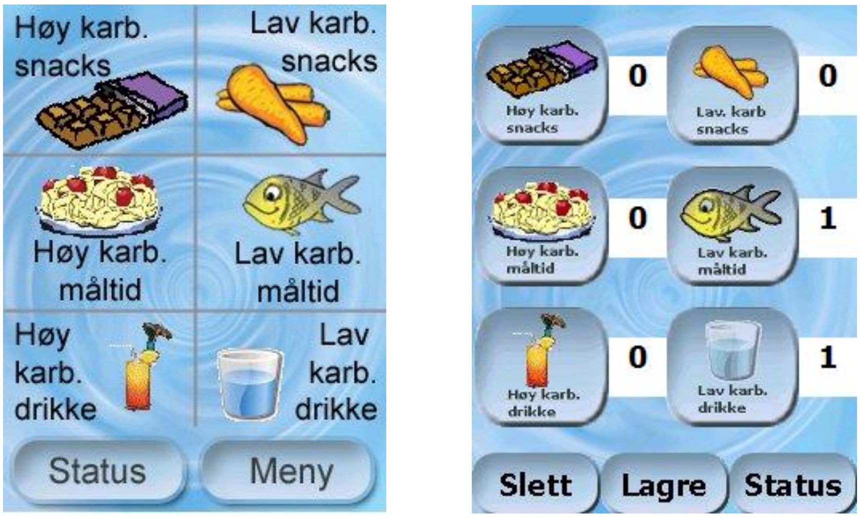


Figure 6.11 User interface for nutrition habit recording: Original design (left), modified design (right)

At Meeting 5, screen (l) in Figure 4.1 image shown on the left-hand side of Figure 6.12) was replaced with the right figure of Figure 6.12. By adding a "back" button as well as a header

[26] "Screen transition diagram of ver. 2" on page 7 of the **APPENDIX 6** is not same as Diabetes Diary version 2 described in Figure 6.13. Screen designs on this page are suggested by a system developer on 20 April 2009.

[27] The guideline is titled as "for the Few Touch application", but it includes only screen designs of Diabetes Diary.

and category name to each tip, the new design improved navigation and made it easier to view the content and to find information [209].

Figure 6.12 User interface for the information (tips) function: Original design (left), modified design (right)

Diabetes Diary version 2 was achieved as a result of implementation of new designs. Design of physical activity recording system reflected user needs of recording physical activities other than walking. We made the design to comply with the “simple and as easy as possible” design principle for the Few Touch application while following recommendations by the Norwegian Directorate of Health [243]. Therefore, we employed time and intensity of physical activity for recording rather than type of physical activity.

Figure 6.13 shows the structure and screenshots of each page in Diabetes Diary version 2. Icons used at the top menu and goal setting menu ((a) and (i) in Figure 6.13) were replaced with those better representing each function than just circles with the name of a function. Basic features remain since version 1 including the two minor updates with one exception: The physical activity sensor system was replaced with a physical activity recording system ((b) in Figure 6.13) and a goal setting function for physical activities ((j) in Figure 6.13).

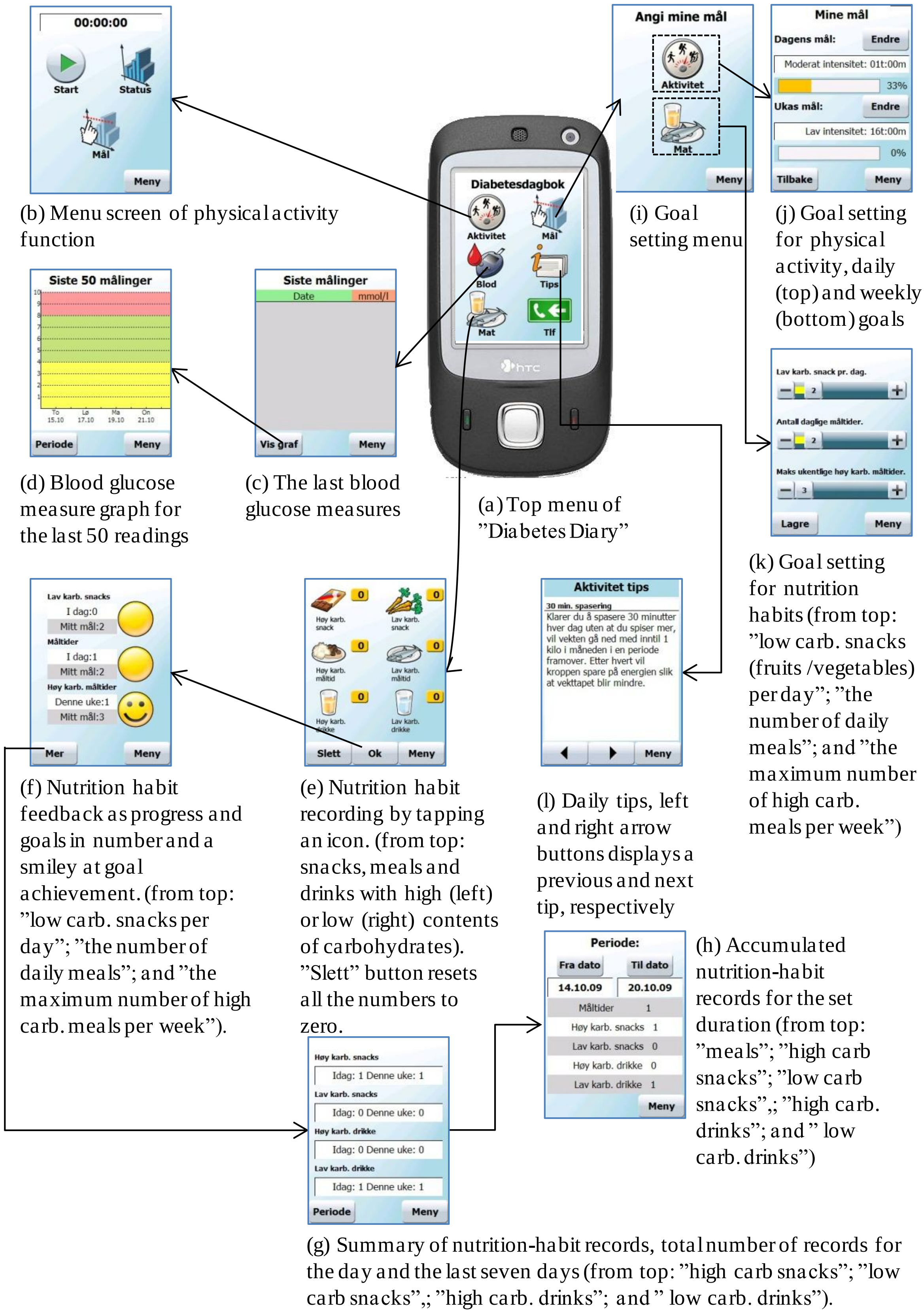
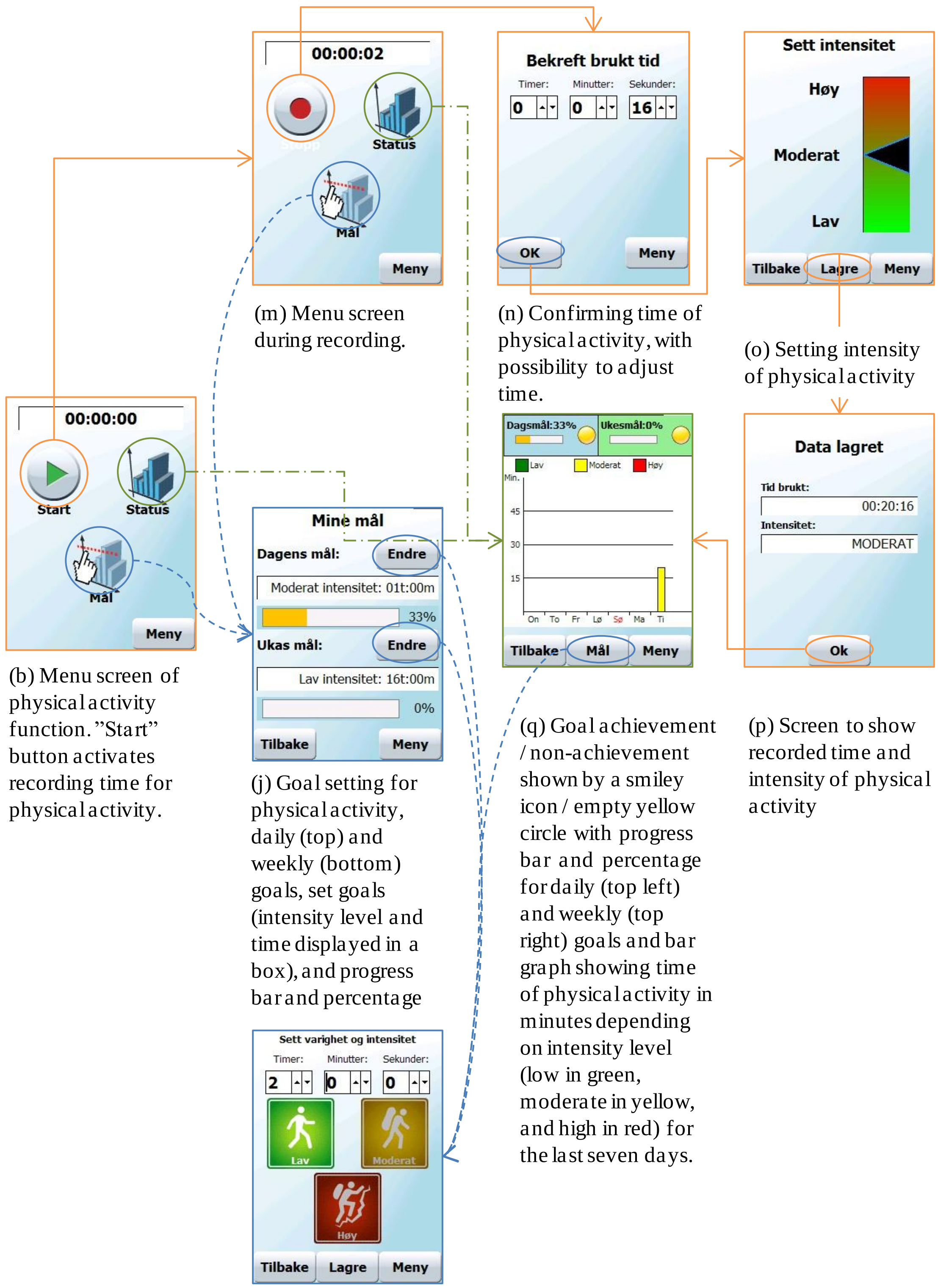


Figure 6.13 Screen design and structure of Diabetes Diary version 2



(m) Menu screen during recording.

(n) Confirming time of physical activity, with possibility to adjust time.

(o) Setting intensity of physical activity

(b) Menu screen of physical activity function. "Start" button activates recording time for physical activity.

(j) Goal setting for physical activity, daily (top) and weekly (bottom) goals, set goals (intensity level and time displayed in a box), and progress bar and percentage

(q) Goal achievement / non-achievement shown by a smiley icon / empty yellow circle with progress bar and percentage for daily (top left) and weekly (top right) goals and bar graph showing time of physical activity in minutes depending on intensity level (low in green, moderate in yellow, and high in red) for the last seven days.

(p) Screen to show recorded time and intensity of physical activity

(r) Setting time and intensity for each goal.

Figure 6.14 Screen design and structure of physical activity recording system of Diabetes Diary version 2

Figure 6.14 shows screen design and structure of physical activity recording system of version 2. The screen (b) in Figure 6.13 shows a timer on top, start button, status icon and goal ("mål" in Norwegian) icon. The screens and arrows with outline in orange show the flow of recording physical activity. By clicking on start button on screen (b), it starts to record time of physical activity like a stopwatch. Time recording runs as a background process so that users can switch the phone to sleep mode or use other functions. While time is being recorded, the activity icon ("Aktivitet" in Norwegian) on the start screen of the Diabetes Diary (screen (a) in Figure 6.13) continues blinking as a reminder to the user. Pressing the stop button represented by a gray circle with a red circle inside on screen (m) prompts the user to confirm and if necessary adjust the time and date (n), then to set the intensity level of the completed physical activity (o). Pressing the save ("Lagre" in Norwegian) button displays saved data, namely time and intensity for the physical activity (p). Pressing "ok" button displays feedback screen (q) with a bar chart of accumulated minutes of physical activity by intensity level for the last seven days, together with bars indicating progress toward set goals. When a goal is achieved, a yellow plain circle next to a progress bar turns to a smile emoticon. The feedback screen (q) can be accessed by pressing status icon on (b) and (m) as well, as shown by long-and-short dash lines in green with an arrow.

Two goals can be set for physical activities: daily and weekly accumulated time (j). By clicking change ("endre" in Norwegian) button at a corresponding goal, target time of physical activity can be set based on one of the three intensity levels: high, moderate or low ("høy", "moderat" and "lav" in Norwegian) (r). The goal setting screen (j) can be accessed by pressing goal ("mål" in Norwegian) icon on (b), (m) and (q) as well, as shown by dash lines in blue with an arrow.

6.2 Trial I - the last 21 weeks

The same 12 participants continued using the Few Touch application with Diabetes Diary version 2 that was introduced at Meeting 6 and was used for 21 weeks until March 2010. Table 6.6 shows a chronological table of events in the last five months of Trial I.

Table 6.6 Time chart of Trial I (last 21 weeks)

Meetings	**Time (month, year) and the number of elapsed weeks**	**Events**
6	October 2009, 56 weeks	Introduction of Diabetes Diary version 2 with a physical activity recording system (manual recording) [a]
		SUS questionnaire for the Diabetes Diary version 2
7	November 2009, 60 weeks	Focus group sessions (the participants were divided into two groups) [b]
		Inquiry 3 in Phase 3 (described in 8.1.3)

8	March 2010, 77 weeks	Presentation of the design concepts of a food-information database module in Phase 3 (described in 8.2.2)

a. For P10, this occurred on 5 November 2009.

b. 11 participants attended the focus group session.

6.2.1 Results of data collection and analyses

At Meeting 6, SUS questionnaire was administered regarding Diabetes Diary version 2. The average scores among the participants were slightly higher than the scores given to version 1, but Wilcoxon's signed rank test did not discard the null hypothesis that there is no difference between scores for two versions.

Table 6.7 The results of SUS questionnaire for version 1 and 2 of Diabetes Diary

	SUS scores	
	Version 1	Version 2
Mean (SD)	84.0 (13.55) [a]	86.0 (10.08)
Range	67.5 – 100 [a]	62.5 – 100
Wilcoxon's signed rank test: T^+, T^- (*P*-value)	34, 21 (0.539)	

[a] The results were presented in [2,22,209].

Figure 6.15 and Figure 6.16 show usage rates of three functions; the blood glucose sensor system (BG), the nutrition habit recording system (NH), and the physical activity recording system (PA-R), for the period in which all the functions were available after Meeting 6. The y-axis shows the days on which a function was used per week. The x-axis shows the number of weeks since the start of Trial I.

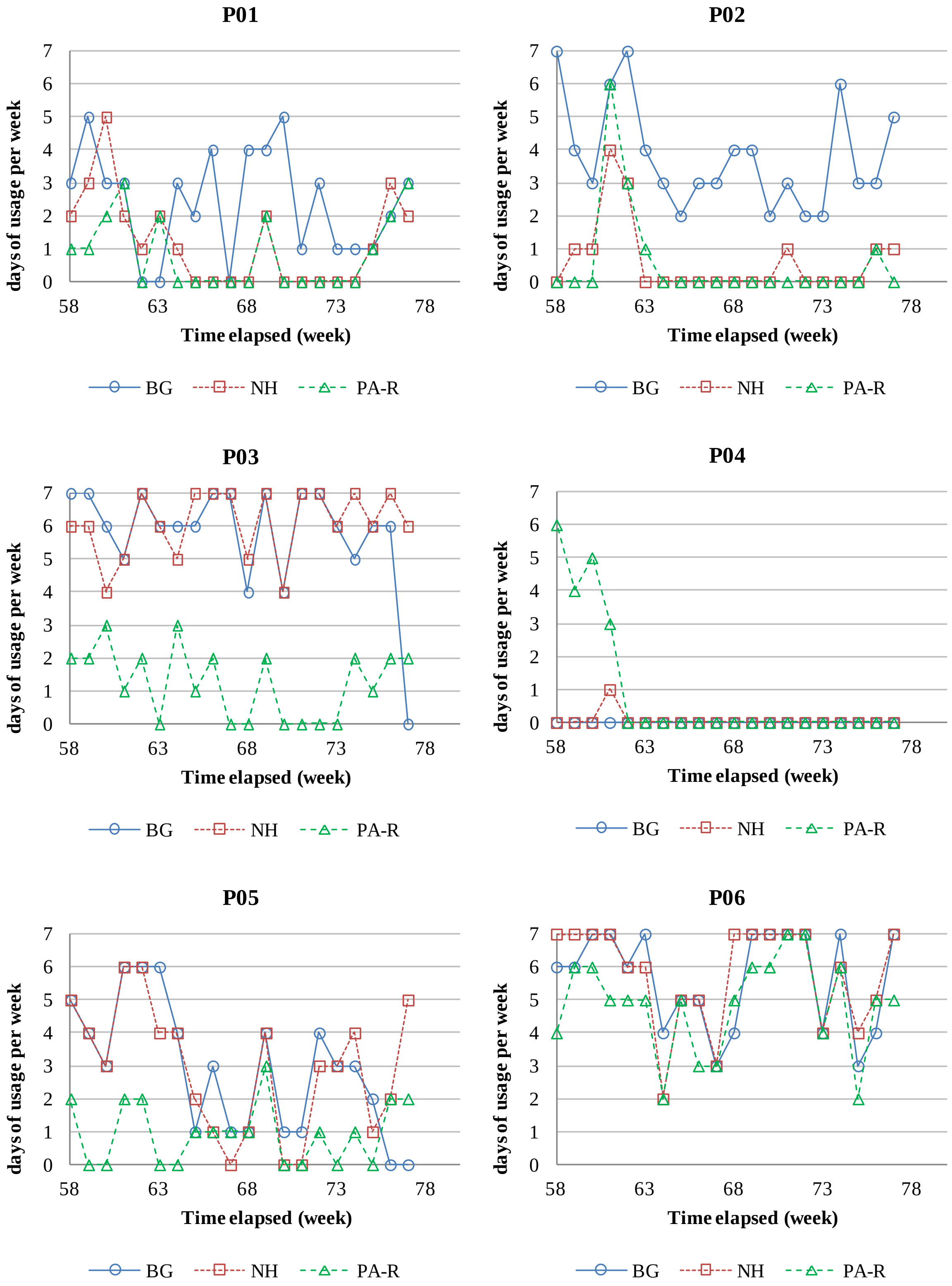


Figure 6.15 Usage rates of each function by P01-P06 for the 20 weeks

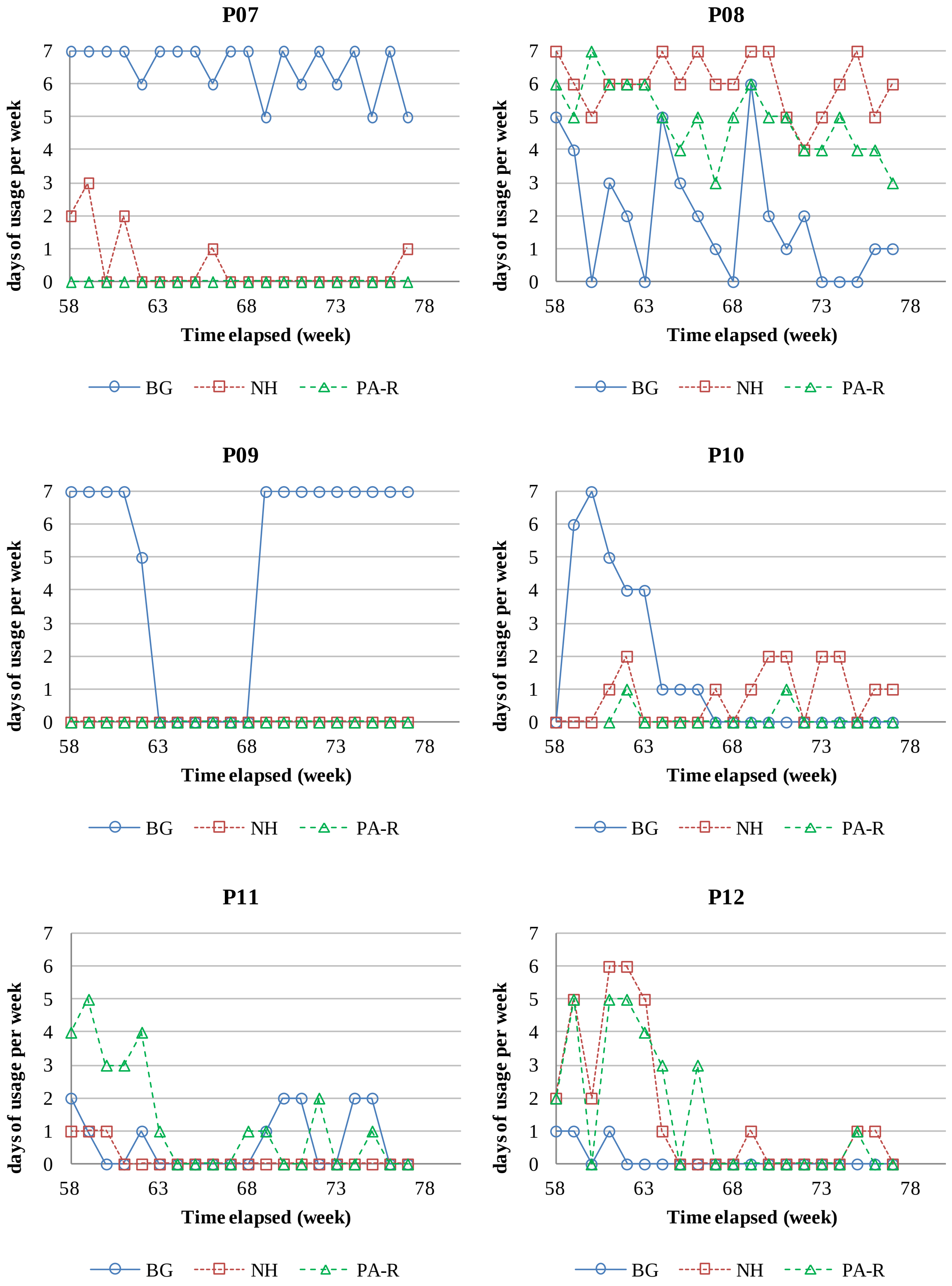


Figure 6.16 Usage rates of each function by P07-P12 for the last 20 weeks

Table 6.8 shows the results of Mann-Kendall trend analysis of usage rates of each function for the same period shown in Figure 6.15 and Figure 6.16. Compared to the first 56 weeks, less participants showed a significantly (*P* < .05) decreasing trend in usage rates; 10 for the first 56 weeks and six for the last 20 weeks[28]. This is mostly because usage of the blood glucose sensor system and the nutrition habit recording system had already decreased to a certain level before Meeting 6.

Table 6.8 Results from Mann-Kendall trend test on usage rate for the last 20 weeks

Participant	**Blood glucose sensor system**		**Nutrition habit recording system**		**Physical activity recording system**	
	Tau-value	*P*-value	Tau-value	*P*-value	Tau-value	*P*-value
P01	-0.10	.595	-0.28	.120	-0.05	.829
P02	-0.25	.158	-0.11	.561	-0.18	.349
P03	-0.26	.147	0.21	.265	-0.19	.299
P04	0.00	N/A	-0.22	.298	-0.59	.002 *
P05	-0.50	.004 *	-0.27	.121	0.04	.836
P06	-0.08	.680	-0.16	.382	0.05	.788
P07	-0.35	.063	-0.31	.102	0.00	N/A
P08	-0.36	.039 *	-0.13	.485	-0.57	.0013 *
P09	0.21	.273	0.00	N/A	0.00	N/A
P10	-0.68	< .001 *	0.33	.076	-0.16	.502
P11	0.03	.881	-0.52	.008 *	-0.50	.005 *
P12	-0.50	.011*	-0.46	.010 *	-0.50	.006 *

* *P* < .05.

Table 6.9 shows the number of days on which any record was made to each function and percentage of such days against the period they used Diabetes Diary version 2. Regarding the physical activity recording system, P06 and P08 used it much more than the others (Table 6.9). They had a problem with a step counter in terms of wearing it when using Diabetes Diary version 1. Participants' feedback at Meeting 7 revealed that they found the following advantages of the physical activity recording system: they could record physical activities which could not be counted as the number of steps; and they could record it after physical activity had been completed with an option to change time. However, they also showed dissatisfaction with the function due to cumbersomeness of recording compared with the

[28] Due to the scheduling of Meeting 8, the last week of the 21 weeks was not counted for the Mann-Kendall test because of less than seven days in which each function was available in the last week.

automatic data recording by physical activity sensor system with a step counter. Feedback included their user needs for recording activities for passed dates and viewing a graph for more than a week, expressed by one participant for each.

Table 6.9 The numbers of days on which each function was used against a period in which physical activity recording system was available.

	Blood glucose sensor system		**Nutrition habit recording system**		**Physical activity recording system**		
Participant	Dr[a]	Dr / Da[b]	Dr	Dr / Da	Dr	Dr / Da	Da
P01	48	32%	29	20%	18	12%	148
P02	83	55%	15	10%	12	8%	150
P03	123	83%	129	87%	30	20%	148
P04	0	0%	2	1%	23	16%	148
P05	63	43%	62	42%	20	14%	146
P06	118	81%	121	83%	100	68%	146
P07	136	92%	10	7%	1	1%	148
P08	41	28%	126	85%	102	69%	148
P09	105	70%	0	0%	1	1%	150
P10	21	17%	16	13%	4	3%	127
P11	14	9%	5	3%	31	21%	150
P12	4	3%	32	22%	31	21%	146

[a] Dr is the number of days on which records were made.
[b] Da is the number of days when physical activity recording system was available.

6.2.2 Resulted design - Diabetes Diary version 3

Based on the users' feedback we obtained in the trial of the Few Touch application with Diabetes Diary version 2, the physical activity recording system was improved at version 3 (Figure 6.17) by enabling changing a date for physical activity to record and by enabling viewing graph for three types of duration with possibility to choose starting date of the period (Figure 6.18). As a part of improvement of the information function, Diabetes Diary version 3 implemented a dictionary of terms relevant to T2DM. The dictionary was made based on materials developed in an earlier project at NST (Figure 6.19).

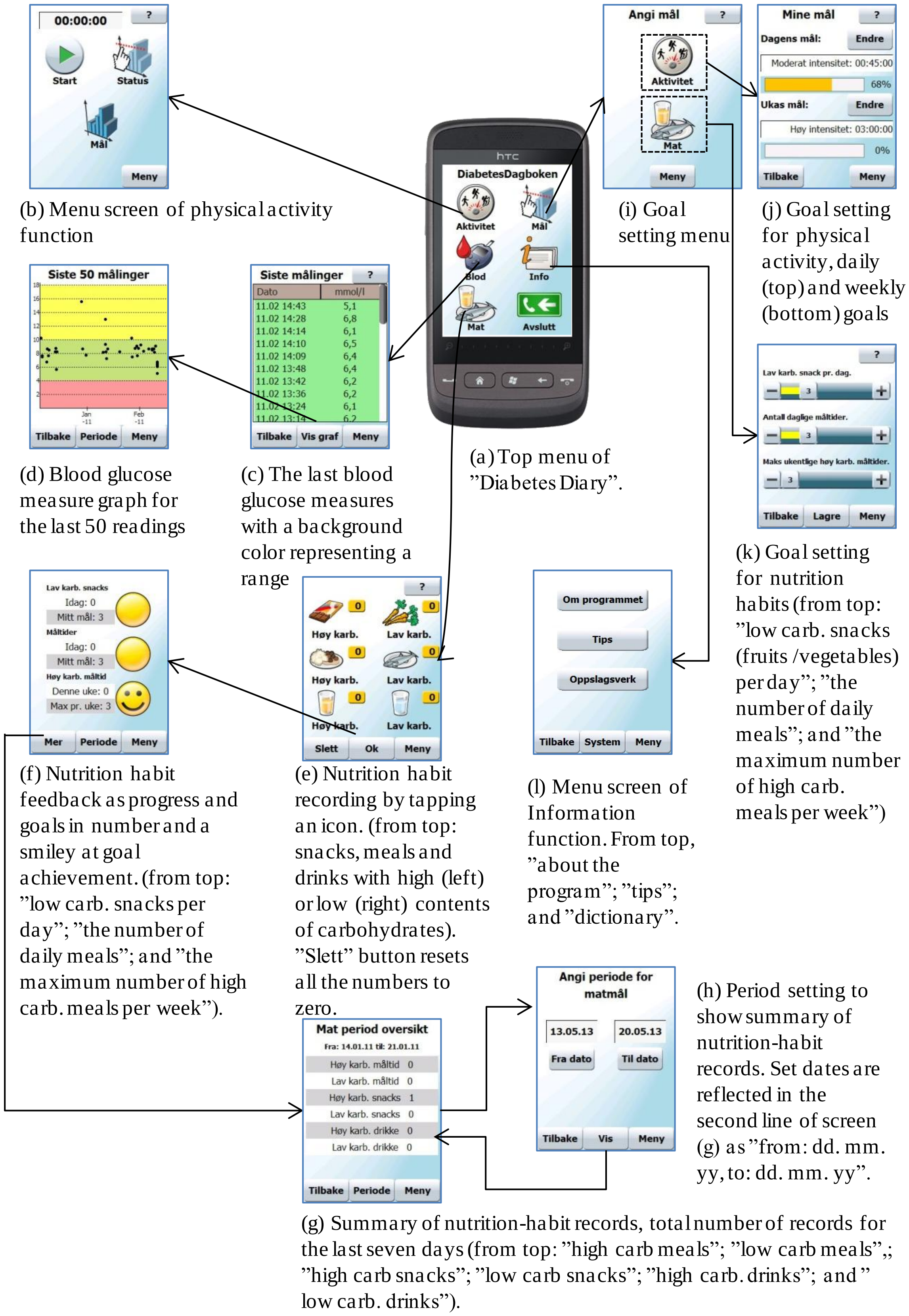


Figure 6.17 Screen design and structure of Diabetes Diary version 3

Diabetes Diary version 3 was made in prerequisites that it would be used as a tool of a clinical intervention [244] where hands-on instruction might be impossible. Figure 6.17 shows the structure and screenshots of each page in version 3. The model of a mobile phone shown in used in Figure 6.17 is HTC Touch 2[29], which was planned to be used as a terminal in the clinical intervention.

Most of the screen design and features remain since version 2, but the following changes were made in addition to some minor changes.

Help icon Most of the screens were added with a help icon represented by a question mark ("?") on the top right corner. Clicking a help icon on a screen displays a help page for the corresponding function. The help pages can be accessed from "info" icon on the top menu (a) in Figure 6.17, which will be described in detail later.

Back button Back (in Norwegian "tilbake") buttons were added on the bottom left of screens where possible.

Close icon An icon at bottom right on top menu screen (a) remained same as version 2 but the icon name was changed from "telephone" ("tlf" as a shortened form of "telefon" in Norwegian) to "close" ("avslutt" in Norwegian). This button displays home screen of HTC Touch 2 but the program remains running.

Background color of the last blood glucose measures A list of the last blood glucose measures are displayed with a background color representing a range within which a value resides (screen (c) in Figure 6.17). The color scheme is the same one used for the blood glucose measure graph (d): 0-4 mmol/dl in red, 4-10 mmol/dl in green, and >10 mmol/dl in yellow.

Summary of nutrition-habit records A Summary of nutrition-habit record on screen (g) shows total number of records for the last seven days by default for the six categories. The period can be changed by pressing period ("periode" in Norwegian") button and set dates on screen (h). Set period is reflected to the feedback screen (f) when getting there by pressing back ("tilbake" in Norwegian) button on screen (g).

Physical activity recording system Figure 6.18 shows screen design and structure of the physical activity recording system of version 3. Version 3 had two major updates for the physical activity recording system from version 2; it enabled adjustment of date in addition to time and configuration of feedback graph.

Date for physical activity can be adjusted by pressing date ("dato" in Norwegian) button on screen (n) in Figure 6.18 and set a date from a calendar. Pressing period ("periode" in Norwegian) button on screen (q) displays screen (s) on which a user can set a period by choosing preceding one week, preceding two weeks or preceding one month. Starting date of each period can be set by choosing dates from calendar displayed by pressing change ("endre" in Norwegian) button right side of the box showing the set period. A bar graph for a set period ((t) in Figure 6.18) shows only bars for the set intensity. This can be changed by pressing a button for corresponding intensity above the graph on screen (t).

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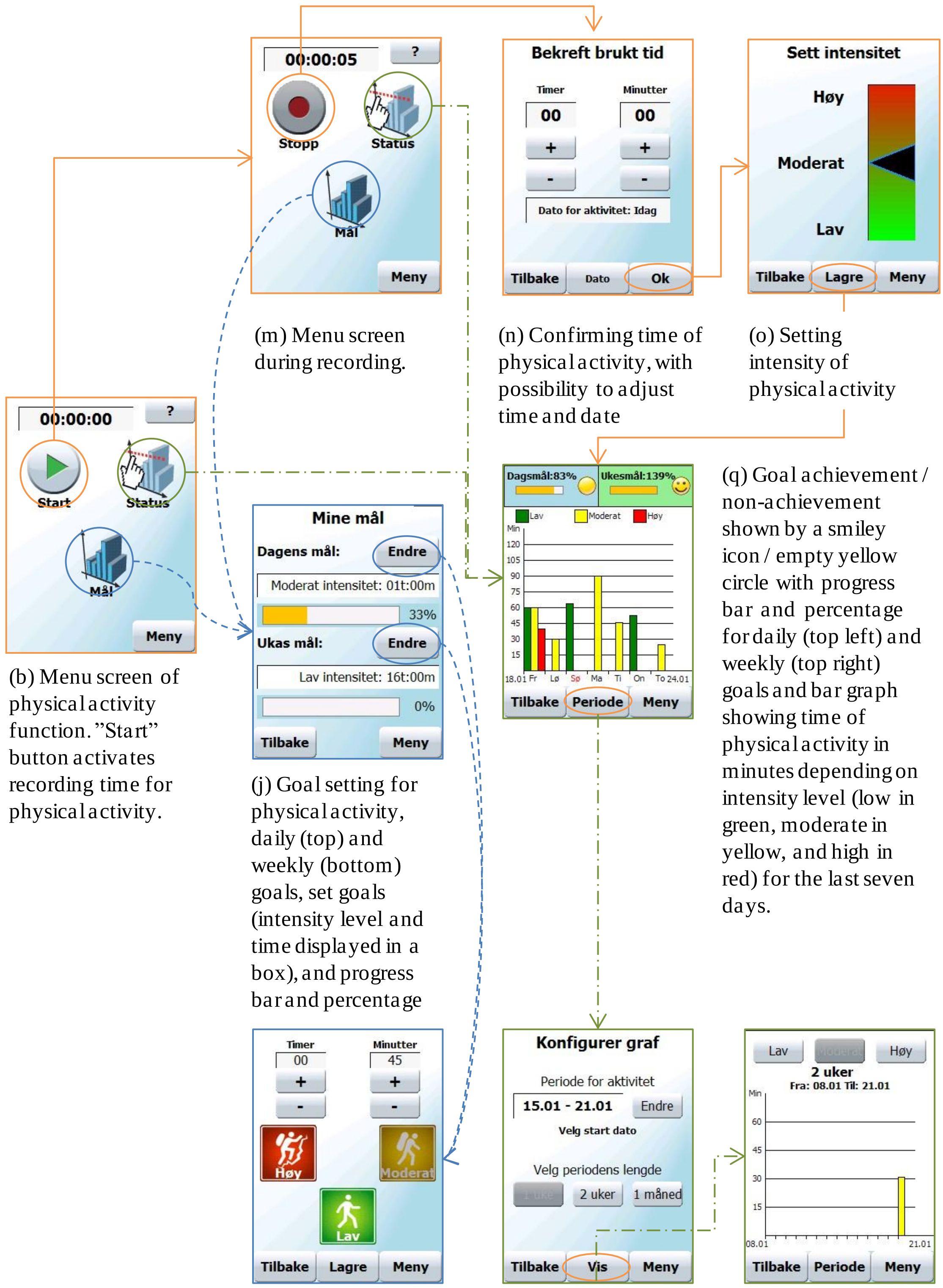
[29] This product is not available anymore. The user manual is available at: http://dl4.htc.com/web_materials/Manual/HTC_Touch2/090901_Mega_HTC_WWE_Manual.pdf (accessed 20th August 2013)

As other updates, time unit seconds (“sekunder” in Norwegian) was removed from screens (n) and (r). Buttons to adjust time at screens (n) and (r) were replaced with big buttons of plus (“+”) and minus (“-“) mark. Most of the other features remained same as version 2.



(m) Menu screen during recording.

(n) Confirming time of physical activity, with possibility to adjust time and date

(o) Setting intensity of physical activity

(b) Menu screen of physical activity function. ”Start” button activates recording time for physical activity.

(j) Goal setting for physical activity, daily (top) and weekly (bottom) goals, set goals (intensity level and time displayed in a box), and progress bar and percentage

(q) Goal achievement / non-achievement shown by a smiley icon / empty yellow circle with progress bar and percentage for daily (top left) and weekly (top right) goals and bar graph showing time of physical activity in minutes depending on intensity level (low in green, moderate in yellow, and high in red) for the last seven days.

(r) Setting time and intensity for each goal.

(s) Period setting to show physical activity graph

(t) Physical activity graph for set period.

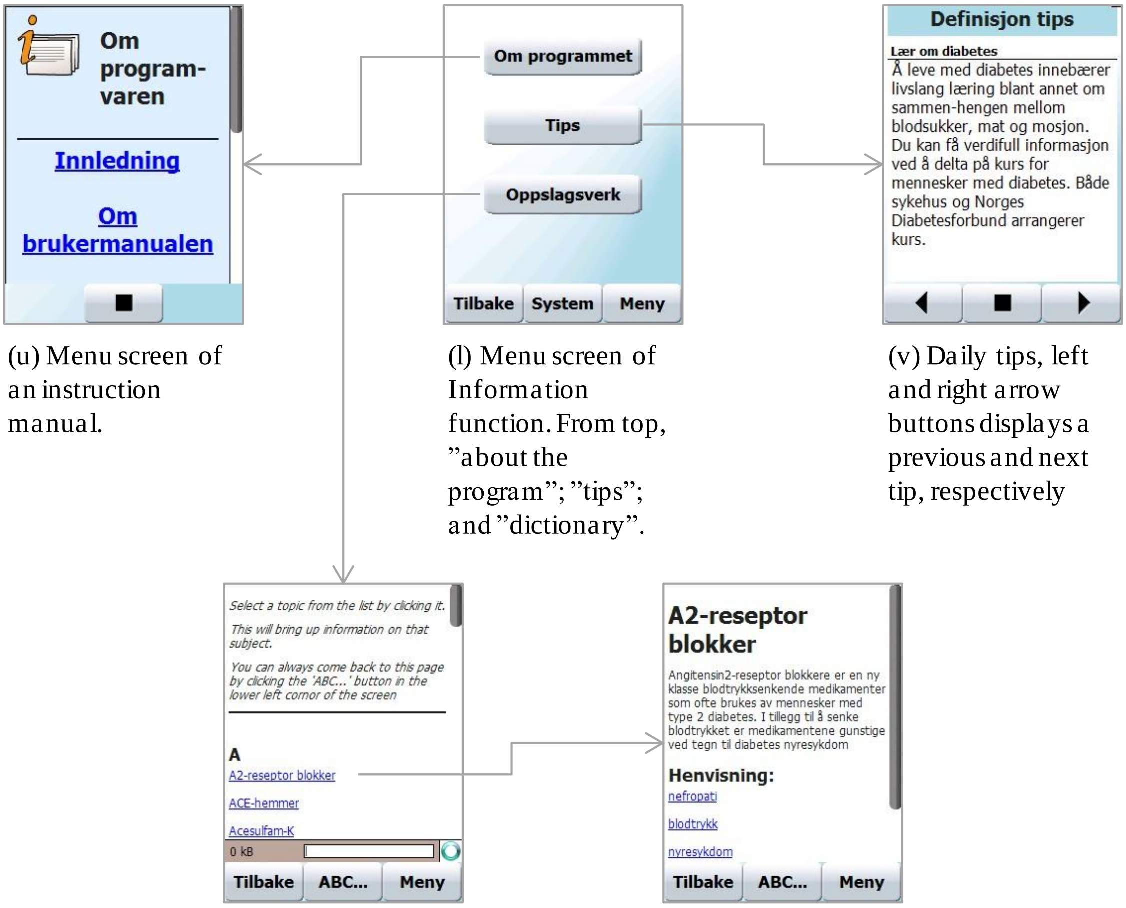
Figure 6.18 Screen design and structure of the physical activity recording system of Diabetes Diary version 3

Information function Figure 6.19 shows screen design and structure of the information function of version 3. The information function has three modules as shown in (l) in Figure 6.17 and Figure 6.19.

“About the program” (“om programmet” in Norwegian) button displays a menu screen of an instruction manual of the Few Touch application (screen (u) in Figure 6.19). This function is made based on HTML, and a title of content is a link to the corresponding page. Examples of screenshots for instruction manual are shown in Figure 6.20.

Tips button displays daily tips ((v) in Figure 6.19), whose function remains almost same as version 2. The middle button with square displays screen (l).

Dictionary (“oppslagsverk” in Norwegian) button displays a list of 413 terms relevant to Type 2 diabetes ((w) in Figure 6.19). A user can scroll by dragging a bar appearing on the right side of the screen. Clicking a term displays a page explaining the term with a list of relevant terms ((x) in Figure 6.19). The middle button with “ABC…” on screen (w) and (x) displays the exactly same screen as (w).



(u) Menu screen of an instruction manual.

(l) Menu screen of Information function. From top, ”about the program”; ”tips”; and ”dictionary”.

(v) Daily tips, left and right arrow buttons displays a previous and next tip, respectively

(w) List of terms in alphabetical order in a dictionary

(x) Explanation of a selected term and relevant terms with a link

Figure 6.19 Screen design and structure of information function of Diabetes Diary version 3

Figure 6.20 Example screen shots of instruction manual under information function

7 Phase 2

Trial II was carried out aiming at gaining a better understanding on "how a design solution developed in a user involved process is experienced by people with T2DM in general in a long-term perspective". Therefore, people who had no previous knowledge about the Few Touch application tested the application. By using mixed methods research, the participants' usage and experiences of the Few Touch with Diabetes Diary version 3 was investigated and the results were compared with the results from Trial I.

7.1 Trial II

As described in section 1.4 and sub-section 5.4.1, Trial II was carried out in conjunction with Motivation with Mobile project in a city of Harstad. Ten patients with T2DM and one at high risk of T2DM (seven men and four women, age ranged from 40 to 73 with a mean age of 57.2 (SD: 8.6) at the time of Meeting 4) took part in Trial II from September 2010 and November 2010, respectively. Hereafter, participants in Trial II are expressed by the code "HPxx" whereas "xx" indicates the participant's ID number. Table 7.1 shows a time chart of events in Trial II.

Table 7.1 Time chart of Trial II including the extension period

Meetings	**Time (month, year) and the number of elapsed weeks**	**Events**
1	September 2010 [a]	Introduction of a mobile phone without Diabetes Diary version 3
2	October 2010, 1 week	Introduction of the Few Touch application (installing Diabetes Diary and provision of a blood glucose meter with Bluetooth transmitter)
3	November 2010, 6 week	A focus group session
4	February 2011, 22 weeks	Custom made questionnaire
		Collection of recorded data on Diabetes Diary
5 [b]	May 2011, 34 weeks	SUS questionnaire and one original questionnaire (Modified version of Questionnaire 1 used in Trial I)

a. For HP07 the application was introduced on 11 November 2010

b. Original plan for Trial II was to collect all the relevant data at Meeting 4, but the two questionnaire answers were collected in Meeting 5 due to limited time allocated to Trial II in a regular meeting of Motivation Group.

A focus group session was held at Meeting 3 in order to obtain feedback in an early phase of the trial. Trial II was originally planned to end at Meeting 4 with collection of recorded data and questionnaire answers. However, because of the limited time, SUS questionnaire and modified version of Questionnaire 1 used in Trial I were administered in Meeting 5. Due to absence of three participants in Meeting 5, only 8 participants responded to the two questionnaires.

7.2 Results of data collection and analyses

In this section, I will describe the results by dividing them into two sub-sections depending on the focus.

7.2.1 Usage and experiences of the Few Touch application

After analysis of the recorded data and questionnaire results, it was found that the participants could be roughly divided into the following three groups in terms of usage and experiences of the Few Touch application.

A. Frequent use with positive experience (HP02, HP04, HP09 and HP10)
B. Moderate use with relatively neutral experience (HP03, HP07 and HP11)
C. Little use of the nutrition habit and physical activity recording systems with mixed experience (HP01, HP05, HP06 and HP08)

In order to make it easier to compare results, I will organize the results by dividing them into the three groups below.

Figure 7.1, Figure 7.2 and Figure 7.3 show usage rates of each function by participants in group A, B, and C, respectively. The y-axis shows the number of days on which a function was used per week when it was available for the whole week. The x-axis shows the number of weeks elapsed since the start of the Trial II, i.e., Meeting 1. Table 7.2 shows the results of Mann-Kendall trend test on usage rate. BG, NH, and PA represent blood glucose, nutrition habit, and physical activity, respectively.

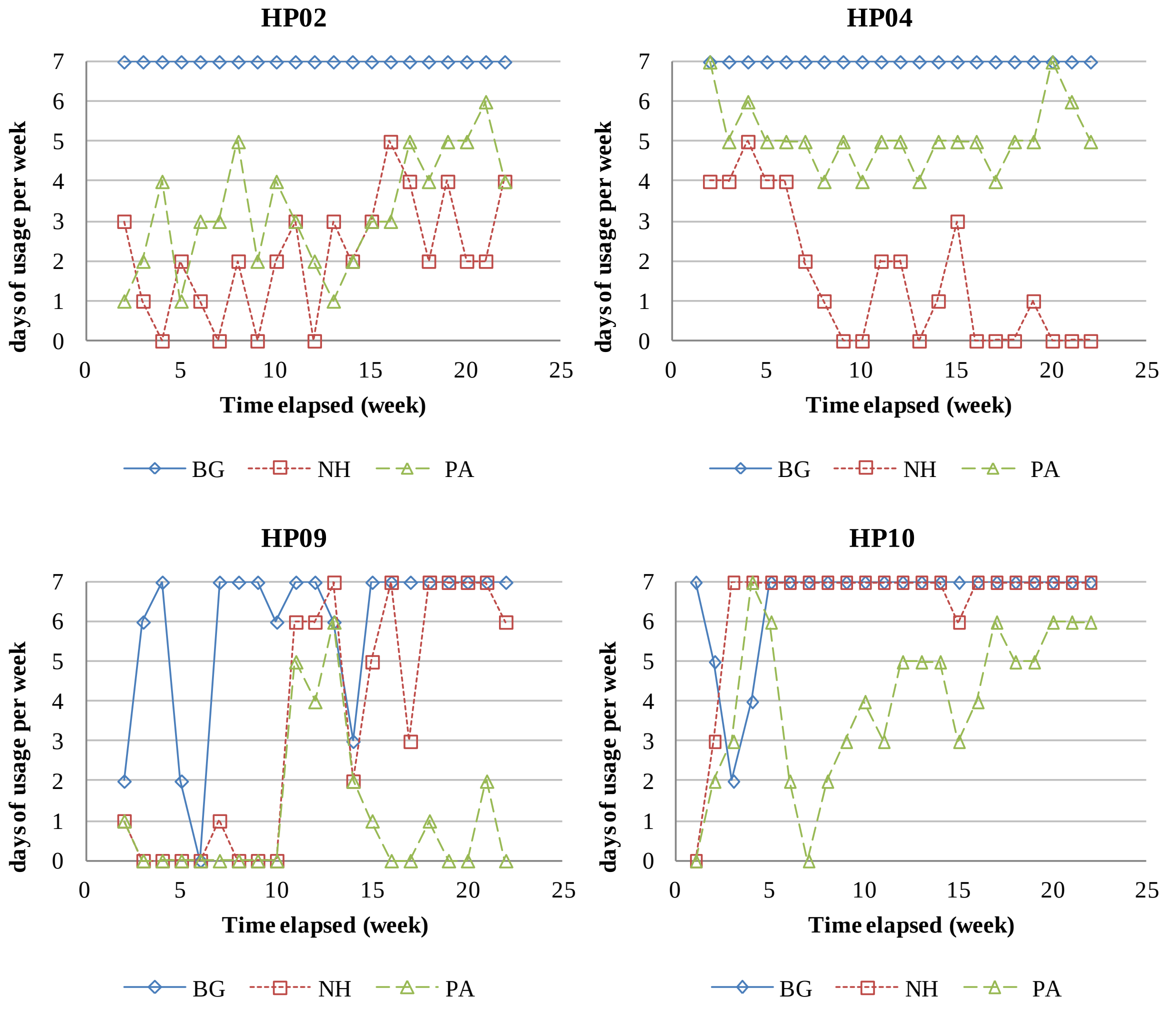


Figure 7.1 Usage rates of each function by participants in group A

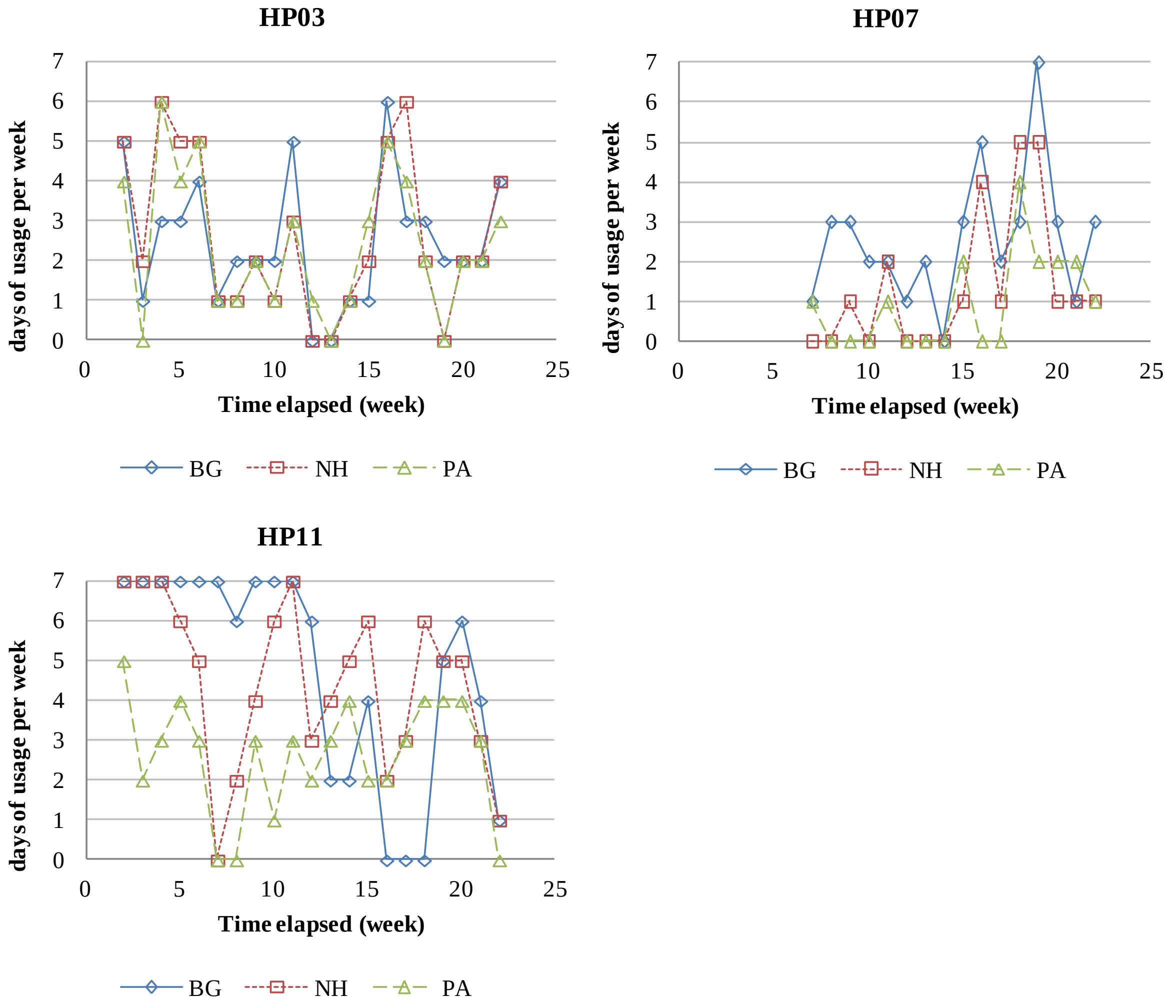


Figure 7.2 Usage rates of each function by participants in group B

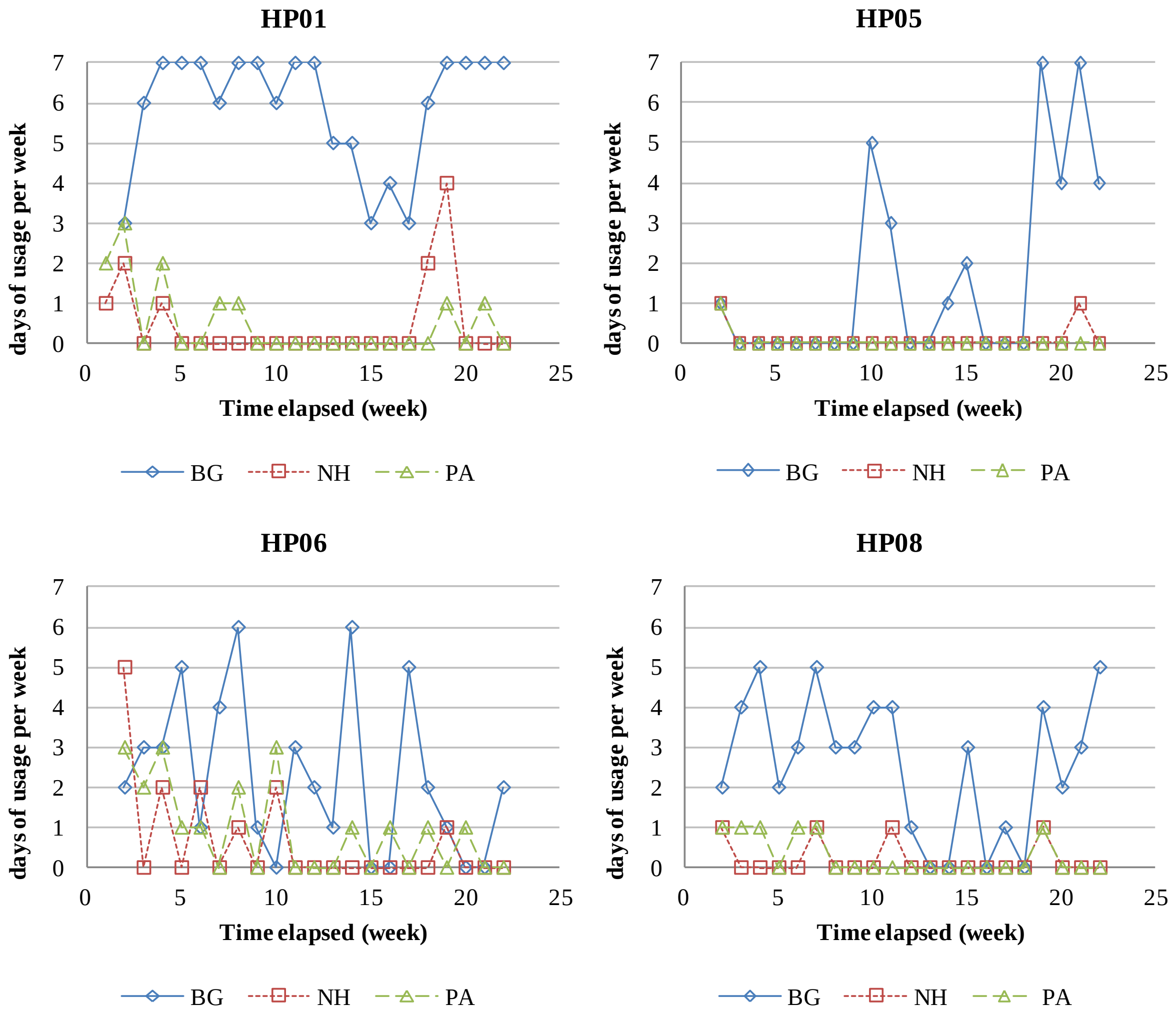


Figure 7.3 Usage rates of each function by participants in group C

Table 7.2 Results from Mann-Kendall trend test on usage rate (modified from Table 2 in Paper 3)

Group / Participant		**BG sensor system**		**PA recording system**		**NH recording system**	
		Tau-value	*P*-value	Tau-value	*P*-value	Tau-value	*P*-value
A	HP02	0.00	N/A	0.45	.008 *	0.38	.025 *
	HP04	0.00	N/A	-0.02	.92	-0.61	<.001 †
	HP09	0.42	.020 *	0.09	.65	0.61	<.001 *
	HP10	0.42	.020 *	0.50	.002 *	0.31	.10
B	HP03	-0.01	.98	-0.07	.69	-0.13	.46
	HP07	0.12	.60	0.47	.033 *	0.38	.074
	HP11	-0.61	<.001 †	0.05	.78	-0.33	.050

C	HP01	0.01	N/A	-0.30	.10	-0.14	0.44
	HP05	0.38	.031 *	-0.31	.12	-0.02	.95
	HP06	-0.28	.10	-0.42	.017 †	-0.38	.039 †
	HP08	-0.15	.39	-0.45	.018 †	-0.15	.45

* mark is given to values smaller than 0.05 when tau-value is positive.
† mark is given to values smaller than 0.05 when tau-value is negative .

Figure 7.4 shows degree of usage of the Few Touch application during the period in which the application was available. The columns are divided into three colors expressing the number of data types recorded per day. Figure 7.5 shows degree of usage of each function during the same period. In the figures, BG, NH, and PA stands for the blood glucose sensor system, the nutrition habit recording system, and the physical activity recording system, respectively.

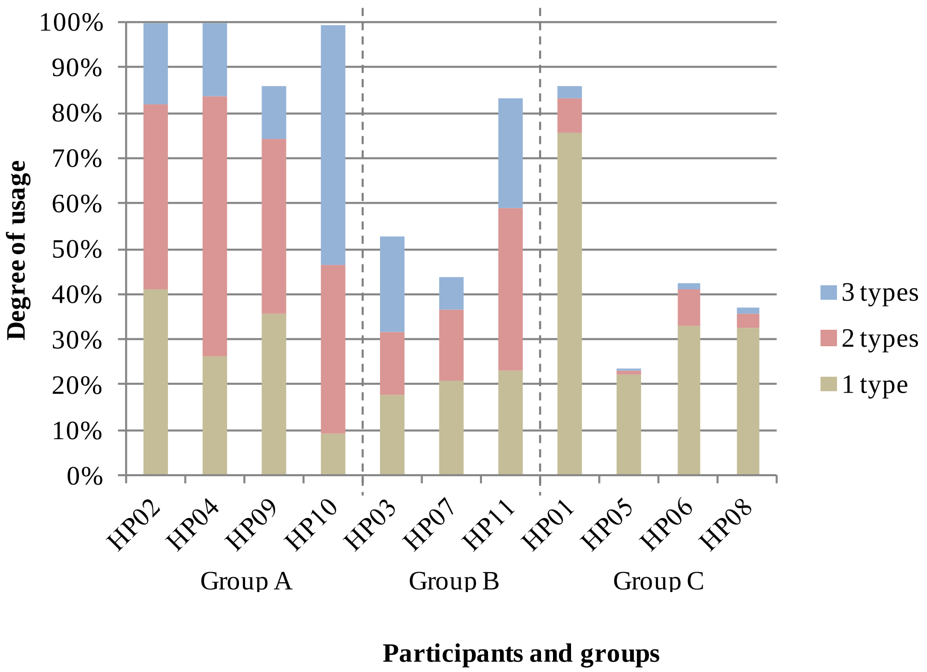


Figure 7.4 Degree of usage of the Few Touch application depending on the number of data types recorded (modified from Figure 2 in Paper 3)

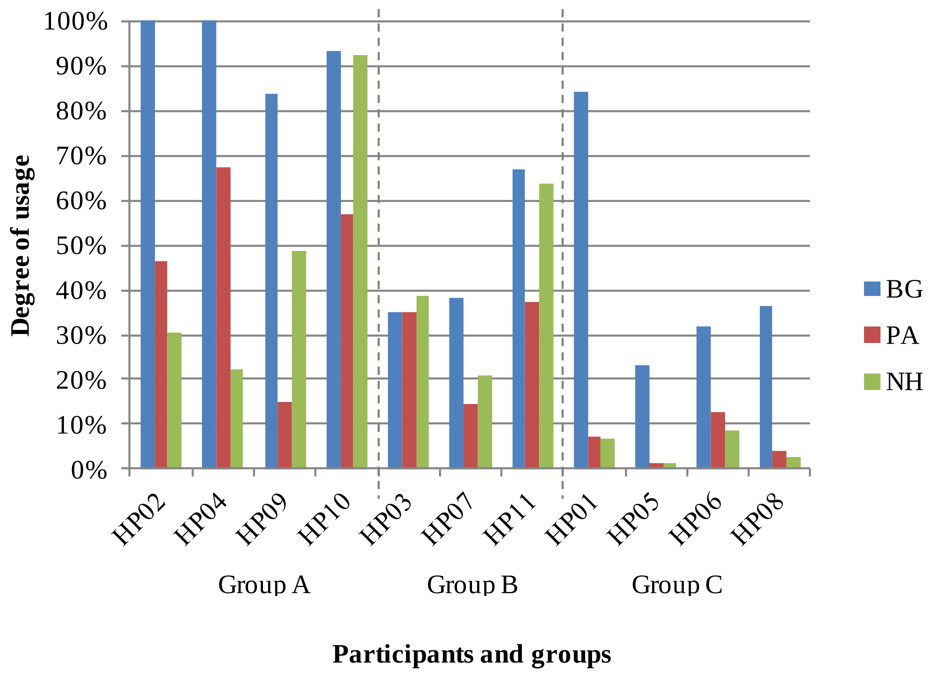


Figure 7.5 Degree of usage of the three functions

Summaries of the questionnaire results regarding major questions are found in **APPENDIX 10** (Parts I and II).

Table 7.3 shows simple statistics regarding blood glucose measurements and answers to Question 11 about the frequency of measurements per week. This table gives information about the number of measurements per day in mean and SD for the period in which the function was available. This separation gives better insight than only weekly measurement frequency. Although this study does not focus much on absolute number regarding measurement frequency, Table 7.3 is useful to better understand their usage of blood glucose sensor system and their needs for measurement.

Table 7.3 Blood glucose measurements in detail

Group / Participant		**The number of measurements per day when any measurement was taken**		**Degree of usage for the period[a]**	**Calculated frequency of blood glucose system per week for the period[a]**	**Answer to Question 11 (weekly frequency of blood glucose measurement)**
		Mean for the whole trial period	SD			
A	HP02	3.00	1.08	100%	21	21
	HP04	1.27	0.55	100%	9	7
	HP09	6.72	2.27	84%	39	35 - 56

	HP10	2.48	1.11	94%	16	18 - 20
B	HP03	1.31	0.58	35%	3	2 - 3
	HP07	1.71	0.94	38%	5	14 - 21
	HP11	1.74	1.11	67%	8	15 - 20
C	HP01	1.98	1.05	84%	12	14
	HP05	2.71	1.61	23%	4	21[b]
	HP06	1.38	0.61	32%	3	3
	HP08	1.48	0.72	36%	4	5 - 10

[a] the period here means that the period in which the Few Touch application was available for the participants
[b] HP05 stated that s/he did not use the Few Touch application

Hereafter, I will summarize the results of usage and experiences of the Few Touch application with a focus on usage depending on the group defined earlier.

Group A: Frequent use with positive experience (HP02, HP04, HP09 and HP10)

Group A is characterized with the very frequent use of the blood glucose sensor system with comparatively frequent use of either or both the nutrition habit recording system or/and the physical activity recording system (Figure 7.1, Figure 7.5). Except HP04, all the other three participants used insulin for treatment, so this gives an account for the high measurement frequency per day as well (Table 7.3). Degree of usage of the Few Touch application as a whole system for the whole period of the trial is therefore also very high; considering degree of usage of at least one function, the four participants are among the top four (Figure 7.4, range: 85.8% - 100%). Another fact that characterizes Group A is that three (HP02, HP09, and HP10) out of four showed significantly increasing trend ($P < .05$) in usage of two out of the three functions (Table 7.2). Questionnaire results showed that except HP02 who had a minor problem with data transfer of blood glucose values, none of them had any problems with the blood glucose sensor system. Negative experience was only observed regarding the nutrition habit recording system by HP04. At question 44 "When do you check the status page of the Diabetes Diary (Figure 6.17 (f)) in the last month?" (**APPENDIX 4**), HP04 wrote his/her experience of difficulties with choosing a right category to record nutrition habit. This difficulty caused him to be "dissatisfied" (scored at question 59 with the 5-Likert scale question (the second worst), **APPENDIX 10** part II) and to decrease usage (Figure 7.1, Table 7.2). Otherwise, the participants found that the application was motivating and they became more conscious about their self-management. All the participants improved either or both HbA1c and/or blood glucose control (Question 69, **APPENDIX 10** part II). They all rated 7 on 7-Likert scale (most positive) of Question 71 asking for perceived usefulness of the Few Touch application (**APPENDIX 10** part II)

Group B: Moderate use with relatively neutral experience (HP03, HP07 and HP11)

Group B is characterized with moderate use of all the three functions (Figure 7.2, Figure 7.5) and moderate perceived usefulness (**APPENDIX 10** part II). When it comes to user experience, it was different between HP07 and the other two. HP07, who was at high risk of T2DM, found that all the four functions were motivating and s/he was satisfied with them. The only exception was that perceived usefulness of nutrition habit recording system for increasing vegetable/fruit intake: the amount HP07 took at that time was 2-4 portions daily while recommended amount by Norwegian Diabetes association was 5 portions. On the other hand, HP03 and HP11 had been originally motivated enough and done well in terms of self-management. In that sense, they did not perceive that the application helped them increase their motivation or improve their self-management activities. HP11 had problems with data transfer of blood glucose measures since late November 2010, which caused a significant decrease ($P < .05$) of usage of the blood glucose sensor system (Table 7.2)

Group C: Little use of nutrition habit and physical activity recording systems with mixed experience (HP01, HP05, HP06 and HP08) Group C is characterized with very little use of the nutrition habit recording system and the physical activity recording system (Figure 7.3 and Figure 7.5). Except HP01, the other three participants' use of the blood glucose sensor system was quite moderate. Three participants out of four (HP01, HP05 and HP08) experienced problems with blood glucose data transmission. HP05 clearly stated that s/he continued using the computer-based self-management program which s/he had used before instead of totally switching to the Few Touch application. HP05 did not like the provided mobile phone and showed a strong opinion that the Few Touch application should have been available on his/her own mobile phone. Regarding the other three participants, their impression of the blood glucose sensor system, the physical activity recording system, and the tips bank in the information function were not negative. HP01 and HP06 stated that their blood glucose measurement frequency increased (not more than double), but their physical activity level remained because it had been good enough from before. HP08 did not change either measurement frequency or physical activity level because they had already been at good level. Regarding the nutrition habit recording system, their impression was not positive. The three participants (HP01, HP06 and HP08) thought their fruit/vegetable intake (0-2 portion, namely 0-300 gram) was good enough and nutrition habit recording system was not useful enough for them to increase this amount. Perceived usefulness of the Few Touch application as a whole system varied greatly (2 by HP01 and 6 by HP06 on 7-Likert scale at Question 71, **APPENDIX 8** part II).

7.2.2 Perceived effects and usability of the Few Touch application

There were not any characteristic differences depending on the group identified above regarding: the participants' perceived effects by using the Few Touch application (Question 72, **APPENDIX 4**); features that they wish that the Few Touch application would be equipped with (Question 73, **APPENDIX 4**); and their satisfaction level with design elements of the Few Touch application (Question 74, **APPENDIX 4**). Similar to answers to Questions 73 and 74, answers to questions asking what elements of each function they liked (Questions 17, 25, 41 and 60, **APPENDIX 4**), degree of agreement on (Questions 26 and 61, **APPENDIX 4**) and suggestions of (Questions 18, 26, 42, and 61, **APPENDIX 4**) possible solutions for improvement did not differ much between groups. Therefore, they were summarized into bar charts and bullet points in **APPENDIX 10** part I. With an exception of free-text commenting, these questions employed 5-point Likert scale for answering: 1 is the most negative ("totally disagree" or "very dissatisfied"), 3 is neutral ("neither") and 5 is the most positive option to the question. The bars in the charts are sorted by three means. They are the total number of participants who scored: I. either "4" or "5", II: "5", and III: "4", in the order of priority. Regarding answers to Questions 73 and 74, **APPENDIX 10** part I shows results from Trial I below the results from Trial II. The bars for results from Trial I are sorted in the same order as the ones for Trial II. Please note that an item for Question 73 about the physical activity sensor (in Trial II) corresponds to a smaller step counter (in Trial I), although they don't mean exactly the same thing. Similarly, an item in Question 74 about the physical activity graph (in Trial II) corresponds to the step graph (in Trial I). Regarding items about simplicity of change goals for physical activity and nutrition habits, it was asked as one item in Trial I, and listed at the same order as the one for nutrition habits in Trial II.

Perceived effects Regarding Question 72, the score 2 "disagree" was given only by HP03 who had had enough motivation and conducted self-management well enough from before (**APPENDIX 10** part I). Although there are three items on which not all the participants answered, the items most of the participants agreed on about the effect of using the Few Touch application were regarding physical activity. Eight out of 10 participants who answered to this item considered that the Few Touch application was effective to measure blood glucose level sufficiently often. HP03 did not give a negative answer only to this item among the others although s/he did not change his/her measurement frequency (Question 12, **APPENDIX 10** part II). This item is followed by items regarding getting confirmation about how self-management activities influence the blood glucose level and also understanding relationship between them. These items were strongly supported by five participants, which indicate that these items were most supported among all the items. After them, items relevant to nutrition habits and positive consequences in terms of their feelings about their diabetes follow. The answer distributions to these items correspond to participants' general feedback regarding nutrition habit recording system, which varied a lot.

Usability To Question 73, their responses were rather neutral compared with the results from Trial I (**APPENDIX 10** part I). It was interesting that only a little less than half of the participants (five out of 11) showed interest to a wearable physical activity sensor in Trial II, while more than half of the participants in Trial I (eight out of 12) strongly agreed on a better step counter than the one they used. Two reasons can be considered for this. First is that the participants in Trial II did not experience how a physical activity sensor, such as the step counter used in Trial I with automatic data transfer, would work for the Few Touch application. Second is their rather high satisfaction level with the physical activity recording system of the Diabetes Diary version 3. This is especially reflected by the results of answers to Question 41 (**APPENDIX 10** part I), to which totally nine out of 10 participants liked the feature that they can record physical activity afterward, compared with using a sensor that records only when it is attached when one does physical activity. Except a physical activity sensor and a reminder for blood glucose measurement which was given score 2 ("disagree") by only HP02, not any items that implied automatic function was given a negative score (**APPENDIX 10** part I). Together with overall very positive response to automatic functions of the blood glucose sensor system, this confirms the identified factor "automation" associated with use of the application in Phase 1.

Table 7.4 shows the results of SUS questionnaire in Trial II together with the results from Trial I regarding Diabetes Diary version 2. Wilcoxon's signed rank test did not discard the null hypothesis that there is no difference between the two versions in SUS scores, although mean scores are different by almost 12 points.

Table 7.4 The results of SUS questionnaire for version 2 (in Trial I) and 3 (in Trial II) of Diabetes Diary

	SUS scores	
	Version 2 in Trial I	Version 3 in Trial

		II
The number of valid answers	12	8
Average (SD)	86.0 (10.08)	74.1 (16.95)
Range	62.5 – 100	45 – 95
Wilcoxon's signed rank test: T^+, T^- (*P*-value)	21, 28 (.131)	

However, comparing two bar charts regarding answers to Question 74 (in Trial II) and the corresponding questionnaire 1 in Trial I in **APPENDIX 10** part I, it is clear that overall satisfaction with design elements of the Few Touch application was lower in Trial II than in Trial I. Especially, opinions regarding elements for the nutrition habit recording system varied greatly from negative to positive, reflecting the results of Questions 58, 59 (**APPENDIX 10** part II) as well as 72 (**APPENDIX 10** part I). Their negative feedback regarding confusion with categories for nutrition habit recording and their wish for more detailed recordings were quite much in line with that by participants in Trial I. For this item in Question 61, the total number of participants who answered "agree" (three participants) and "strongly agree" (six participants) were nine out of 11 participants, and none answered negatively (**APPENDIX 8** part I). In the focus group interview, a part of the participants stated that they had very clear interpretation or own rules regarding what types of foods they record as "high carb." and "law carb." and either "meal" or "snack". However, many others had problems in deciding which category to choose. At Meeting 3, much time was spent on discussing their experience about difficulty with diet. At the end, their conclusion was that they needed to find out how food intake influences their blood glucose level on their own. Nevertheless, they were very much interested in learning more objective fact about foods as well as a guideline showing how to choose a category to record. This was also in line with the results in Trial I. Although there was not any new suggestions for improvement of the tips bank, totally seven out of 11 participants agreed on ideas of "updating the tips" and "enabling access to internet for more information" to improve tips bank at Question 26 (**APPENDIX 10** part I). The results here support the identified factor "rich learning materials, especially about foods" associated with use of the application in Phase 1.

Regarding physical activity recording system, the participants also gave many suggestions at Question 42 (asking for any suggestions to improve the function, **APPENDIX 4**) and at meetings for improvement of the user interface design. Concrete suggestions are shown as answers to Question 42 in **APPENDIX 10** part I. Feedback at meetings included: keeping previously set goals for the periods and that the graph should reflect them when they change periods to show the results; use of calendar week but not the last seven days to set a weekly goal, because it is difficult to follow progress towards the end of a week; enabling recording specific types of physical activity.

Feedback regarding usability of the blood glucose sensor system was much in line with that by the participants in Trial I (**APPENDIX 10**). One new suggestion given by HP11 about the blood glucose graph was enabling a user to set the default number of values to be shown in a graph. This was because s/he did not need to measure so often that the last 50 measures gave an overview of a too long period.

Many usability problems with the provided mobile phone were reported regardless of the age of the participants, including for example; a touch screen that did not function well in a cold environment, a short battery life, quality of the equipped camera function and photos, migration of an address book from another mobile phone, and some problems with sounds. One participant used the provided mobile phone only as a terminal of the Few Touch application but not as his/her personal mobile phone. On the other hand, as described earlier, HP05 did not use the Few Touch application so much partly because s/he could not use it on his/her own mobile phone. This implies the importance of usability of a total system and also confirms the identified factor associated with use in Phase 2 “integration with everyday life”.

8 Phase 3

Design of a food-information database module as a part of improvement of the information function of the Few Touch application was initiated by feedback from the participants in Trial I: the participants wanted more and richer information, especially about food (6.1.2). As described in 2.1.3, a survey of relevant scientific literature also supported the findings from Trial I as well as the feasibility of implementation of a food-information database on a handheld device to tackle these difficulties. Findings from Trial I and a literature survey can be summarized as follows:

- Changing dietary habit is a great challenge for people with T2DM
- Lack of knowledge about diet is a fundamental barrier for dietary adherence
- Patients need right information about food in an interpretable format at right timing
- Use of a food database on handheld device is feasible
- Currently available food databases however require a certain level of preliminary knowledge about food items, which may cause difficulties in finding a food item

Based on these premises, most of the research activities were carried out with sub-goals to answer the following questions:

> "How can user-interaction designs of a food-information database module on a mobile terminal with a small screen be designed so that a user can:
>
> 1. easily and quickly find information s/he wants
> 2. easily understand the information
>
> as a part of resources for user's reasoning process in their self-management that eventually develops a skill in making a better choice in diet?"

First, I will describe results of inquires to "understand and specify the context of use" and "specify the user requirements" [23]. A great focus is given on design of a food-information database module. Description of "producing design solutions" [23] follows. Last, I will report about pilot usability testing.

8.1 Initial requirement identification

To improve the information function so that it answers the user needs of the participants in Trial I, the research team of Lifestyle planned to increase the amount of information and redesign the information function of the Few Touch application[30]. Inquiries were made to

[30] As shown in Phase 2, the information function was updated at Meeting 4 in Trial I by adding a "back" button as well as header and category name to each tip. This update was a similar to a "patch" to solve a critical problem the participants experienced rather than a major update to reflect most of the feedback. This decision was made for the purpose to respond to the participants' feedback as quickly as possible and, by doing so, to keep the participants' engagement and trust to us further.

different stakeholders depending on the purpose of the inquiry. Inquiries 1-3 were made to the participants in Trial I to understand "end-user needs" which were context based and mental-model based. Inquiry 4 was made to "domain experts" to identify requirements from educational point of view.

8.1.1 Inquiry 1

Inquiry 1 was done to **collect user needs regarding methods for access to information relevant to T2DM and situations in which they would need the information**. Questionnaire used is shown in **Appendix 5**. At Meeting 5 in Trial I (Table 6.1) 11 out of the 12 participants in Trial I answered to the questionnaire. The results are summarized into tables shown in **Appendix 11**.

The results showed that most of the participants wanted to get "tips"-type of information when they want it rather than as a "pop-up". On the other hand, there was not high consistency among the participants in terms of which types of information they want to look up and in which types of situation it happens. However, given the fact that only a few participants chose "I don't need it (any tips)" option; the result shows that the participants were interested in most of the types of information in general regardless of situation. In spite of the free space on the questionnaire sheet where participants could freely suggest opinions about type of information or situations for lookup, no one suggested any new ideas.

All the participants showed their needs for a bookmark function while only a little more than half of the participants showed their interest in a link to a webpage that offers further information about the particular information. This result may imply their needs for a function on a mobile phone to be "quickly accessible and quickly done" in terms of integration into their everyday life, because the context of use can vary a lot.

8.1.2 Inquiry 2

Inquiry 2 was done to **understand users' mental model of information architecture** so that the results could be used to redesign structure of the information function of the Diabetes Diary.

Card sorting technique was used (5.2.1). Fifteen cards were prepared as follows together with blank cards where the participants could make their own cards or duplicate other cards (**Appendix 5**, p.4).

a. Food
b. Physical activity
c. Disease
d. Diabetes in general
e. Blood glucose
f. Information to show others (e.g. acute information, foods that are not recommended to eat)
g. Picture of a food item in an amount that contains 10 gram of carbohydrates
h. Glycaemic Index (GI)
i. Amount of carbohydrates in a normal portion of a food item
j. Nutrition contents of a food item
k. Reference book about diabetes
l. Quiz about diabetes

m. Bookmarks
n. List of items in alphabetical order
o. Search by word with manual typing/writing
p. Others – write your own category on a Post-it™

Contents of the cards could be divided into: categories for the updated version of the information (tips) function of Diabetes Diary version 1 (Figure 6.12) (cards "a"-"e"); topics or types of information reflecting feedback from the participants (cards "f'-"j"); contents that were suggested after a discussion in the Lifestyle project team (cards "k" and "l"); and options to enable quick access to information (cards "m"-"o"). The answer sheet[31] had a matrix with four columns and three rows. Each row represented the level (the top, the second, and the third, as described above). The participants were instructed to choose at maximum four cards to place at each cell of the top row. The rest of the cards were expected to be placed at the second or the third level, but it was not necessary to use all the cards.

As same as for Inquiry 1, 11 out of the 12 participants in Trial I carried out the card sorting at Meeting 5. The results are summarized into the tables shown in **APPENDIX 11**.

The cards were sorted into either three (by five participants) or four (by six participants) groups (**APPENDIX 11**, Results of Inquiry 2, Table 1). Ten out of 11 participants used "a. Food" and nine used "b. Physical activity" while "c. Disease", "d. Diabetes in general" and "e. Blood glucose" were used moderately and evenly (each by five participants). All the 11 participants used at least one of these three cards ("c"-"e") for the top level, and four participants used two of them for the top level. This illustrates that the information represented by the names of the cards "c"-"e" are regarded as important as food and physical activity, but not regarded as independent as food and physical activity. Thus, it is plausible to combine them into one category.

While information relevant to foods were clearly sorted under card "a", not any clear tendency was observed for the information sorted under cards "b"-"e" (**APPENDIX 11**, Results of Inquiry 2, Table 2).

Only one participant (P12) used card "p. Others – write your own category on a Post-it™" to write suggestions. P12 gave several concrete suggestions in a questionnaire held in previous user-meetings as well. And there was only one participant (P05) who duplicated a card (card "m. Bookmarks"). P05 used card "m" at the third level of all the groups whose top levels were: card "a", "b", and "e".

The result of HC analysis (Figure 8.1) well confirms the results described above. "Height" on the Figure 8.1 expresses dissimilarity. The higher a pair of cards meet, the less similar the participants on average regarded they were.

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[31] The answer sheet for Inquiry 2 was distributed separately from the questionnaire sheet. This is not attached as appendix.

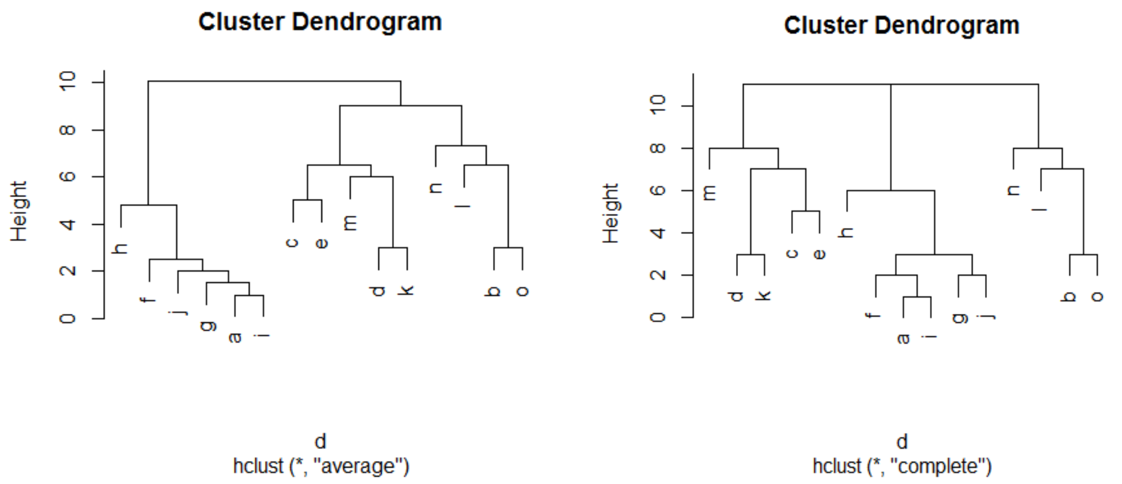


Figure 8.1 Result of a hierarchical cluster (HC) analysis of the summed data of all the card sorting results using "average" method option (left) and "complete" method option (right)

Although the two cluster dendrograms show slightly different results in terms of the heights of meeting points of cards or clusters, both show that there are three major clusters, each of which consists of same cards in both dendrograms. Considering the three major clusters, match between the grouping by HC analysis and the grouping by the participants was at average 79.7% (SD: 10.9, Range: 60.0% - 97.1%). When dividing participants into two groups depending on the number of groups they sorted cards into (e.g, either three groups and four groups, not considering "unnecessary" as a group) and compare these two groups of participants, the average of match is better for the participants who sorted cards into three groups (84.6%, SD: 7.7%, Range: 69.5% - 97.1%) than four groups (75.7%, SD: 10.0%, Range: 60.0% - 84.8%), but this difference was not statistically significant by Students' t-test[32].

Figure 8.2 shows result of a MDS analysis of summed distance matrices for all the participants. How well an MDS plot reflects the original data is measured by a stress value: the smaller, the better; and according to Tullis and Albert [58], "a good rule of thumb is that stress values under 10% are excellent, whereas stress values above 20% are poor". The stress value for Figure 8.2 was 10.8%, which is satisfactory. The plot illustrates relative distance between each other. The axes don't mean anything special, and the plot area can be rotated. Figure 8.2 illustrates the contrast between similarity among cards "a", "f-j" and dissimilarity among the other cards. This result therefore implies a rather low consistency among the participants when it comes to grouping of the prepared cards.

[32] Shapiro-Wilk normality test could not discard the null-hypothesis that samples come from a normally distributed population for both groups. F-test could not discard the null-hypothesis that variances between the two groups are not different. Therefore, Student's t-test was applied with assumption of equal variances.

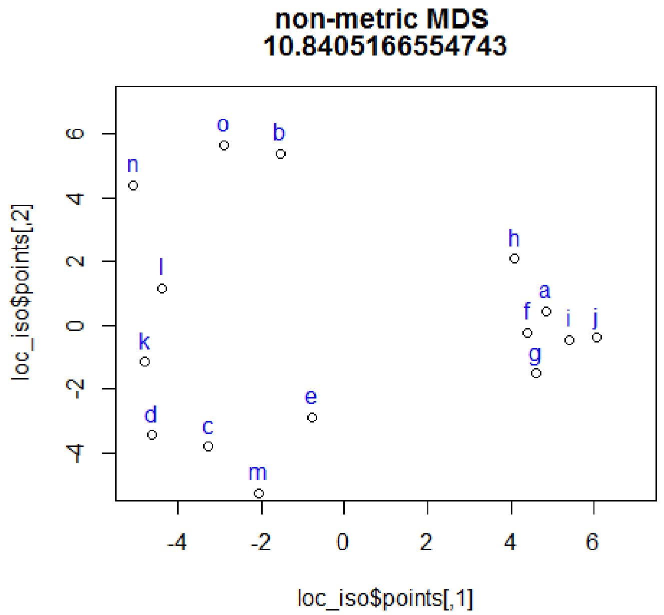


Figure 8.2 Result of a Multidimentional Scaling (MDS) analysis

Lessons Learned Against my anticipation, cards “k”-“o” were not used for the top level except one case that P07 used “n. List of items in alphabetical order”. On the contrary, card “n. List of items in alphabetical order” and “m. Bookmarks” were regarded as unnecessary by three and two participants, respectively. The reason for this might be because of unfamiliarity with them: these had never been used as a part of the information (tips) function while cards a-e showed the categories used in the updated version of the function. Another phenomenon which needs to be noted is that card “o. Search by word with manual typing/writing” was placed at the second level under card “b. Physical activity” by five participants. This seemed quite odd to me, but the Norwegian wording “Skrive inn manuelt fysisk form[33]”, of which “fysisk form” means “physical fitness”, is a sound reason for the participants to misunderstand what card “o” meant. In order to avoid leading the participants to choose certain cards that I (and the research project team) expected them to use for the top category, I did not use any concrete examples such as illustration-based mockups to show images of possible redesigns of user interface for the information function. However, these results above well illustrate that only oral explanation and the wordings on the cards might not have been explanatory enough.

One participant (P09) used cards “h. Glycaemic Index (GI)”, “i. Amount of carbohydrates in a normal portion of a food item”, “j. Nutrition contents of a food item” for the top level in addition to card e”. (**APPENDIX 11**, Results of Inquiry 2, Table 3) Given the fact that P09 explicitly expressed his/her wish for information represented by cards “h”-“j”, it is understandable that s/he used them at the top level. However, considering the cards used for the second and third level of each group, it is very questionable if s/he understood the concept of the card sorting. This question is applicable to two other participants (P01 and P03),

[33] This wording was made by a native Norwegian-speaking researcher as a modification of my suggestion “skriv inn form”. “Form” in Norwegian mean fitness. There must have been a miscommunication between me and him.

although the cards they chose for the top levels are consistent with most of the other participants.

8.1.3Inquiry 3

Inquiry 3 was administered **to understand user needs regarding user interface design of a page that shows information of each food item in a food-information database module**. At Meeting 7 in Trial I (Table 6.6), a questionnaire was administered to gather ideas and preference on information to display in a detail view of a food item. The questionnaire used paper prototyping technique and VAS to rate each idea. A focus group interview was also arranged. Eleven out of the 12 participants participated, but 10 participants filled the answer sheets.

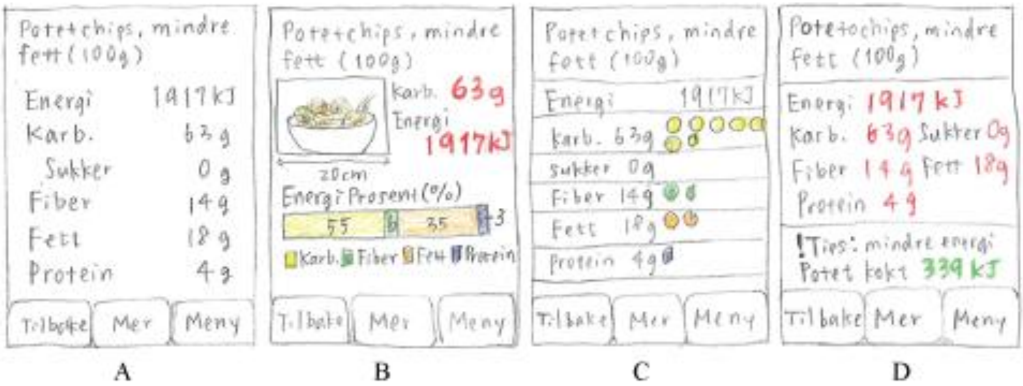


Figure 8.3 Presented UI-design suggestions in hand writing sketch for paper prototyping

The answer sheets showed four UI-design suggestions shown in Figure 8.3. All the drawings were printed on answer sheets in approximately the same size with the screen of their smartphone that had Diabetes Diary (HTC Touch Dual, Taiwan). Each suggestion has “More” (“Mer” in Norwegiean) button that shows other information relevant to the food item. Concepts of each design are as follows:

- Design A	Totally text based, and all the texts are in a comparatively large size.
- Design B	It shows information with graphics, such as a photo of the food item and a chart for energy proportion.
- Design C	A combination of text-based and graphical design, showing the amount of each nutrient by the number of icons together with numerical numbers.
- Design D	It squeezes information shown in design A and shows an additional tips information.

The participants were asked to rate each design on a VAS, which was located right below each drawing and indicated the left end is “bad” while the right end is “good”. They were also asked to make comments or suggestions of design ideas. There was a large enough space to draw two sketches that the participants could suggest.

Reflecting the lessons from the card sorting experience, before the session I explained the followings by using presentation slides on a big screen.

- The purpose and the concepts of the paper prototyping and rating on VAS

- Characteristics of typical UI design of nutrition table used in smartphone applications that were available at that time by showing two screenshots
- Concepts of each UI-design suggestion

The rating showed that the design D scored the highest (Mean: 0.817, SD: 0.171) followed by design B (Mean: 0.788, SD: 0.200), design C (Mean: 0.679, SD: 0.237), and design A (Mean: 0.470, SD: 0.220). Shapiro-Wilk normality test discarded the null hypothesis of normality for distributions of scores given to designs B (W=0.82, P=.03) and D (W=0.78, P=.009). Therefore, I carried out Kruskal-Wallis rank sum test of which the null hypothesis is that there is no difference in distribution of the scores among different designs. The result showed that there is a difference at least between one pair of samples (Chi-squared = 12.70, df=3, P=.005). Table 8.1 shows results of a post-hoc Bonferroni test with P-values as calculated by Wilcoxon rank sum test. Applying Bonferroni adjustment to α-value of .05 (and .10 for marginal significance) by dividing with the number of tests, i.e., 6, makes a new α-value of .0083 (and .017 for marginal significance). There were only marginal differences between: design A and B (B is better than A), A and D (D is better than A), and B and C (B is better than C)[34]. There was no one who gave suggestions for other designs.

Table 8.1 Results of Bonferroni test

Compared designs	A-B	A-C	A-D	B-C	B-D	C-D
T+ [a]	1	7	2.5	51	24	18.5
P-value by Wilcoxon rank sum test	.011*	.037	.011*	.017*	.770	.359

* $P \leq .017$

[a] Values are sums of ranks of absolute values of difference when design-left is scored higher than design-right

Given comments on answer sheets and in focus group sessions, the participants' needs could be divided into mainly the following four themes; recommendations, visual information, focus on carbohydrates, and information for daily use of the Few Touch application.

Recommendations on the food include; suggestions for alternative foods which are better in view of nutrition, better way of cooking, and amount of intake in relation to the recommended energy intake from protein, fat, and carbohydrate.

Visual information was welcomed because it was regarded as intuitive to get to know what the information is about. If the picture shows the food item in a certain weight, for example 100 gram, which is the unit for nutrition label in Norway, it would help users to grab ideas about nutrition contents within a certain amount of a food item visually.

It is carbohydrate which influences the blood glucose level, so it is natural that the participants show their needs for information with a focus on carbohydrate. The participants also meant that recommendations should be made with a focus on carbohydrates.

[34] Actually, in spite of using VAS, there was a tie between scores given to two designs (A and B) by one participant, and also between absolute differences between scores by different participants. Therefore, exact P-values could not be calculated for combinations of: A and B, A and D, B and C, and C and D.

Feedback included a wish to use such information in combination with nutrition habit recordings and needs for information of ordinary foods. This is in line with the results of Q2 in Inquiry 1 (**APPENDIX 11**, Results of Inquiry 1). One participant complained that nutrition labels on food products were too small. Another participant mentioned that which types of nutrients nutrition labels showed were different from one to another. This illustrates again how difficult it is for them to get necessary information about nutrition for even ordinarily available foods.

8.1.4 Inquiry 4

By following the design guideline of the Few Touch application (**APPENDIX 9**) communication concepts of a food-information database module part needed to be refined so that requirements for the module would be clarified. More concretely, the refined communication concepts should address how the food-information database module could be utilized so that a user could overcome the barriers against establishing healthy diet habit. The results in the previous sub-sections showed that the participants in Trial I might need such information regardless of specific timing or situations and they wanted "fact sheets" of food items. Considering these findings together with the archetypical activities that Kanstrup et al. identified [49], making task scenarios of "calculating (or estimating)" were regarded useful to obtain requirements for the module.

For this purpose, I made an inquiry to the two research project leaders of Lifestyle project [1] as domain experts. I asked them to suggest specific task scenarios for planning and calculating tasks as well as any user interaction design ideas for a food-information database module as an educational tool.

8.1.4.1 Suggestions 1

Suggestions 1 is by one of the two project leaders of Lifestyle project, Leader 1. Suggested task scenario can be summarized as "choosing foods to eat for: a lunch at a cafeteria and night snacks" in view of the amount of carbohydrates content.

This suggestion was based on the two perspectives about food habits: "normal habits" and "habits in out-of-ordinary situations". Normal habits mean daily food intake that one has more or less control over in terms of timing, ingredients, preparation, and amount. On the other hand, out-of-ordinary situations mean cases such as out-dining with others in which one has, if any, little or limited control.

Leader 1 meant that regarding normal habits, there are some things that a patient should just remember by learning once in order to improve their skills in diet. Examples included memorizing rough categories of food items with regard to type and amount of carbohydrates, such as berries don't contain much carbohydrates or one banana contains approximately same amount of carbohydrates that two apples contain. Habits in out-of-ordinary situations are more difficult than normal habits with regard to planning task and calculating task. Especially "lunch at cafeteria"-situation is a perfect setting as a training because it offers a certain degree of flexibility to a patient, namely a patient can choose what to take although the number and types of options are limited.

Figure 8.4 Examples of food circles.[245]

Suggestions for concrete tasks for “lunch at cafeteria” scenario were the following:

- Estimate an amount of carbohydrate of a certain food item
- Choose food items (from a buffet) to compose a plate so that a meal can fulfill a certain condition
- In a set menu (a complete meal consisting of fixed food items), try to change amount or type of food items, which are under the category of grain, and see how much total amount of carbohydrate will change.

Leader 1 showed a strong interest in use of a “food circle” (“kostsirkelen” in Norwegian). Examples of food circles are shown in Figure 8.4. A food circle “gives an indication of what the proportions of your daily food intake should consist of” [246

]. A brochure “Carbohydrates and insulin” (“Karbohydrater og insulin” in Norwegian) [245] shows a food circle on the leftmost side of Figure 8.4. This food circle shows grouping of foods based on its impact on blood glucose level. Leader 1 suggested to take advantage of this as a part of interactive user interface of the food-information database module, so that it would make it easier to make a choice of what type of food items to eat. Leader 1 also suggested an idea of user interaction design for food-information database module that fits the third task scenario above (Figure 8.5). By choosing one food item from a food circle and drag it into a “plate” area, it automatically calculates the total amount of carbohydrates and show it to a user. This idea was inspired by a “dish model” (“tallerkenmodellen” in Norwegian) [247]. Dish model shows how a patient with T2DM should compose a dish and it can be used as a portion control tool.

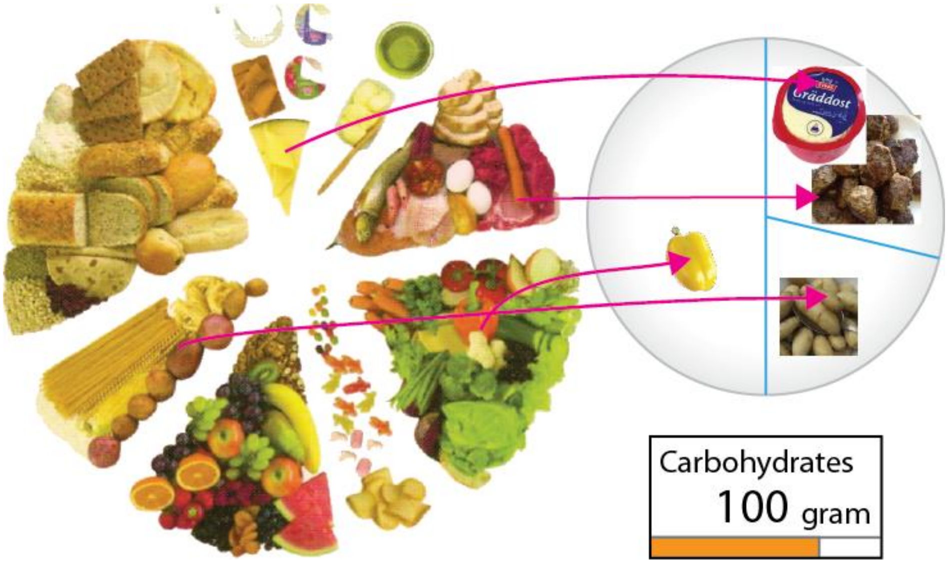


Figure 8.5 Illustration of the suggestion about an interactive user interaction design for a food-information database module.(The food circle on the left side is reproduced from [245])

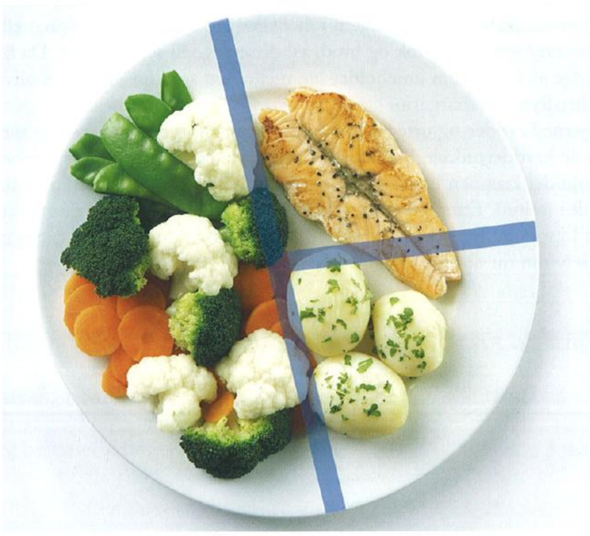


Figure 8.6 Example of a "dish model"[247]

8.1.4.2 Suggestions 2

Task scenario by Leader 2 was comparison of food items by conditions relevant to ingredients or the amount of nutrients. Leader 2 also suggested two ideas of interactive user interfaces for the food-information database module, as shown in Figure 8.7.

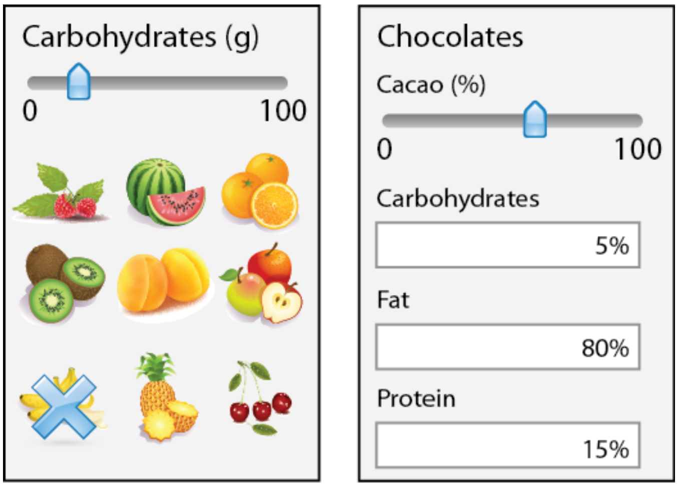


Figure 8.7 Illustration of the suggestions about two interactive user interaction designs for food-information database module

The first idea is shown on the left-hand side of Figure 8.7. By moving a slider on a scale shown above, a user can find food items that satisfy the condition given by the indicator. The second idea is shown on the right-hand side of Figure 8.7. This user interaction design also employs the same idea of using a slider to adjust amount of certain ingredients. His example was chocolates, because in his experience of having T1DM, he had wondered whether or not amount of macro nutrients might be different depending on the amount of cacao. This type of user interface may provide a user with a rough idea regarding what types of chocolates they should choose.

8.1.5Summary of initial requirement identification

The identified requirements for improvement of the information function and design of a food-information database module can be summarized as follows:

- The participants in Trial I wanted to get access to any type of general information relevant to T2DM regardless of situation.
- The participants' needs for information about food were divided into mainly four themes: recommendations, inclusion of visual information, focus on carbohydrates, and being useful for daily use of the Few Touch application.
- The two project leaders suggested a task scenario and interactive user interface designs to encourage learning by using a food-information database module.

Lessons learned from the inquiries can be described as follows:

- Previous experience of using the information (tips) function of the Few Touch application influenced the way of thinking about redesigning structure of the information function.
- Balance of information to provide the participants in order to avoid misunderstanding, unintentional misleading, and a bias, must be carefully considered.

8.2 Concept design

Hereafter, I will write only about a food-information database module as a part of improvement of the information function.

8.2.1 Conceptual models

I developed following conceptual models for user interactions of functions for search and comparison of food items. They were based on the findings from literature survey (2.1.3 and 3.2), Inquiries 3 and 4 as well as consideration into constraints by both technical possibilities and time respect. Related works to the suggested designs are summarized in a master thesis [248] by the master student whom I was a collaborating with.

8.2.1.1 Search of food items – "Food Map"

The literature survey showed the problems with a text-based user interface for search of a food item in a category-based information structure. I reached a concept of using a food circle as a "map" of food items to search as a potential solution to the problems. Table 8.2 summarizes the conceptual model for a function to search food items.

Table 8.2 Description of conceptual model for search of food items

Items of conceptual model	**Description**
The major metaphor and analogy	Web mapping services that enables: • zooming in and out to switch the view point between getting an overview and looking into detail • panning on a map to shift the place to focus on at the same level of view point It has a certain analogy with finding a food item in a grocery store.
The concepts	Task-domain objects: Food items and a food circle where items are located Attributes: Category and sub-category that a food item belongs to, images of food items, information about nutrition, location of food items on a food circle, size of food circle, zoom level, level of details to display at a zoom level, division of a food circle by categories and sub-categories Operations / actions: searching food items on a food circle, viewing details of information about a food item
The relationships between concepts	Food items are visually recognizable on a food circle in a corresponding part that represents a category and a sub-category. Details of food information can be accessed from the image of the item on the map.

The mappings	When a user zooms in a food circle that shows an overview of included items and positions of categories, it displays a more detailed view of the area of interest. The user operates the food circle by zooming and/or panning to find an item that s/he is searching. By clicking on the image of the item, the user can view detailed information about the food item.

Web mapping services, for example Google Maps®[35], enable zooming in/out and panning on a map. By zooming in/out, web mapping shifts image files to show on a browser depending on the scale. The bigger the scale is, the less the details are shown (Figure 8.8). A user can pan on a map to move around the map at the scale, if a target is outside of the frame of a map.

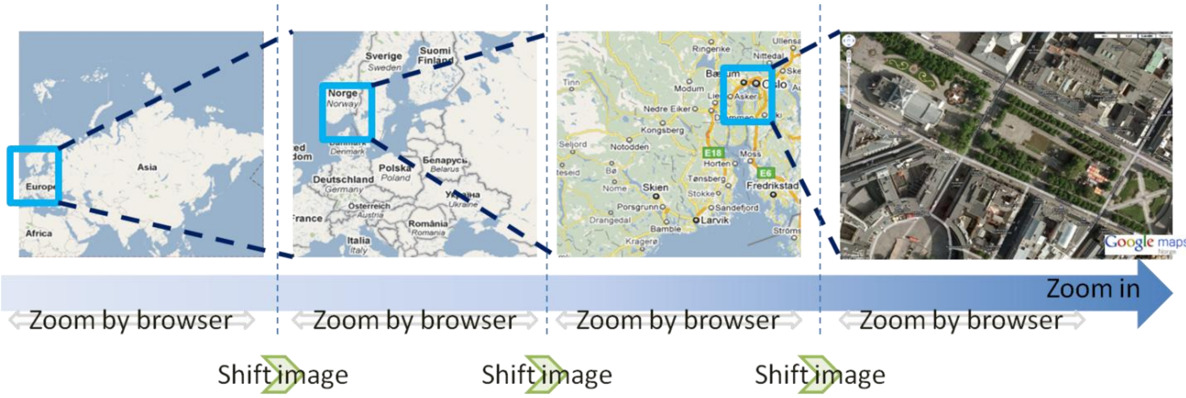


Figure 8.8 Zooming of web mapping (screenshots were obtained from Google Maps®)

Applying this idea on a food circle might have the following potentials. Firstly, the panning feature enables a user to go across the boundaries between categories, sub-categories, or even lower levels of the hierarchical structure. By locating similar categories or groups close to each other and positioning food items near borderline, it may reduce steps back upward to the root of the hierarchy to go to the other. In addition, as represented by a wide use of thumbnail view in many of modern operating systems (OS)[36], images of food items might be easier for a user to find an item regardless of the level of literacy or knowledge about name of food items. Figure 8.9 illustrates the Food Map concept.

[35] https://developers.google.com/maps/

[36] http://en.wikipedia.org/wiki/Thumbnail

Figure 8.9 Concept of "Food Map" for search of food items (Paper 5, Figure 1)

8.2.1.2 Comparison of food items – "Scatter Plot"

Trial I revealed that the participants needed "fact sheets" of food items. Inquiry 3 also revealed the user-needs for suggestions of alternative food items. To fulfill these needs by incorporating Suggestion 2 obtained from Inquiry 4 (to use a slider on a scale to set a condition for search of food items), I reached an idea to apply scatter plotting technique to comparison of food items as shown in Figure 8.10.

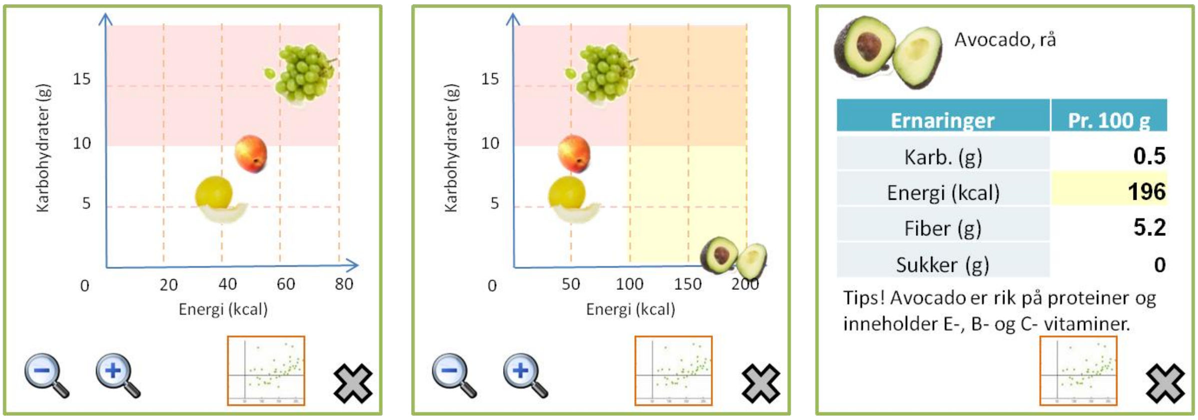


Figure 8.10 Concept of "Scatter Plot" for comparison of food items

Table 8.3 summarizes the conceptual model for a function to compare food items. This conceptual model does not have any analogy to other things.

Table 8.3 Description of conceptual model for comparison of food items

Items of conceptual model	Description
The major metaphor	Ordinary "scatter plot diagram" that enables: • mapping objects according to its values in two attributes
The concepts	Task-domain objects: Food items and a scatter plot field

	where items are mapped Attributes: images of food items, types of information (such as nutrients), numerical values that explain the property of a food item in terms of each type of information, axes of a scatter plot, parameters that axes express Operations / actions: compare food items of interest in one or two parameters of interest
The relationships between concepts	Food items are visually recognizable on a scatter plot field at a location corresponding to their properties, which are values of parameters that x- and y-axes represent. Parameters represented by x- and y-axes are those included as attributes of food items in terms of its nutritional property. Details of food information can be accessed by clicking on the image of the item on the map.
The mappings	When a user compares (selected) food items, it displays the images of the food items mapped on a scatter plot field according to their properties regarding two parameters that are represented by x- and y-axes. When a user clicks on an axis, s/he can change the parameter from a list. This will change the mapping of the food items on the scatter plot according to their values of the selected parameter.

A scatter plot diagram is a widely used method for information visualization in simple statistics, where normally plots are shown on an X-Y area corresponding to its values for each attribute of an axis (Figure 8.10, left).

This design was proposed based on notion that it is important for people with T2DM who are not using insulin for treatment to get ideas about approximate amounts of nutrients in food items rather than very precise amounts [3]. Besides, amount of nutrients in one portion of a food item can vary, especially when it is non-processed food items such as raw potatoes, vegetables, fruits and berries.

As an idea for enhancing ease of understanding information, I also proposed use of color-coding of the background of the scatter plot according to the value of each axis. (Figure 8.10, middle). A screen that shows nutrition information of a food item can also take advantage of this back ground color as that of cells in a table of nutrients so that the design will keep consistency (Figure 8.10, right).

8.2.2 Presentation of the design concepts to the participants in Trial I

At Meeting 8 (Table 6.6), the master student and I had a presentation to explain the concepts of user interaction designs of a food-information database module to the participants in Trial I.

For this presentation, a low-fidelity role prototype (5.2.2.2) was used. Figure 8.11 shows some of screenshots of the prototype.

Figure 8.11 Example screenshots of the low-fidelity role prototype

At the presentation, we also asked the participants the following questions to clarify their needs and to identify requirements.

- Whether or not the task scenario suggested by Leader 1 sounded realistic for them
- Types of food items that they often wonder about nutritional contents or that they often have difficulties to get to know their nutritional contents

The participants were generally satisfied with the design concepts. No participant considered that user-interaction designs of the prototype looked difficult. There was only one feedback given to a user-interaction design issue, which was that icons on the Scatter Plot should also be clickable to display details of nutrient information.

At the first meeting, the following feedback was given.

- While “having a snack” is realistic, “lunch at a cafeteria” is less realistic situation, because many of the participants bring a lunch pack. However, a concept of “composing a meal” is realistic, and it can be for whichever type of a meal.
- “Exception”, such as having chocolate for a snack, is realistic. They wonder for example which type of chocolate is healthier (or better) than others.
- It is difficult to say which food items are difficult to estimate amount of carbohydrates.

- In spite of a certain degree of knowledge about healthy and unhealthy foods in terms of T2DM, not much care is taken for amount of food items to eat. In another word, estimation of the amount of a food item itself is the difficult part, although healthiness of foods also depends on amount of intake.
- Information about amount of carbohydrate contents should be given in detail; for each type of carbohydrates, such as sugar, mono- and disaccharide. Such information is not available for many of food items today.

At the second meeting, the following feedback was given.

- All the participants agreed that the suggested task scenarios (snacks and lunch at a cafeteria) are realistic
- Information telling which product is the healthiest among similar products, for example, which sour cream product to choose, is appreciated.
- Including all the food items in a database sounded an enormous work. If included food categories would be limited because of this, the followings were the most appreciated categories:
    - Fruits
    - Dairy products
    - Alcohol drinks (though P01 believed red wine was healthy, s/he found that it contains a great amount of carbohydrates.)
    - Bread (due to the fact that many eat bread and it has a lot of variations)
    - Snacks
- Food items that normally don't show nutrient labels should be included in the database.

8.2.3 Summary of the concept design

This section can be summarized as follows:

- Based on results and findings from the previous inquiries and identified problems with available food-information databases on a handheld device, two design concepts for user interaction were suggested.
- A role prototype was made to demonstrate the design concepts using animation function of Microsoft Office PowerPoint®.
- The prototype was presented to the participants in Trial I. They considered user interactions of the demonstrated prototype simple and easy.
- All the participants in Trial I considered "choosing snacks" is realistic, while "lunch at cafeteria" was not agreed by all of them.

8.3 Resulted Design – Prototypes for pilot usability testing

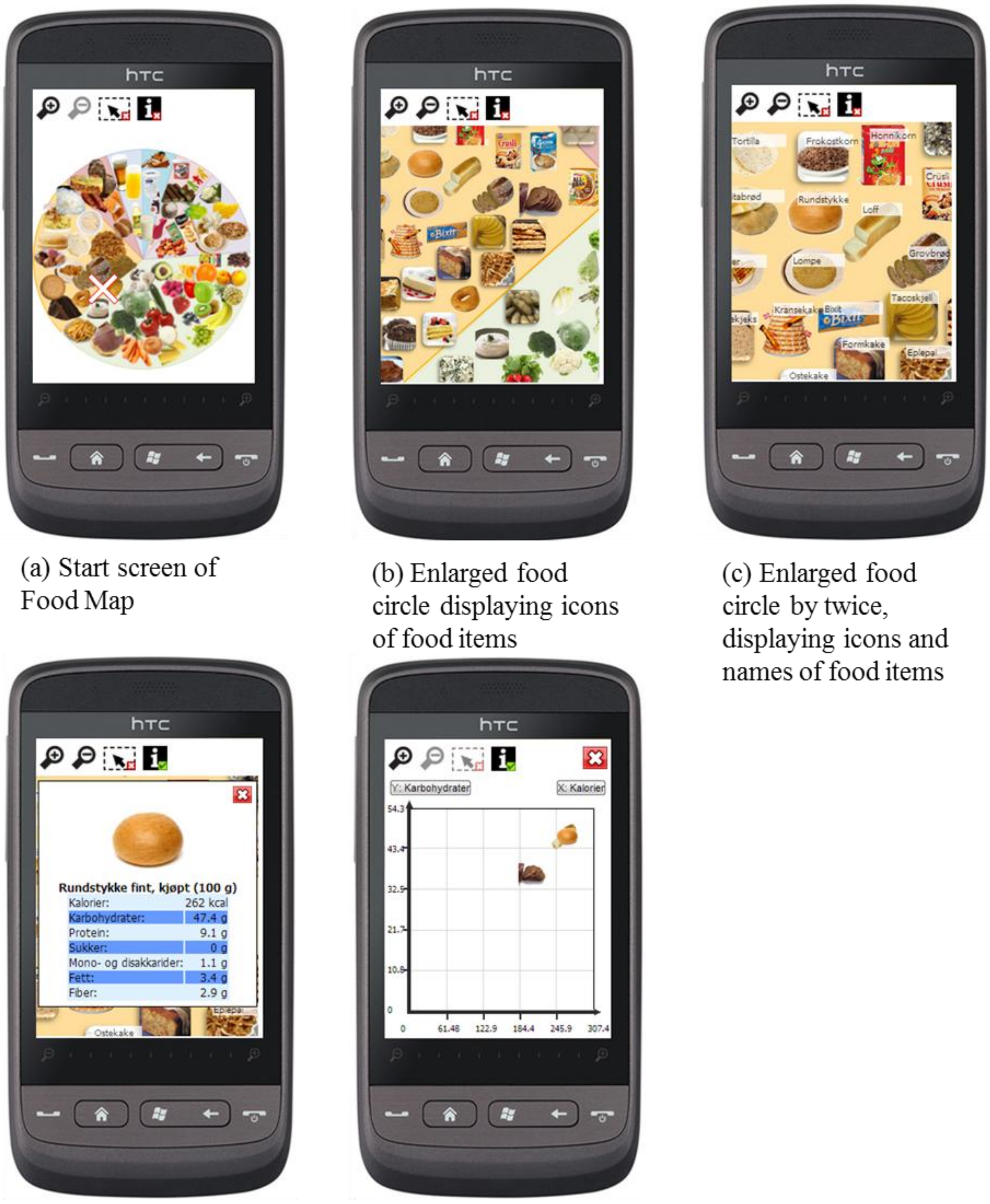
Working prototypes of a food-information database module with two types of user interaction designs were developed. One is “Food Browser” in which “Food Map” search interface and “Scatter Plot” comparison interface were implemented. The other is “List View” in which a text and list-based interface for both search and comparison was implemented. We intentionally made “List View” user interface totally text and list based so that we could examine whether or not the design concepts actually solve the reported problems (3.2) with the common and traditional list based user interface with text and number. This would also yield knowledge for improvement of the design.

HTML/JavaScript solution was taken prior to making a native application with Windows Mobile System Development Kit using C#. This was for the ease of migration to mobile environment regardless of a potential shift to another OS of a mobile phone as a platform of the Few Touch application in future.

8.3.1 User interaction design

8.3.1.1 Food Browser

User interfaces of Food Browser are shown in Figure 8.12. Food Browser shows a food circle as the initial view of Food Map search function (Figure 8.12 (a)). The food circle is divided into pies with different background colors. One pie corresponds to one food category. The food circle shows only limited number of icons of food items that represent the corresponding category. By clicking wherever of the food circle a user wants to search a food item for, the screen displays an image of an enlarged food circle with icons of all food items included in the prototype (Figure 8.12 (b)). The enlarged food circle is displayed by locating the corresponding position of the initial food circle which was clicked at (in the case of Figure 8.12 a cross mark on (a)) to a center of the screen (Figure 8.12 (b)). A user can see area of the food circle outside of the screen by dragging the food circle. By clicking an icon of a magnifier with a “+” mark on a navigation pane located above the screen, a user can zoom in the screen: The screen enlarges the same image and display name of each food item on the icon (Figure 8.12 (c)). Although the design of Food Map focuses on use of images of food items as the primary clue to search an item, from the zoom level 2 (Figure 8.12 (c)), it displays the name of food items in font size of approximately 10 pt so that a user can confirm the icon to choose without going into a detail view. There are four levels of zooming. By zooming in further than zoom level 2 (Figure 8.12 (c)), both icons and text size for food names are enlarged. By clicking an icon of a magnifier with a “-“ mark on a navigation pane, a user can zoom out the screen.



(a) Start screen of Food Map

(b) Enlarged food circle displaying icons of food items

(c) Enlarged food circle by twice, displaying icons and names of food items

(d) A detail view of a food item

(e) A comparison view by Scatter Plot

Figure 8.12 User interfaces of Food Browser

Clicking an "i" icon on the navigation pane enables selection of a food item to see a detail view (Figure 8.12 (d)). User interface design of a detail view is same for both Food Browser and List View. The detail view shows only a picture of a food item and information about a limited number of nutrients (carbohydrates, protein, sugar, mono- and disaccharide, fat and fiber) and energy (kcal) per 100 gram. This is due to simplification of prototype development for use in only the pilot usability testing. By clicking a red cross mark on the right shoulder of the detail view, a user can close the detail view and get back to the Food Map. Selection of a food item is possible at the magnification levels shown in (b), (c) in Figure 8.12 and further. A small green check mark at the right bottom of the "i" icon indicates that selection of a food item to show a detail view is enabled. Clicking the "i" icon again disables selection, and the green check mark turns to a red cross mark.

Clicking an icon of a rectangular with break line and an arrow enables selection of food items to compare by Scatter Plot user interface. Clicking a food item displays a rectangular with break line on the selected item. By clicking the food icon marked with a rectangular, the item is deselected. After selecting food items that a user wants to compare, clicking a green check icon appearing at the right end of the navigation pane (where a red cross mark is seen on Figure 8.12 (e)) displays Scatter Plot screen (Figure 8.12 (e)). By default, the attributes for X-axis and Y-axis are set to be energy (kcal) and carbohydrates, respectively. The attribute for each axis can be changed by selecting from a dropdown list appearing by clicking the axis name. As same as on the Food Map user interface, clicking "i" icon on the navigation pane enables selection of a food item to see a detail view. Clicking a red cross mark on the navigation pane closes the Scatter Plot and displays the Food Map again. This at the same time deselect the food items and disables selection for comparison.

8.3.1.2 List View

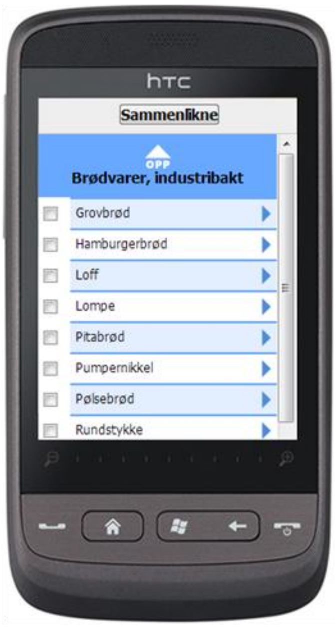
User interfaces of List View are shown in Figure 8.13. List View shows a list of food categories on the initial screen (Figure 8.13 (a)). Clicking a line where a category name is written displays a list of sub-categories under the selected category (Figure 8.13 (b)). Similarly, clicking a line where a sub-category name is written displays a list of food items (Figure 8.13 (c)). The names and order of the categories and sub-categories are in line with The Norwegian Food Composition Table 2006 [200]. However, the names of food items were simplified in order to keep consistency with the names displayed on the Food Map of Food Browser prototype. Food items under a sub-category are listed in alphabetical order. By clicking a white triangle with a text "up" ("opp" in Norwegian) in the header area where category name or sub-category name is shown, a user can get back to a list of the upper level of the category structure.

Clicking a line with a name of a food item displays a detail view of the selected item (Figure 8.13 (d)). By clicking a small rectangular on the left end of each line where a name of a food item is written, a user can select food items to compare. After selecting items, by clicking a "Compare" ("Sammenlikne" in Norwegian) button at the top of the screen, a user can see a list of food items selected (Figure 8.13 (e)). By clicking a triangle above each attribute, a user can re-order the selected items in ascending or descending order according to the clicked attribute. Clicking "Close" ("Lukk" in Norwegian) button closes the comparison screen and returns to the list of food items which was displayed right before clicking "Compare" button.

Design of List View prototype is well described in the master thesis section 3.3 [248].

(a) Start screen with a list of categories

(b) A list of sub-categories



(c) A list of food items under a sub-category

(d) A detail view of a food item

(b) A comparison view

Figure 8.13 User interfaces of List View

8.3.2 Design of Food Map

As described in the previous section "Concept design", Food Map is based on the concept of food circles. Food circles are essentially designed to give an idea about category of food items by each pie. This posed the following challenges in actual design and development of Food Map as a basis of a look-up module.

8.3.2.1 Size of Food Map and food-item images

As described later in 8.4.1, the premise of design of Food Map was to use a mobile phone whose display size is 2.8 inches with resolution of 240 x 320 pixels. Therefore, the food circle shown in the initial view of Food Map search function (Figure 8.12 (a)) needed to be at maximum 240 x 240 pixels. On the other hand, the food circle that contains all food-item images was made after iteration of design, implementation, and test. This is due to requirement to find a balancing point between rendering speed and image quality of images. Especially because of dragging, which is the essential design element of Food Map, this was a great challenge. As a consequence, the circle was made in the size of 1736 x 1736 pixels, as shown in Figure 8.14.

Figure 8.14 Entire view of a food circle containing all the food-item images

In order to show food-item images at recognizable size while covering a large enough area around clicked position on the food circle at the initial view, the size of this food circle displayed at the zoom level 1 (Figure 8.12 (b)) scales down to 2:5. By using a magnifier icon with "+" mark, the size of this food circle scales up by step of 20% of the original size. Font size of text used for names of food items is approximately 10 point at the zoom level 2 (Figure 8.12 (c)), and it becomes 16 point at the maximum zoom level of 4.

Image files showing food circles (both for the initial screen and the zoomed screen) were formatted as portable network graphics (.png). This enabled displaying text to show names of food items layered over image by using half transparent background image.

8.3.2.2 Positioning of food-item images

In order to keep consistency with List View structure for pure purpose of comparing the two user interaction designs, food-item images were placed in a chunk of category and sub-category first. Where it is possible to divide into several pies, I divided a pie into the number of sub-categories to place the items. Background colors were used to divide items by categories, but not by sub-categories because it caused a clutter. For some categories, center angle of a pie was already too small to divide it into even smaller pies. In such cases, I divided a pie along radius following the way the food circle shown in the brochure "Carbohydrates and insulin" ("Karbohydrater og insulin" in Norwegian) [245] (Figure 8.4, left) takes. And then they were placed along radius according to the amount of carbohydrates.

As described later, prototypes include a greater number of food items categorized under sub-categories of fruits and vegetables than items in the other sub-categories. Since there are no more sub-groups under sub-categories, placement of food-item images has an additional degree of freedom, namely radian, besides radius that is used as an "axis" for the amount of carbohydrates. Care was taken so that the food items placed outer side contains more carbohydrates than ones placed inner side regardless of placement in terms of radian within a pie for a sub-category. However, another care was taken so that "similar" food items were placed close to each other unless it extremely violated the concept of placement of items according the amount of carbohydrates along radius. For example, food items categorized under "berries" were placed closer to each other. This idea also assumes a certain knowledge regarding "similarity" of food items, thus it still has a risk that users have different mental models, which may cause confusion. This compromise was made so that it would have a relatively high potential for a user to find an item in the quickest manner among other ideas for placement of items, for example, use of alphabetical order but still following the idea of using radius as an axis for amount of carbohydrates.

8.3.2.3 Choice of pictures to make food-item images

Images to represent food items were chosen in the following manner. Firstly, pictures of commercial products were used for corresponding items. Secondly, for vegetables, fruits and berries, I utilized pictures used in a website "frukt.no[37]" [249] ("frukt" means fruit), which provides information about vegetables, fruits and berries. Thirdly, pictures showing food items in amount that contains approximately 10 gram of carbohydrates in the brochure for people with diabetes "Carbohydrates and insulin" ("Karbohydrater og insulin" in Norwegian)

[37] ".no" is Norwegian domain.

[245] were used as long as they are easily recognizable. For the rest of items, I used Google image search™ by using Google.no. By looking through search results, I chose one that was similar to many other images. To confirm that images are in line with what native Norwegian people have in mind, I asked the master student, who is a Norwegian citizen, and several Norwegian colleagues to check appropriateness of choice of images.

For most of the images that had background color, I removed the background color so that it can save space of the food circle. For images that is difficult to clip background or which becomes difficult to recognize if I clip out only one corresponding item (for example, crabsticks, fish balls, rice, and noodles), I tried to keep the images as they were.

All image files were edited into size of 100 x 100 pixels including margin and below size of 30 KB. These image files were used for detail view.

8.3.3Food items and information included in the prototypes

Both prototypes include nutrition information and food-item images of approximately 200 food items. Based on feedback from the participants in Trial I described in the previous section, we included most of the vegetables, fruits and berries listed in the resource database, The Norwegian Food Composition Table 2006 [52][38]. In order to simplify the prototypes, we included only one type of similar food items. For example, we used only information about unspecified type of apples although there were Norwegian apples, imported apples and unspecified type of apples. The selection of items in other sub-categories than vegetables, fruits and berries is based on a list in a reference booklet for people with diabetes "Carbohydrates and insulin" (in Norwegian, "Karbohydrater og insulin") [245], because we considered the list represents food items that the patients with diabetes should have knowledge about. Categorization and nutrition information on each item are obtained from The Norwegian Food Composition Table 2006. This in turn means that the food items that are listed in the booklet but not in The Norwegian Food Composition Table 2006 were not included.

[38] The Norwegian Food Composition Table was updated in 2012.

8.4 Pilot usability testing

Pilot usability testing of the two working prototypes was carried out with healthy volunteer testers to find out any usability flaws in design of both of the prototypes to fix them before taking a further step to test them by real users of the Few Touch application.

8.4.1 Test design

Participants The participants were chosen at convenience. The only requirements were:

- Being a native speaker of Norwegian language
- Not having been exposed to either the Food Browser prototype or the design concepts of Food Browser (Food Map and Scatter Plot) before
- Having a good experience with computer use.

16 people (gender; 8 females, 8 males) working at the office of NST were asked for participation orally and agreed to participate. The selection of participants was made with care for the variety of occupations, gender and age range. They were all fluent in English as well.

Hereafter, UPxx is used to express a participant in the pilot usability testing where xx stands for participant ID.

Tasks I tried implementing ideas that were given as feedback from the participants in Trial I previously, but simultaneously tried not making tasks too much context oriented, due to the healthy volunteer participants without knowledge or experience of having T2DM.

Tasks are mainly divided into two, which are search tasks and comparison tasks. For each task set, the participants were asked to carry out tasks with both prototypes. In order to avoid influence of memory regarding information of target food items from the test with the first prototype, a different set of target items was used in the test with the second prototype. Aims of the tasks are as following.

[Search tasks]

1. To find out information of a food item whose category is obvious, and whose name starts with an alphabet that comes;
   1.1. late in alphabetical order.
   1.2. early in alphabetical order.
2. To find out information of a food item whose category is not very transparent.
3. To find two food items whose sub-categories are different but next to each other.

[Comparison tasks]

4. To compare three food items in a same sub-category in one parameter that is;
   4.1. one of parameters set by default (either energy or carbohydrates).
   4.2. not either parameters set by default.
5. To compare three food items found under different categories in one of the parameters set by default.

6. To find out food items that satisfy conditions with regard to two nutrients (e.g. “among food items A-H, find food items that contain less amount of carbohydrates and higher amount of protein than food item I”).

This test is a counter-balanced within-subjects design, so we divided participants into four groups shown in Table 8.4.

Table 8.4 Combinations of a prototype and item set for each group

Group	**Participant ID**	**Combination of a prototype and item set**	
		Prototype 1	Prototype 2
K	1, 5, 9, 13	Food Map + Item set A	List View + Item set B
L	2, 6, 10, 14	List View + Item set B	Food Map + Item set A
M	3, 7, 11, 15	Food Map + Item set B	List View + Item set A
N	4, 8, 12, 16	List View + Item set A	Food Map + Item set B

Concrete questions and target item(s) are shown in **APPENDIX 12**. Several Norwegian citizens were asked if they also think selection of food items is well corresponding to the aim of each question, and they agreed.

Tasks were given in the form of question appearing under the mobile phone image (see, **Settings** below) when a participant press “Start task x” (“task” is “oppgave” in Norwegian. A task number is shown where “x” is) button. Participants were supposed to enter an answer in a form and press “Answer” (“svar” in Norwegian) button. No assists were provided once they started the tasks. We did not set time limits on tasks, but participants could give up a task when s/he felt it seemed impossible to complete.

Procedure Before testing, participants were explained the following (**APPENDIX 7**):

- The objective of the pilot usability testing and its positioning in the research relevant to the Few Touch application for people with T2DM.
- The importance of their participation.
- The participants’ rights to withdraw from the test anytime without explaining the reasons, handling of data with anonymous manner, and the procedure of the rest of the testing.

The entire procedure is shown in Figure 8.15. First, a pre-test questionnaire was administered. The questionnaire included questions about:

- Demographic information: gender and age-bracket [20<40, 40<60, 60+]
- Use of geographical ZUI technique, such as web mapping service
- Use of the website of Norwegian version of The Norwegian Food Composition Table 2006 (Matvaretabellen 2006).

At completion of the pre-test questionnaire, we introduced the first prototype using a tutorial mode of prototypes. We used checklists of items to instruct (**APPENDIX 13**) so that we would provide the same amount of information to all participants. The tutorial mode enabled the participants to try using the prototype to familiarize themselves to the user interaction design. An example task was also shown so that the participants could experience the same procedure of test task: read a question, find information by navigating the prototype, enter an answer in the form, and confirm the entered answer. Participants could ask any questions during the instruction session, and they could repeat the example task as many times as possible. After the instruction session was over, it was not allowed for participants to ask us any questions or request assistance in conducting tasks. Participants conducted search tasks followed by comparison tasks. Entered answers to each question in tasks and task completion time were recorded by the program implemented in the prototypes [248]. We observed the participants conducting tasks and took a note when necessary. SUS and AttrakDiff™ questionnaires (**APPENDIX 14**) were administered at completion of task sets for the prototype to rate its user interface. At the completion of the two questionnaires for the second prototype, we administered the post-test questionnaire (**APPENDIX 6**). A short interview regarding their experiences followed. Questionnaires were written in English. Interview was held in English as well unless a participant preferred speaking in Norwegian.

Two Norwegian citizens who had known little about the design concepts were asked to carry out task sets as a pilot study of this pilot usability testing. They completed tasks within reasonable time when considering total time allocated to the test was one hour. Therefore, we decided to employ the procedure and the task sets described above.

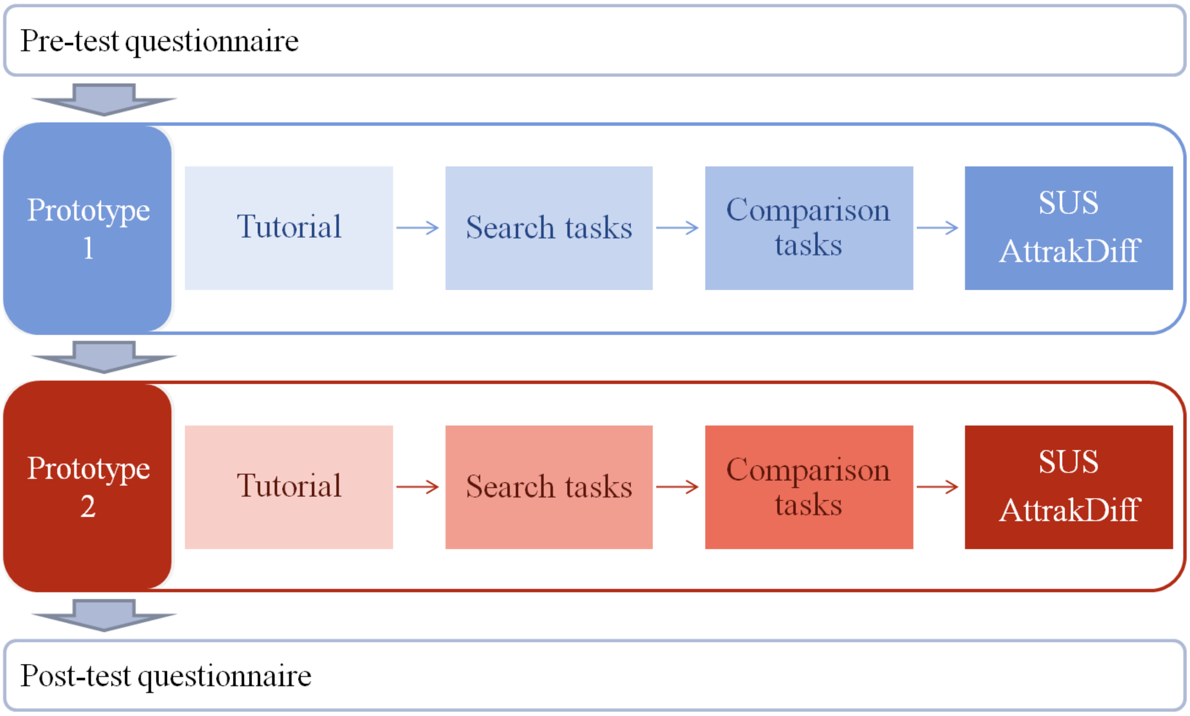


Figure 8.15 Test procedure

Settings Our main interest in comparing the two prototypes for their usability was assessing primary differences the proposed designs would make from a traditional text- and list-based design on a small screen. We chose testing the prototypes running on a desktop web browser Mozilla Firefox (ver. 3.6.3, the most updated version at the time of the test) on which prototypes appear in the identical size with a mobile phone (HTC Touch2[39], display size: 2.8 inches, 240 x 320 pixels) that was going to be used in the RCT of the Few Touch application [244]. The final aim was to implement a module as a part of the information function of the Few Touch application running on a mobile phone. We understood therefore the importance of assessment of total performance when they were implemented on a target mobile phone. We particularly understood the importance of assessing impact of processing power and rendering speed as well as specification of a mobile browser that is typically different from one for desktop. However, we made a choice of using a desktop web browser instead of a mobile terminal for testing was based on the following reasons.

1. Focus on identification of usability flaws in design of the prototypes
2. Technical and practical advantages of a desktop browser for testing purpose

First, physical user interaction techniques of mobile phones varied among models more greatly than those on desktop browsers. Considering that each individual is accustomed to interaction techniques of his/her own mobile phone, use of a specific mobile phone for a test might pose different levels of challenge to a participant depending on similarity of user interaction style between personal mobile phone and one for the testing. The choice of desktop browser was considered advantageous in this sense because participants had already been used to basic interaction style of it. Furthermore, specification of a chosen mobile phone might cause additional problems that might make it difficult to distinguish problems caused by design concepts or specification of the mobile phone. Second, positioning of cursors on a desktop browser represents the area where a tester gives attention to a certain degree. For the purpose of identifying usability flaws in design of the prototypes, understanding of how and where a tester's attention is given is important. It was also technically too difficult to set up experiment with a mobile phone to obtain such information within the limited resources and time frame. In addition, it was much easier to implement programs for testing and to collect test data with a desktop browser than with a mobile browser.

The test was carried out in a simple single-room setup with a meeting room that can accommodate approximately six people at maximum with one big table. We sat on one side of the table and a participant sat on the other side. A laptop computer (Lenovo Thinkpad T61p (Processor: Intel® Core™2 Duo CPU 2.40 GHz, RAM: 2.00 GB, OS: Windows 7 Service Pack 1)) and an external mouse were used for a participant to conduct tasks.

8.4.2 Results of data collection and analysis for the first five participants

The test was held on 21st, 25th and 26th of May in 2010. In the course of the first day of the pilot usability testing by UP01-UP05, we observed the following unexpected phenomena. Below, Sx and Cx (x represents a number) refer task id (**APPENDIX 12**).

- Only UP01 and UP05 conducted tasks in the way we instructed.
    - At search tasks using Food Browser:
        - Instead of pressing "i" button on the Food Map, three participants used a rectangular button to see the item on Scatter Plot and then selected the

[39] http://dl4.htc.com/web_materials/Manual/HTC_Touch2/090901_Mega_HTC_WWE_Manual.pdf (p.198, Appendix A.1 Specifications)

    - item by enabling detail view function. (UP02: at all tasks, UP03: at S2,3 and 5, and UP04: at S1)
    - UP03 had a problem with understanding how buttons in navigation pane would work in spite of having an instruction session.
  - At comparison tasks using Food Browser
    - UP04 used Scatter Plot only at C6. Otherwise, s/he used a detail view of each item to compare values.
    - Two participants gave up with tasks before displaying indicated food items on Scatter Plot (UP02: at C5, UP03: at C3-6).
  - At comparison tasks using List View, UP04 did not use "compare" ("sammenlikne" in Norwegian) button but used a detail view of each item to compare values.
- At a comparison task (C4) using List View, UP01 could not find one food item "water ice" ("saftis" in Norwegian).
- UP05 was very much irritated with navigation on Food Map interface. When dragging the Food Map by keeping pressing on the left button of a mouse and a cursor is moved outside area of a frame (IFrame) which a screen display of a mobile phone is imitated, even after releasing the press, dragging status remained. This caused unexpected behavior of dragging.
- Participants often forgot enabling and disabling selection of food item to display a detail, namely clicking "i" icon on the navigation pane. This also caused irritation of participants.
- When it was difficult to conduct a task, it took unexpectedly long time before they gave up with the task. For example, UP02 spent 352 seconds at task S6 for ListView (fish fingers and cashew nuts ("fiskepinner" and "cashewnøtter" in Norwegian, respectively), and could not complete the task. (In this case, UP02 could not find cashew nuts).

The most critical problem identified was that the test design had been made to treat Food Browser as one entity and List View as a separate one, although they included different user-interaction designs for different tasks. In addition, due to the fact that many tasks were carried out in an unexpected manner, many task-completion time records did not represent what we wanted to evaluate. Not all error rates explained effectiveness of a user-interaction design in question, either. Therefore, it is not reasonable to show results regarding effectiveness and efficiency, especially regarding comparison tasks. However, it is noteworthy that all the participants gave correct answers to all search tasks using Food Browser while there were some cases where participants gave up with completing tasks when using List View (UP02: S6, and UP03: S4, 5 and 6 (only "fish fingers" ("fiskepinner" in Norwegian)).

8.4.2.1 Pre-test questionnaire

The first five participants consisted of three males (age: 20-40) (UP01, 02, 04) and two females (age: 40-60) (UP03, 05). All of them were familiar with the web mapping service using geographical ZUI techniques but had no experience with use of the Matvaretabellen 2006.

8.4.2.2 SUS and AttfakDiff™ questionnaires

Another problem we identified was that the SUS and the AttrakDiff™ questionnaire were administered so that participants evaluated Food Browser as a total system and List View as another. Figure 8.16 and Table 8.5 shows the results of the two questionnaires. Wilcoxon's signed rank test was used to compare the SUS and Pragmatic Quality scores. Test results did not reject the null hypothesis for difference between the means of the two samples. Due to a very small sample size of five participants, the test results must be interpreted carefully.

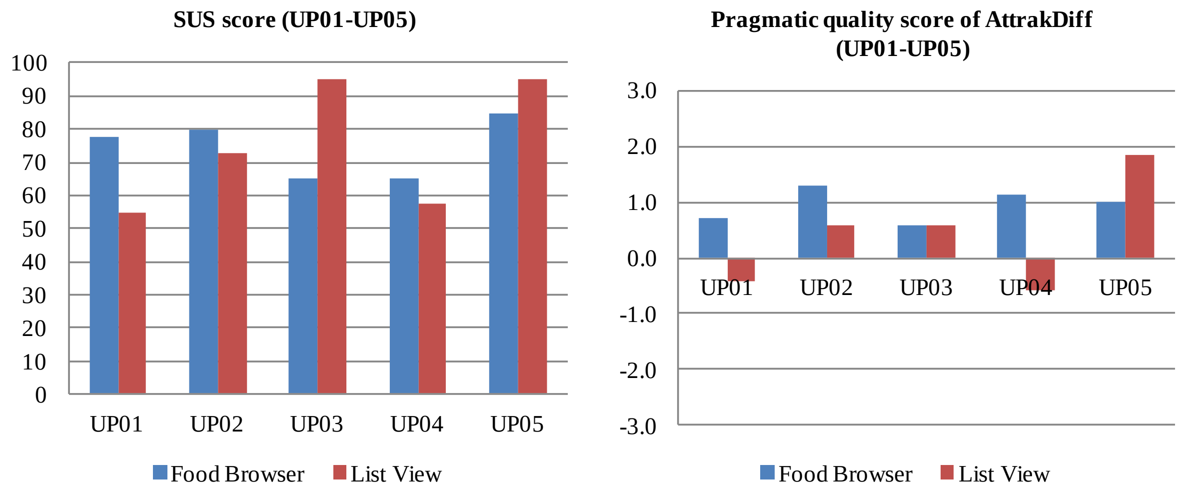


Figure 8.16 Scores for SUS (left) and AttrakDiff™ (right) questionnaires by UP01-UP05

Table 8.5 Statistic summary of questionnaire results by UP01-UP05

	SUS scores		**Pragmatic quality scores by AtrakDiff™ (Averaged values for the seven items)**	
	Food Browser	List View	Food Browser	List View
Mean (SD)	74.5 (9.08)	75.0 (19.45)	0.94 (0.29)	0.42 (1.00)
Range	65.0 – 85.0	55.0 – 95.0	0.6 – 1.3	-0.6 – 1.9
Wilcoxon's signed rank test: T^+, T^- (*P*-value)	7, 8 (1)		8, 2 (.361)	

8.4.2.3 Post-test questionnaires

Table 8.6, Table 8.7, and Table 8.8 show results of the post-test questionnaire.

Table 8.6 Results of the post-test questionnaire, question 1 (preference on prototype as a whole system) by UP01-UP05

Participant	**Answer**	**Reason**
UP01	Food Browser	Easier to find the different food groups
UP02	Food Browser	Easier to use and more intuitive

UP03	List View	Picture in the map was too small
UP04	Food Browser	Visual navigation through recognition
UP05	List View	It was much easier to navigate

Table 8.7 Results of the post-test questionnaire, question 2 (a prototype which participants thought more efficient to search food items) by UP01-UP05

Participant	**Answer**	**Reason**
UP01	Food Browser	The list view was not too obvious about where to find what
UP02	Food Browser	If you don't know the food it might be difficult to find. If you know the food, the food map is much easier because of much better overview
UP03	Food Browser	Gave a quick overview
UP04	Food Browser	Categories are subjective and can fool you. Recognition works better
UP05	List View	It takes more time to drag the food map, and one has to exercise more to remember when to click to stop moving the map

Table 8.8 Results of the post-test questionnaire, question 3 (a prototype which participants thought more efficient to compare food items) by UP01-UP05

Participant	**Preference**	**Reason**
UP01	List View	It was difficult to mark several items on the map. Often more items than you wanted
UP02	List View	The computer sorts after numbers. The graphical display in the food map is a bit small
UP03	List View	Faster to choose from a list
UP04	Food Browser	Easier overview
UP05	List View	The values of the list view seemed to be more precise.

Table 8.6 and Figure 8.16 correspond well although UP03's pragmatic quality scores of AttrakDiff™ are same for Food Browser and List View.

Reasons provided explain well what participants felt most problematic.

As we expected, Food Map was considered better to get faster access to food items whose category defined by The Norwegian Food Composition Table 2006 was unclear for participants (Table 8.7). However, as UP02 wrote, “it depends on what a user knows about a food item, either name or how it looks”. UP03’s feedback shown in Table 8.6 also illustrates that the size of food-item images matters for search of visual information.

Regarding user interaction design of Scatter Plot, the design concept was to provide an approximate idea about the difference or similarity in terms of nutrition between food items but not precise number. Considering this, the provided reasoning (UP02, 03 and 05, Table 8.8) implied that either (or both of) questions or (and) food items in the comparison tasks might have been inappropriate.

For some participants, problems stemming from not design concept but technical issues were hindering usability of Food Browser. One is navigation problem of Food Map when panning, which later turned out to be due to specification of Mozilla Firefox version 3.6.3[40]. The other is that we implemented a function enabling selection of food items while it was also possible to drag Food Map. On the other hand, no problem stemming from technical implementation was reported regarding List View. While List View was technically designed and implemented by following a commonly used design, Food Browser included variety of issues that we needed to solve in the technical design and implementation process. The result in which technical problems hindered usability shows the importance of a thorough testing to find out and solve every possible problem.

8.4.3 Modified test design

After testing by the first five participants, we found that the test design was not appropriate. Based on the results from the first five participants, we modified methods for the rest of the participants with focusing on:

- The complete separation of search tasks and comparison tasks
- The completion of each session in one hour per participant

As a matter of fact, we made more modifications after feedback received from a test by UP06. For simplification, I will intentionally include these modifications with clarification.

Tasks Revised task sets are shown in **APPENDIX 12**. The number of tasks in each set was reduced from six to four with the aim of reducing the time to take per participant. For search tasks, tasks S4 and S5 were withdrawn so that there was one task for each aim and sub-aim. On the other hand, for comparison tasks, tasks C3 and C4 for aim 5 were withdrawn, because aim 5 was not different from aim 4.1 in terms of comparison. In addition, we modified all the comparison tasks to be in the form of multiple-choice questions to make it easier to answer than typing.

Selection of food items in item sets was also revised so that all items were taken from under sub-categories of “vegetables, raw and frozen” and “fruit and berries, raw/fresh”, both under category of “potatoes, vegetables, fruits and berries”. The reasons were two-fold. First, it was obvious that the participants’ mental model of food category did not match the one used in The Norwegian Food Composition Table 2006. Second, these sub-categories were considered

[40] On the Mozilla Firefox version 18.0.2, this problem does not occur.

adequate for showing the inconsistency between categorization of food items in participants' mental model and that in the resource database. Both sub-categories contain 42 food items. In order to reduce the time spent on search, relatively common food items were selected. Especially for comparison tasks, same food items were repeatedly used so that it would help reducing time spent on searching items.

The following modifications apply only to tests by the participants UP07-UP16.

We also decided that one of us would take over searching and selecting food items for comparison tasks on request to avoid wasting time for irrelevant part of the task (search) with the purpose (comparison). In addition, we decided to explain meaning of questions when participants obviously did not understand or asked us.

Procedure (applying only to tests by the participants UP07-UP16) In order to make sure that participants would use correct functionalities for each task sets, we revised the procedure as shown in Figure 8.17. Instructions were given regarding only the necessary functions for each task set. Therefore, we carried out four tutorial sessions in total.

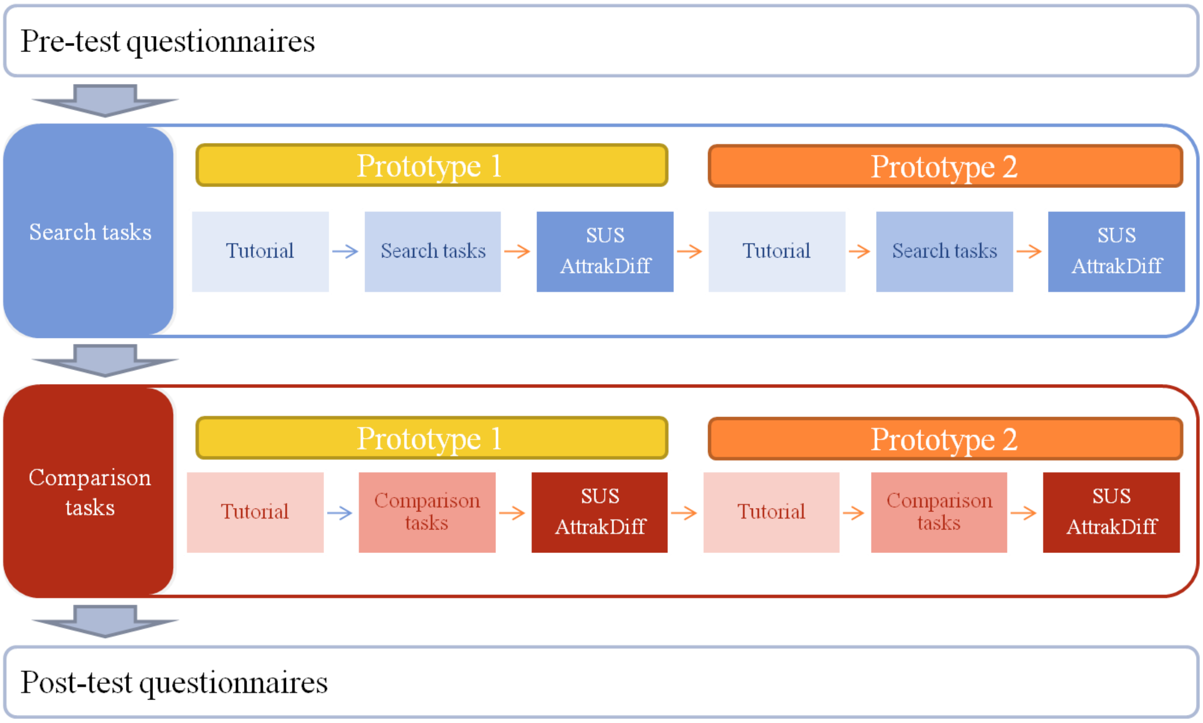


Figure 8.17 Revised test procedure

We administered SUS and AttrakDiff™ questionnaires for all the combination of tasks and prototypes, namely Food Browser (Food Map) for search tasks, List View for search tasks, Food Browser (Scatter Plot) for comparison tasks, and List View for comparison tasks.

For SUS, we told participants to mark "3" at the item 1, "I think that I would like to use this system frequently", because this item assumes that an answerer is a potential user of a tested system.

Setting In order to enable analysis of participants' interactions with prototypes on tasks after the test when necessary, we captured a browser window in which tasks were carried out by using Debut Video Capture Software (ver 1.48, Unlicensed Basic Free Version) (©NCH Software, USA).

8.4.4 Results of data collection and analysis for the rest of participants

After completing SUS and AttrakDiff™ questionnaire for the prototype 1, here List View, UP06 decided to withdraw from the test. Due to withdrawal by UP06 and modifications of methods after that, data from a test by UP06 are only shown for tasks where List View prototype was used.

8.4.4.1 Pre-test questionnaire

The 11 participants consisted of five males (UP07-09, 13, and 16) and six females (UP06, 10-12, 14, and 15). Six participants (UP07-11,16) were in the age range 20-40 and five participants (UP06, 12-15) were in the age range 40-60. They were all familiar with the web mapping service but it was UP14 only who had experience with use of the website of the resource database.

8.4.4.2 Search tasks

Effectiveness

For all search tasks, all the participants could find target items, although four participants (UP06 at RS2 and 3 with List View, UP09 at RS1 and 2 with Food Browser, UP10 at RS1 with Food Browser, and UP15 at RS2 with List View) entered information about a nutrient that was not questioned (e.g., one entered a value for protein, though the question asked for a value for carbohydrates). In view of the purpose of search tasks; to find a target food item but not its information, these answers did not actually matter the completion of the tasks. Therefore, completion rates and error rates were 100% and 0%, respectively, for all tasks in both prototypes.

Efficiency

Table 8.9 shows the basic statistics for the task completion time. At all the tasks, Mann-Whitney's U-test did not reject the null hypothesis that there was no significant tendency of difference in the time spent to complete the same tasks with the two prototypes.

Table 8.9 Statistic summary of task completion time for search tasks

Task id	Prototype	Mean (SD) (unit: seconds)	Range (unit: seconds)	Mann-Whitney U-test: U, U' (*P*-value)
RS1	Food Browser	43.79 (33.18)	17.4 - 126	
	List View	28.10 (6.40)	17.0 – 38.0	39, 71 (.260)
RS2	Food Browser	45.14 (41.43)	17.5 - 156	
	List View	21.75 (4.18)	14.6 – 27.4	29, 81 (.067)
RS3	Food Browser	31.09 (12.01)	16.4 – 58.3	44, 66 (.438)

	List View	28.88 (12.94)	17.8 – 61.0	
RS4	Food Browser	59.96 (24.65)	28.5 – 112	
	List View	62.52 (33.29)	38.5 – 154	54.5, 55.5 (.972)

Observation of captured video records of the web browser revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

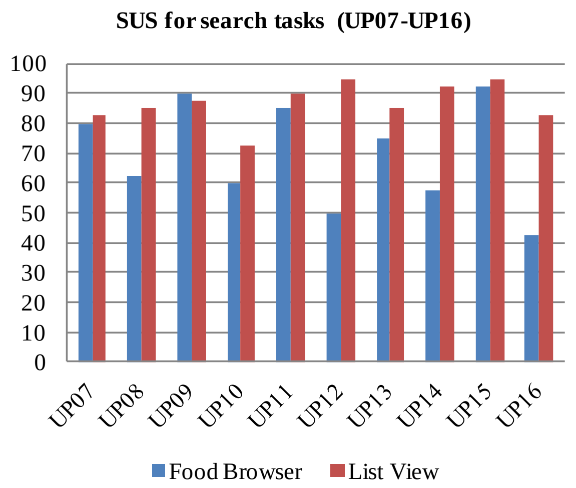
- Food Browser prototype
    - Difficulty with recognition of images
        - Due to similar look
        - Due to little or no knowledge or uncertainty regarding how target items look
    - Difficulties with use due to user interaction design
        - The problem that was experienced by UP05 (8.4.2)
        - Necessity of deactivating selection and information buttons (Figure 8.12) while dragging for a smooth dragging operation
    - Not utilizing direct zoom in by clicking on Food Map
    - Extra time consumed irrelevant to task itself

- List View prototype
    - Different mental model for categorization of food items from source of information
    - Difficulties with use due to user interaction design
        - Invisible "compare" button when a list is scrolled down
    - Extra time consumed irrelevant to task itself

Complete details regarding the efficiency of search tasks can be found in **APPENDIX 15**.

Satisfaction

Figure 8.18 shows scores given to SUS (left) and pragmatic quality measure of AttrakDiff™ (right) by each participant. Except UP09, all participants gave higher score to List View than Food Browser. Figure 8.19 shows distributions of scores by prototypes and Table 8.10 shows the summary statistics of the questionnaire results. Wilcoxon's signed rank test was used to analyze each pair of SUS scores and AttrakDiff™ pragmatic quality dimension scores, assuming that x_i and y_i were assigned as score values to the Food Browser and the List View, respectively. The test rejected the null hypothesis of no tendency of difference in scores for both questionnaires, SUS and AttrakDiff™. Therefore, for search function, participants' satisfaction was higher with List View than Food Browser.



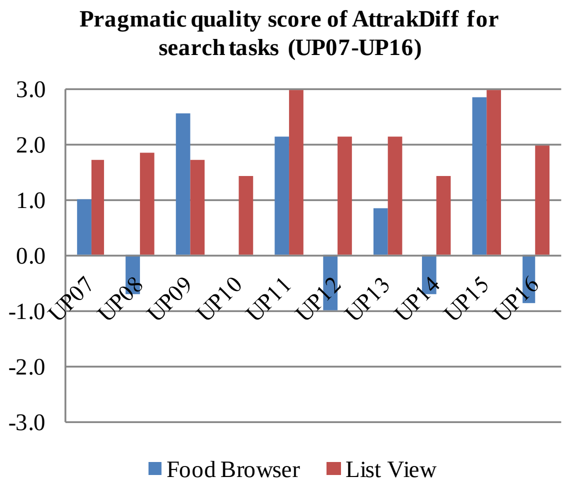
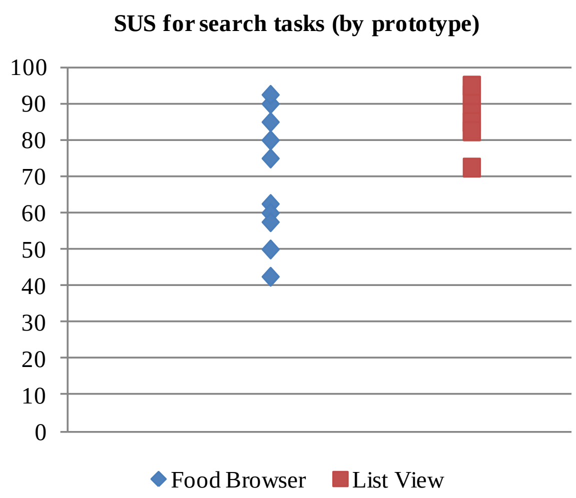


Figure 8.18 Scores of SUS (left) and AttrakDiff (right) questionnaires regarding search function of the two prototypes by UP07-UP16



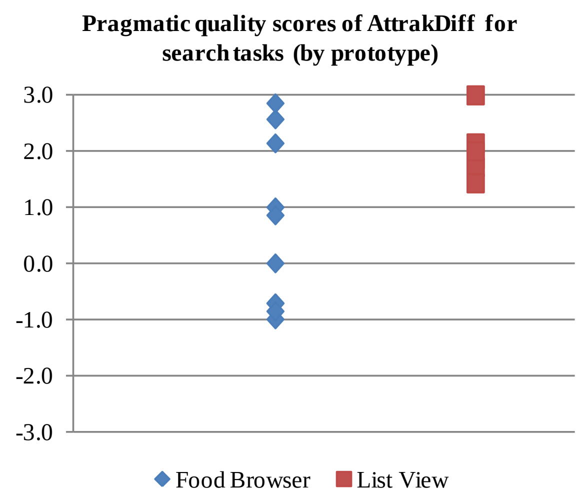


Figure 8.19 Distribution of scores of SUS (left) and AttrakDiff (right) questionnaires regarding search function by prototypes

Table 8.10 Statistic summary of questionnaire results for search function by UP07-UP16

	SUS scores		**Pragmatic quality scores by AtrakDiff™ (Averaged values for the seven items)**	
	Food Browser	List View	Food Browser	List View
Mean (SD)	69.50 (17.39)	86.75 (6.88)	0.61 (1.49)	2.04 (0.56)
Range	42.5 –92.5	72.5 – 95.0	-1.0 – 2.9	1.4 – 3.0
Wilcoxon's signed rank		2, 53 (.009)		3, 52 (.010)

test: T^+, T^- (*P*-value)		

8.4.4.3 Comparison tasks

Effectiveness

Table 8.11 shows summary of completion rate and error rate.

Table 8.11 Summary of completion rate and error rate

Task ID	Prototype	Not completed	Completed	Completion rate	Incorrect answer	Correct answer	Error rate
RC1	Food Browser	0	10	100%	0	10	0%
	List View	0	11	100%	1	10	9%
RC2	Food Browser	0	10	100%	0	10	0%
	List View	0	11	100%	0	11	0%
RC3-1	Food Browser	0	10	100%	0	10	0%
	List View	0	11	100%	1	10	9%
RC3-2	Food Browser	3	7	70%	3	4	43%
	List View	4	7	64%	3	4	43%
RC4-1	Food Browser	0	10	100%	1	9	10%
	List View	0	11	100%	2	9	18%
RC4-2	Food Browser	0	10	100%	1	9	10%
	List View	2	9	82%	4	5	44%

For the first two tasks RC1 and RC2 whose common aim is to "to compare three food items in a same sub-category in one parameter", completion rates are 100% and error rates are 0% with one exception of RC1 with List View. The first questions of RC3 and RC4 also asked participants to compare items with regard to only one parameter, and completion rates for them are also 100%. On the other hand, completion rates for the second questions of RC3 and RC4 are low except RC4-2 with Food Browser. Incorrect answers were given oftener in RC3 and RC4 than RC1 and RC2. Analysis on captured video records revealed reasons for incompletion and errors can be categorized as follows.

1) Primarily due to user interaction/interface design of prototypes
   a) Food Browser (Scatter Plot)
      - Difficulty in recognizing a difference in value between two food items which were too closely located on Scatter Plot (Figure 8.20 (a) shows a screenshot

taken at RC4-2 in which yellow bell pepper and red bell pepper are too closely located with regard to carbohydrates).

b) List View
   - Pure nature of text-, number- and list-based user-interface being difficult and error-prone to compare items in two parameters.

2) Primarily due to other reasons rather than user interaction/interface design of prototypes
   a) A question RC3-2 being incomprehensible or misleading
   b) Not setting two parameters that were asked about (fiber and carbohydrates) at RC3-2 and RC4-2
   c) A wrong choice of an option in spite of knowing a correct answer at RC4-1
   d) Bugs of List View
      i) Misleading display of values
         - A value whose first decimal place was 0 (e.g., 3.0) was displayed as an integer (e.g., 3). However, all the values were right aligned regardless of having a decimal fraction. An example is shown in Figure 8.20 (b).
      ii) Direction and color of arrow above nutrition name not reflecting sorting of a list of selected items
         - When parameter is changed, a list is sorted in ascending order by the chosen parameter. However, this change was not reflected by color and direction of arrows above parameters. An example is shown in Figure 8.20 (c). In this case, UP14 first sorted a list in descending order by fiber, and then changed the second parameter (on the right-hand side) from energy to carbohydrates ("karbohydrater" in Norwegian). Figure 8.20 (c) is a screenshot right after this parameter change.

(a) Screenshot of Scatter Plot at RC4-2 by UP13 (x-axis: carbohydrates, y-axis: fiber), illustrating problem 1)-a)

(b) Screenshot of List View at RC1 by UP11, illustrating problem 2)-d)-i)

(c) Screenshot of List View at RC4 by UP14 , illustrating problem 2)-d)-ii)

Figure 8.20 Screenshots illustrating problems caused by design of Food Browser (Scatter Plot) (a) and bugs of List View ((b) and (c))

Many issues above are also relevant to a longer task completion time as well. Details regarding the reasons for incompletion and errors are explained in **APPENDIX 15**.

Efficiency

Table 8.12 shows a statistic summary of task completion time. Regarding RC3, only four participants completed the task by both prototypes. Observation of captured video revealed some problems with conducting either prototype for all the four participants. Therefore, I concluded that statistical comparison would be meaningless for RC3.At all the tasks, Mann-Whitney's U-test could not discard the null hypothesis that task completion time when using one prototype does not tend to be shorter or longer than when using the other.

Table 8.12 Statistic summary of task completion time for comparison tasks

Task id	**Prototype**	**Mean (SD) (unit: seconds)**	**Range (unit: seconds)**	**Mann-Whitney U-test: U, U' (*P*-value)**
RC1	Food Browser	18.75 (7.86)	12.2 – 35.3	
	List View	24.29 (14.85)	12.9 – 61.4	64.5, 35.5 (.273)
RC2	Food Browser	16.17 (9.69)	7.88 – 41.1	
	List View	17.32 (11.36)	6.56 – 45.5	56.5, 53.5 (.916)
RC4	Food Browser	85.30 (55.60)	30.7 – 193	
	List View	86.73 (37.60)	55.3 – 140	14, 18 (.808)

Satisfaction

Figure 8.21 shows scores given to SUS (left) and pragmatic quality measure of AttrakDiff™ (right) by each participant. For SUS, UP08, UP12 and UP16 gave higher score to Food Browser, while the other seven participants gave higher score to List View. Regarding pragmatic quality scores of AttrakDiff™, scores by UP08 were equal for both prototypes (0.1), UP10, UP12 and UP16 gave a higher score to Food Browser, and the rest of the participants gave a higher score to List View. Figure 8.22 shows distributions of scores by prototypes and Table 8.13 shows statistic summary of the questionnaire results. Wilcoxon's signed rank test was used to analyze each pair of SUS scores and AttrakDiff™ pragmatic quality dimension scores, assuming that x_i and y_i were assigned as score values to the Food Browser and the List View, respectively. The test did not reject the null hypothesis of no tendency of difference in scores for both questionnaires, SUS and AttrakDiff™. Therefore, for comparison function, it can be concluded that there was no difference in satisfaction level between the two tested prototypes.

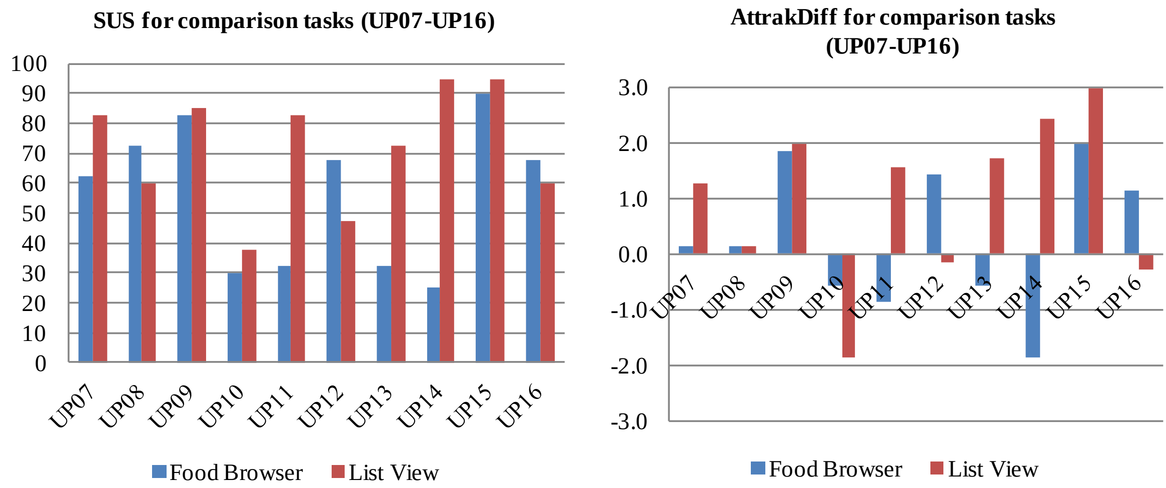


Figure 8.21 Scores of SUS (left) and AttrakDiff (right) questionnaires regarding comparison function of the two prototypes by UP07-UP16

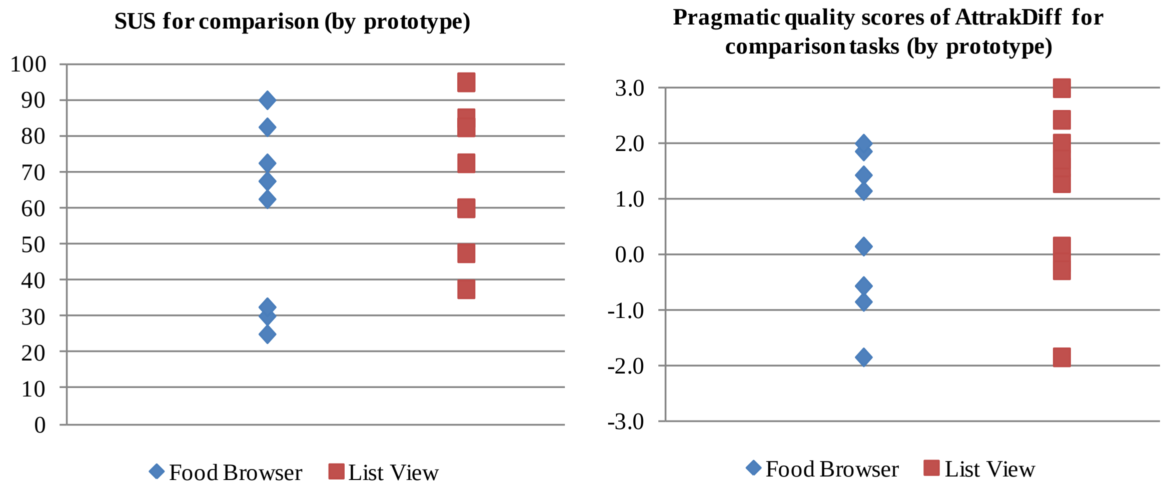


Figure 8.22 Distribution of scores of SUS (left) and AttrakDiff (right) questionnaires regarding comparison function by prototypes

Table 8.13 Statistic summary of questionnaire results for comparison function by UP07-UP16

	SUS scores		**Pragmatic quality scores by AtrakDiff (Averaged values for the seven items)**	
	Food Browser	List View	Food Browser	List View
Mean (SD)	56.25 (23.99)	71.75 (19.79)	0.29 (1.28)	0.99 (1.48)
Range	25.0 – 90.0	37.5 – 95.0	-1.9 – 2.0	-1.9 – 3.0
Wilcoxon's signed rank	15, 40 (.202)		15, 30 (.374)	

test: T^+, T^- (*P*-value)		

8.4.4.4 Post-test questionnaires

Table 8.14 shows results of Question 1 regarding preference on prototype as a whole system.

Table 8.14 Results of the post-test questionnaire, Question 1 (preference on prototype as a whole system) by UP07-UP16

Participant	Preference	Reasons
UP07	List View	Too small icons, need to zoom in completely to see the names anyway. Difficult to know food items on pictures because of the size and knowledge of food.
UP08	List View	Easier to search with List View.
UP09	Food Browser	I like to click on images, and I don't know in which category all food items would fit (List View)
UP10	List View	With more overview and easier to find out. Don't have to search specific picture of a food item.
UP11	List View	I think it is easier to maneuver with the help of text and form than visual pictures of for example fruits. In addition, this is more similar to the way people works with data.
UP12	List View	It went quicker and easier to find out food items a user want to find out from alphabetical list. It was cumbersome to search picture-map, even though people know how food items look like.
UP13	List View	Easier to find out food items and information.
UP14	List View	Easier to find out food items.
UP15	List View	Easier to look up alphabetically. Need to search longer on pictures (FoodMap) to find important food items.
UP16	List View	Better, less confusing selection of foods.

It was only UP09 who preferred Food Browser to List View, because of categorization of food items that was unclear to him. The provided reasons were mostly relevant to search part rather than comparison part. They clearly indicate that most of the participants had difficulty in recognizing images on Food Browser.

Table 8.15 shows results of Question 2 regarding their perception of efficiency of prototype in terms of search food items.

Table 8.15 Results of the post-test questionnaire, question 2 (a prototype which participants thought more efficient to search food items) by UP07-UP16

Participant	**Preference**	**Reasons**
UP07	List View	Alphabetical sorting is easy.
UP08	List View	It was easier to see texts than unstructured pictures to find out food items. The only challenge was to find out the right category.
UP09	Food Browser	I could see the items
UP10	List View	I prefer alphabetical sorting in each food group. But obviously a picture can be nice as well, because sometimes I don't know the name of a food item but know only how it looks like.
UP11	List View	I think it is easier to maneuver with the help of text and form than visual pictures of for example fruits. In addition, this is more similar to the way people works with data.
UP12	List View	Quicker/easier to search in an alphabetical list, maybe because the FoodMap does not show enough overview when a user could not see the whole map, and there is so many food items with pictures that it became messy and takes time to find the right item.
UP13	List View	Easier to find out food items and information.
UP14	List View	Difficult to interpret pictures
UP15	List View	Easier to look up alphabetically. Need to search longer on pictures (FoodMap) to find important food items.
UP16	List View	Seems to be an intuitive and good grouping, the map is too large and confusing

Again, it was only UP09 who perceived Food Browser more efficient than List View. It was also only UP09 who completed all the four tasks faster when using Food Browser than List View, so in this sense, the results of their perceived efficiency is mostly consistent with the results of task completion time. UP08 answered that List View was more efficient, although he completed three tasks out of four (RS1, RS2 and RS3) faster when using Food Browser. This is probably because of little difference in time for all the tasks. (1.8 seconds at RS1, 0.5 seconds at RS2, 0.4 seconds at RS3 and 2.6 seconds at RS4). UP10 completed RS1 and RS2 faster with List View while RS3 and RS4 faster with Food Browser. As shown in Table 8.15, UP10 admitted the advantages of images for search as well.

As shown in the reasons provided to Question 2, most of the participants considered that it was difficult to recognize images of food items on Food Map compared with alphabetical sorting of List View. Together with reasons provided to Question 1, only UP08 and UP09 mentioned potential difficulty in finding a right category in List View.

Table 8.16 show results of the post-test questionnaire, question 3.

Table 8.16 Results of the post-test questionnaire, question 3 (a prototype which participants thought more efficient to compare food items) by UP07-UP16 (Table 2 in [248])

Participant	**Preference**	**Reasons**
UP07	List View	Easier to find out food items. Though for comparison the two systems work much the same.
UP08	Food Browser	The graph showed simply what has the highest value. Became a bit difficult to see all the items if many items were selected.
UP09	Food Browser	Easier to watch a graph than to compare values. It is also harder to make mistakes that way.
UP10	List View	I prefer simple layout such as lists. It is not obvious that I could change categories (she meant parameter) on the selection. The disadvantage here is that if there is anything I forget to choose, I need to choose everything from the first.
UP11	List View	I think it is easier to maneuver with the help of text and form than visual pictures of for example fruits. In addition, this is more similar to the way people works with data.
UP12	Food Browser	I think it is a bit easier to see visually in a diagram, and here it works better with pictures. It was also a bit easier to see differences or similality visually in the diagram.
UP13	List View	Easier to find out food items and information.
UP14	List View	In the graph, it was not so easier to see which food items were chosen. Combersome.
UP15	List View	Quite the same. Both are nice.

UP16	Food Browser	The graph (plot) of different items makes it visually easier to compare.

For purpose of comparison, four (UP08, UP09, UP12, and UP16) answered that Food Browser was more efficient than List View. Although UP07 and UP15 answered that they perceived List View more efficient than Food Browser, they considered both prototypes worked quite similarly [248].

In view of consistency with the task completion time, UP16's task completion time was faster with Food Browser at all the tasks except RC3 which he did not complete.

On the other hand, UP14 showed a strong preference to List View, although UP14's task completion time was much faster when using Food Browser at all the tasks. The differences in time were 23.8 seconds at RC1, 9.2 seconds at RC2, 40 seconds at RC3 and 31.9 seconds at RC4. Furthermore, the bug of List View (described as 2)-d)-ii) under Effectiveness) caused her task completion time relatively long at RC3 and RC4.

Regarding the other participants, the results regarding superiority of prototype in task completion time were mixed.

Provided reasons show that at least for the four participants (UP08, UP09, UP12, and UP16), information visualization by using Scatter Plot was more intuitive for comparison of food items than comparing numerical numbers and text in List View. However, this also depends on how easy it is to recognize items on the Scatter Plot. Especially when several items have similar values in both parameters for x- and y-axes, overlap of images will make it difficult or impossible to recognize items [248]. Although the point of Scatter Plot was to provide an "approximate" idea about amount of nutrients, complete overlap of images disabled distinction of items. RC3 which was made to evaluate the Scatter Plot in this point of "providing and approximate idea about amount of nutrients" was considered incomprehensible and the results were not good enough to make any conclusion out of them.

8.4.5Summary of pilot usability testing

This section can be summarized as follows:

- A pilot usability testing was carried out in order to identify usability flaws in design of the two prototypes, Food Browser and List View, in the previous section. In addition, the testing examined whether or not Food Map for search and Scatter Plot for comparison of food items could solve the reported usability problems with a text- and list-based interface.
- Usability testing was conducted by inviting 16 convenient samples of healthy volunteers. They all had a high literacy in Norwegian. Within-subject design was employed. The participants were divided into four groups depending on combination of food-item set and the order regarding which prototype to test first in order to take a counter balance.
- They compared Food Browser and List View by conducting search tasks and comparison tasks.
- Effectiveness was evaluated by task completion rate and error rate, efficiency was evaluated by task completion time, while satisfaction was evaluated by two questionnaires, the SUS and the pragmatic quality dimension of AttrakDiff™.

- The methods were modified after finishing the first five participants due to some serious problems that hindered achievement of purpose of the testing.
- The sixth participant withdrew the test halfway. Additional modification was made on methods, and the rest 10 participants completed the test.
- For search tasks by the 10 participants:
  - Effectiveness: all participants completed the tasks and no error was made except careless mistakes which was not relevant to the fundamental issues regarding design concepts. These mistakes called for attention to the design of tasks and practical issues around implementation of tasks, such as types of form to use for answer form and how to display questions. In addition, it became clear that the table of nutrient values shown in a detail view needed a better design.
  - Efficiency: Various reasons were identified as reasons for delays in task completion time in both prototypes. When comparing cases in which tasks were completed in the most efficient manner (without any navigations considered as detour or time-loss), for all the tasks Food Browser was comparable with List View or even outperformed. However, this was strongly depending on the target food items and matching between users' mental model and the placement of food-item icons on food circles.
  - Satisfaction: It was only one participant who scored Food Browser higher than List View for the both measure.
- For comparison tasks by the 10 participants:
  - Effectiveness: Depending on a task, completion rate and error rate varied a lot. All participants completed the first two tasks, while one participant made an error due to a bug of the List View. For the third task, completion rate was low and error rate was high by both prototypes, due to poor wordings of the question. For the fourth task in which participants were asked to compare food items with regard to two nutrients, completion rate was higher and error rate was lower with Food Browser than with List View.
  - Efficiency: Various reasons were identified as reasons for delays in task completion time in both prototypes. For the first task in which participants were expected to compare three items with regard to one nutrient by changing parameter setting, neither prototype outperformed the other. For the fourth task, Food Browser was comparable with or having a potential to outperform List View. Due to many cases with incomplete tasks and errors in addition to time-loss by irrelevant issues from tasks or fundamental user-interaction designs of both prototypes, it was difficult to compare the two prototypes with regard to efficiency by results from the other two tasks.
  - Satisfaction: Three and two participants gave a higher score to Food Browser by SUS and pragmatic score of AttrakDiff™, respectively. One gave equal score to both prototypes by pragmatic score of AttrakDiff™.
- Overall the results showed the following:
  - The main issue with the Food Map was the inherent difficulty in recognizing food-item icons due to:
    - The actual size of icons; this was too small when keeping overview of the area around without zooming
    - Placement of icons which were considered unstructured
  - A part of the participants (four out of ten) perceived that Scatter Plot was easier to quickly grasp an idea about the relative amount of nutrition among several food items, but for four other participants, the difficulty in recognizing

icons remained as a factor of inferiority to List View that provided precise textual and numerical information.

- Importance of pilot usability test was shown: many usability flaws stemming from both design concepts and technical implementation as well as test methods were identified; also impact of task design including technical implementation exclusively for the tasks on results was shown.

9 Discussion

Table 9.1 shows findings obtained. In this chapter, I will discuss the results according to the findings by comparing with findings from relevant studies according to the findings.

Table 9.1 Relationship between findings, research phases and research questions

#	Findings	Addressed in Phase(s) and paper(s)	Research question
F1	There were considerable differences in usage of the Few Touch application in terms of usage pattern and level of engagement, and in addition they changed over time.	Phase 1, 2 (Paper 2, 3)	R1
F2	Motivation to use the application is a result of balancing between the expected effort required to use it and the expected benefit, mainly learning about user's T2DM, by using the application.	Phase 1, 2 (Paper 2, 3)	R2
F3	Factors that reduced effort required for self-management of T2DM while enhancing learning about a user's T2DM seemed positively associated with usability of the Few Touch application.	Phase 1, 2 (Paper 2)	R3
F4	Usability of the Few Touch application is strongly influenced by individual user's needs and various types of backgrounds both directly and indirectly relevant to the problem domain that the application addresses.	Phase 1-3 (Paper 2, 3, 4, 5)	R4

9.1 Finding 1

R1 was "how do users use the Few Touch application over time?" The first finding is to answer R1.

"There were considerable differences in usage of the Few Touch application in terms of usage pattern and level of engagement, and in addition they changed over time".

In both Trial I and Trial II, analyses of usage data of each function revealed heterogeneity in usage among the participants in terms of pattern and degree of usage. It also showed that both usage patterns and degree of usage had changed over time. Although attrition of usage is a known phenomenon in eHealth, it was confirmed it is not the only pattern that occur: increase in usage was observed in a long-term trial.

In Trial I, the Few Touch application was flexibly used depending on spontaneous needs as well as regular self-monitoring. A variety of patterns and purposes of the usage of the application were observed. The variation was mostly related to the individual needs depending on the status of diabetes and the lifestyle factors that are both directly and indirectly relevant to the self-management activities. Two deployment studies of a health monitoring application, MAHI (Mobile Access to Health Information), also showed difference in usage patterns and purposes depending on the target users; to develop reflective thinking skills for newly diagnosed patients [166] and to use as identity-construction tool for people with more extensive diabetes experience [250]. Consistent with these findings, the finding in Trial I supported the idea that a design that allows divergent interpretation supports flexible appropriation [251].

On the other hand, such flexibility in patterns and purposes of engagement with the Few Touch application was not clearly observed in Trial II. Instead, clear difference was observed in the levels of self-management that the participants considered sufficient for themselves. In their study about design and development of an ICT system for supporting self-management of diabetes, Calero Valdez et al. "decided to include features that are required for the different types of the disease (both T1DM and T2DM)" [235]. As a matter of fact, some of the participants with T2DM were depending on insulin treatment, as found in Trial II. The employment of a flexible design to accommodate different needs and backgrounds is a sound direction to take.

9.2 Finding 2

R2 was "what are users' motivations for usage of the Few Touch application for their self-management?" The second finding is to answer R2.

"Motivation to use the application is a result of balancing between the expected effort required to use it and the expected benefit, mainly learning about user's T2DM, by using the application".

The Few Touch application was developed for continuous use with the purpose of improving the users' blood glucose management by increasing physical activity and encouraging a healthier diet [22]. In Phase 1 and 2, it was confirmed that the Few Touch application basically served as a tool that simplified users' learning process through which the users understood and confirmed how self-management activities influenced their blood glucose level. The Few Touch application simplified learning process by offering means for the following:

- Quick and easy recording of self-management activities and health status in the form of blood glucose level
- Instant access to the recorded information to review trends and find association between them
- A possibility to set their own goals for physical activity and nutrition habits
- An access to grounded and concise information helpful for self-management of T2DM

Below, I will look the Few Touch application through the lens of Fogg's Behavior Model (FBM) [83] and Persuasive Systems Design (PSD) model [86]. Note that the "target behavior" in FBM corresponds to take an action for self-management activity and the "motivation" in FBM is to take the action. Therefore, it is not the same as the motivation to use the Few Touch application, which I discuss here mainly.

Most of the features of the Few Touch application contribute to the simplification of certain tasks and thereby increasing "ability" in FBM compared to the pen-and-paper based diaries. Based on the Persuasive Systems Design (PSD) model [86], "reduction" and "self-monitoring" is the most used principles in the design of the Few Touch application. Use of these principles mainly contributed to reduction of "time" and "physical effort" among the simplicity factors in FBM. Visualization such as graphs for physical activities and blood glucose measures contributed to simplicity factor "brain cycles" and core motivator of "hope" or rather closer to "pleasure", when looked through the lens of FBM. The step counter used in the version 1 was basically contributing to simplicity factor of "non-routine" compared with the physical activity recording system used in version 2 and 3, especially for the participants in Trial I. Design principle "praise" is used as indicators of goal achievement and progress towards goals. It was also used as a target range of blood glucose level that was indicated by differentiating back ground color of blood glucose graph. These features contribute to core motivators of "hope" in FBM model. However, as we saw in the two trials, the learning experiences seemed the biggest contributor to motivation to take the target behavior, namely increasing physical activity and encouraging a healthier diet. What they learned was mainly concentrated around how physical activity, nutrition habits, and even other factors such as health status or sleeping, influence the blood glucose level. And this also enhanced the usage of the Few Touch application.

As we wrote in Paper 2 [209], "the learning process based on personal experiences on top of necessary knowledge provided by diabetes education builds a foundation for designing the patient's own self-management plan". This is explained by assimilation theory which is described by Davis and Bostrom [252] referring to Ausubel [253] as follows:

> "Meaningful learning occurs when an individual connects new information in a non-arbitrary and substantive manner with knowledge that already exists in memory. It reflects a fundamental understanding of concepts underlying the newly acquired knowledge and an ability to apply those concepts to new or novel situations".

As relevant studies also advocate, a system to support self-management should facilitate learning process [39,254]. In addition to a certain level of motivation for goal achievement, the Few Touch application supported users' learning, which consequently improved their attitudes and behaviors or maintained a good level of those.

In Phase 1, the mechanism of user's long-term engagement with the Few Touch application was modeled as a flow chart shown in Figure 6.10. A long-term engagement with the application was explained as a cycle of usage of the application, learning experiences and/or experiences of goal achievement, and increase in motivation for use of the application. As another consequence of learning experiences and/or experiences of goal achievement, motivation for improving behavior or for maintaining good behavior was increased. This led to actual behavior change that led to goal achievement and/or obtaining sense of mastery over diabetes. This is the effect that the application aimed. As discussed above, the Few Touch application mainly increased ability for learning that consequently increased likeliness to adopt the target behaviors. Motivation for adopting target behavior might remain over time. However, achieving the target effects and reaching "satisfactory" level of self-management clearly decreased motivation for "being engaged with the application for a goal achievement". Consequently, decrease in usage was generally observed as a result of balance between the following two factors: the expected effort required to use the application; and the benefit, especially the learning effect, a user could expect by keeping being engaged with it. Although the Few Touch application achieved the simplified use of the application, it still required some operations. Such decrease is in line with findings by relevant studies [135,188,192]. However, an interesting finding in Trial I was that a part of the participants flexibly adapted use of the application for learning on a different purpose from pure goal achievement.

Experiencing problems by using the application was another reason to negatively influence simplicity factor "brain cycles" in FBM and thereby increased effort required to use the application. Compared with Trial I, degree of engagement with the Few Touch application in Trial II were more clearly associated with their experiences of the application. Participants who used functions often tended to use the application very frequently over time and also to perceive the application in a positive manner. On the other hand, participants who experienced problems with the application used functions in a limited fashion and had tendency to decrease the use over time or to stop using it. In Trial II, the participants were highly motivated for self-management of T2DM. Therefore, the extent to which the Few Touch application met their expectations as a learning tool was the very factor that determined its usefulness of the application for each individual. In Trial II, we could not observe cases that "sense of mastery over diabetes" explained in Figure 6.10 caused decrease in use of the application. This might be partly due to the shorter duration of Trial II than Trial I. A complete description of the problems the participants experienced will be given in the next section.

9.3 Finding 3

R3 was "what are the factors that contribute to the usability of the Few Touch application?" The third finding is to answer R3.

"Factors that reduced effort required for self-management of T2DM while enhancing learning about a user's T2DM seemed positively associated with usability of the Few Touch application".

Five major factors were identified concretely. Below, I will explain them in detail.

9.3.1 Integration with everyday life

Most of the people with T2DM are normally active citizens. As mentioned in Introduction chapter, the mobility and pervasiveness of mobile phones played an important role in supporting the participants' self-management activities. Especially due to the trend of owning smartphones, they are considered more suitable as a terminal for self-management of lifestyle-related diseases than conventional mobile phones or PDAs [208,255]. The results in both trials showed that the usability of a smartphone is equally important to the usability of the application. Although all participants in Trial I reported that they used the application in a relaxed setting, they used it outside the home as well, e.g., at work, on the bus, during visits to their general practitioner, in meetings with family and friends, and so on. No participants in Trial I used the history view function on the blood glucose meter. This fact may indicate a preference for easier access to the information on a mobile phone, where other data about their self-management activities are also accessible.

The step counter employed in the Trial I was not fully pervasive. The reasons resided in its physical design, such as the shape, size, appearance, and how it was attached to a user, in addition to the function that counts only steps. The complaints about the physical features of the step counter especially from female participants, are very much in line with the findings in other studies using activity sensors [256–258]. Though the physical features were not very well accepted by many of the participants, its physical presence was considered positive because it served as a reminder of physical activity. As a matter of fact, in the design process, the participants showed their preference for the physical features of the step counter, such as integrity with their daily tools and outfits [259]. However, technical constraints made it difficult to achieve both automatic data transfer and the ideal physical features for all the participants. For example, an activity monitor used in a study by Lacroix et al [260] was small enough to be put in a pocket or worn with a necklace. However, it required manual connection to a PC to upload activity data, which added an extra burden for a user. The choice of a step counter was considered reasonable in the design process with the participants [259] and it was actually very well accepted in Trial I by most of the participants. However, during the trial period it became more evident that their engagement in other types of sports or physical activities should not be overlooked. Especially because of a long wintertime with much snow in the city where the participants live, walking was not always a good option for increasing their physical activity level. In this context, a step counter was not fully pervasive in their lifestyle. After the introduction of the Diabetes Diary version 2, except from the subjects that were dissatisfied with the step counter, the usage rate of the physical activity recording system was rather moderate among the participants. For them, the manual recording of physical activity was perceived to be very cumbersome: they had experienced the advantages of the step counter represented by automatic data transfer and visualization of the step counts as a graph. This illustrates the negative effect of increasing time and physical effort instead of simplifying those tasks [83] to make users stay away from the target behavior in FBM.

9.3.2 Automation

Automation of data transfer from the blood glucose meter and the step counter played a key role to achieve a design principle "reduction" in PSD model and it made the use of the application as effortless as possible. The participants in both Trial I and Trial II appreciated the automatic transmission of blood glucose values to the Diabetes Diary without any additional manual operation, especially given that they did not have to write down the values any more. The participants also appreciated the fact that the graphical feedback was automatically generated based on the transferred data. Appreciation of the automatic data transmission of blood glucose measures is in line with some of the previous studies where automatic wireless data transmission was employed [165,171,261]. Some other studies do not specifically mention participants' satisfaction with automatic data transmission but rather negative opinions due to their experience of technical difficulties in operating the whole system [166,262]. In the present study, automation was employed only to reduce unnecessary burden in tracking self-management activities, such as transcribing data, so that it would support longitudinal use of the application as advocated by Mulvaney et al. [14]. As a result, together with simple manual data entry for nutrition habits, this helped the participants accumulate a sufficient amount of data so that they could engage in reflective thinking and identify associations between their effort in self-management activities and their blood glucose level. It is noteworthy that the Few Touch application was without any additional specific design to enhance the reflective thinking process, such as the MAHI system [166], which was intended for intensive use for a short period by newly diagnosed patients.

The application was not equipped with the design principles "tailoring", "suggestion", or "reminders" in PSD model, which could have been also incorporated as automatic functions.

Such design principles were considered important as “push” factors for promoting target behaviors [112,135,263,264]. Results of questionnaire (Questionnaire 8 in Trial I and Question 73 in Trial II, **APPENDIX 10** part I) also show that the participants had user needs for such functions. This indicates that inclusion of these design principles would strengthen long-term engagement.

9.3.3 Balance between accuracy and meaningfulness of data with manual entry

As mentioned in 9.2, the participants’ motivation to use the application was enhanced by the process of finding a relationship between their self-management activities and blood glucose levels. For this process to be successful, it is critical that the collected data are sufficiently accurate and meaningful for a user. In other words, accurate and meaningful data make it easier and simpler for a user to learn from it. This was reflected by the requests made by some of the participants at the early stage of Trial I to include functionalities for: (i) tracking physical activity data more than simple step counts and (ii) recording more details for nutrition habits.

Accuracy of data obtained by a sensor is critical in terms of giving proper credit to users [39,257]. On the other hand, the accuracy of manually collected data should be examined in the light of how meaningful it might be for a user investing this additional effort. Sevick et al. [189] and Forjuoh et al. [188] published the results of clinical intervention studies with commercially available PDAs and installed applications. The applications supported the detailed logging of food intake and exercise through the selection from a built-in database with thousands of items. They reported that their participants generally considered the application useful for behavior improvement and diabetes control. However, the participants, (especially the elder participants) experienced difficulties in using the application. There was also a burden of daily data entry that did not fit in with other daily activities. These findings imply that the manual recording of nutrition habits in detail would be eventually too cumbersome, as explained in 9.2.

The basic concept of the nutrition habit recording system was to encourage a user to have a healthier diet. The categorization was designed in accordance with this target and was not guided by the goal of registering nutrition content as in the studies described above [188,189]. In addition, the premise for this categorization was that the participants are knowledgeable enough about nutrition. Otherwise, they were expected to learn more about it. In the long-term trials of the Few Touch application, the participants recorded food and drink items in one of the six categories according to their own judgment.

However, in the course of the trial period, some of the participants found that the categorization employed was not appropriate. They felt that it was not precise enough for their reflective thinking and did not match the participants’ individual preferences based on their accumulated personal experiences. This phenomenon was not completely in line with the intension of the design: “to encourage a user to have a healthier diet”. Because the phenomenon indicates that the participants often had meals, snacks or drinks that they could not confidently record as “low-carb.”, a “healthier choice” in this context. On the other hand, this design succeeded in triggering users to think over meals, snacks and drinks in relation to amount of carbohydrate and their healthiness. Mamykina et al. [166] explain “routine breakdown” in their research as “moments in individuals’ daily lives when their diabetes becomes the center of their conscious thought and attention”. They also advocate the importance of articulation of the “breakdowns” because it “serves as a trigger for reflection when individuals become open to analytical engagement with the situation”. Reflective thinking was encouraged through simple but still manual recording of their nutrition habits in their own manner, although it was not the primary purpose of this function.

These findings suggest the importance of facilitating learning processes by offering a meaningful but simple manual data recording function. Data recording function should be customizable, in addition to features intended to encourage the accomplishment of a certain activity. The idea of making a recording function customizable resonates with the design implications given in a study by Chen et al. [254]. They advocate that a self-management system should be equipped with functions that “capture data more than quantifiable physiological numbers and provide space for patients to report personal experiences beyond food diary for over long periods of time” and that “simply build upon the patient’s experiential associations between their reported diet, exercise and other influential factors, and their daily glucose”.

9.3.4Intuitive and informative feedback

The accurate and meaningful data need to be shown in an intuitive and informative manner for a user to find a relationship between self-management activities and blood glucose levels. The graphs for blood glucose measures and for step counts were considered easy to understand by most of the participants (**Appendix 10** part I). The historical distribution of blood glucose measures were shown on the background divided into three colors that show appropriate range within which blood glucose level should be. This design made it intuitive to confirm whether or not a user is “doing all right” over time. The usefulness of visualizing trends in blood glucose levels is supported by the participants in a study by Forjuoh et al. [188]. On the other hand, in Trial I, the progress toward daily goals of nutrition habits and physical activity was considered the most important, and feedback screens for longer periods were very little used. This was confirmed by all the participants in one of the two focus group meetings in Meeting 4 of Trial I. Users’ appreciation for feedback showing progress toward goals is in line with findings by Kelders et al. [265]. As previously mentioned, the design of the Few Touch application is based on the concept of encouraging “daily” self-management activities. From this point of view, the employed design of feedback screens for both step counts and nutrition habits are intuitive and informative enough.

In contrast to our study, the participants in a study where a pedometer was used as a part of a mobile-phone based system wanted to have a longer time frame such as months to a year. This was because “they were hoping to find patterns of success and failure that could help them figure out when they were particularly active or inactive to plan for a more successful future” [257]. This finding prompts a discussion about the design of feedback screens for “learning processes”. Many participants in Trial I told us that they found the application useful for identifying the relationship between self-management activities and blood glucose levels. On the other hand, some asked for a better feedback function in which they could easily and clearly find the relationship between the three factors. Actually, the participants who mentioned that they had a difficulty in keeping focus or that it was easy for them to lose motivation made a request for such a function. This might be in line with the discussion in the study by Russell-Minda et al. [15], where they mentioned the importance of usability to the patients who need encouragement or help with self-management activities. Interestingly, this agrees with the FBM that shows trade-offs of motivation and ability [83].

The feedback screens in the nutrition habit recording system were perceived as less satisfactory than the feedback screens for the other two functions in both trials. These screens showed the cumulative data for the day, the week or a period a user wants to see. However, none of them provides a visual overview of historical data distribution like the graphs for physical activities or blood glucose measures. In the reflective thinking process, time perspective is important. A visual feedback screen showing historical distribution of the nutrition habit recording might have helped in finding patterns of relationship with blood glucose levels.

It is generally known that visualization of information has a strong impact on intuitive understanding of the data. Nevertheless, designing visually integrated feedback for all the three factors incorporating a time perspective would be a great challenge. In addition, such design needs to be carefully developed to avoid the risk of inadvertent reinforcement of "individuals' preconceived notions and biases" [39]. Mamykina et al. [39] advocate that "individuals' preconceived notions and biases" may lead to a wrong assumption between their self-management activities and blood glucose level. Good example of such design is shown in studies of design and development of an "Affective Health system" which "empowers people to monitor and understand their own stress levels vis-à-vis their everyday activities" [266–268]. These studies show the researchers' iterative exploration in making intuitive feedback design on a mobile device that shows continuously gathered biomedical data from several sensors. The latest design of the feedback screen for the Affective Health system, the "spiral" system, shows a layer of spirals expressing the last minutes, hours, or days with colors corresponding to the levels of biomedical data obtained at the time [266,268]. The spiral system is considered most promising in terms of giving intuitive and informative information to a user while keeping a space open for users to find their own pattern in their reflective thinking process [266,268]. As another example, a graphical summary of medical history together with notes is suggested by Powsner and Tufte [269]. This graphical summary achieves both compression of data and provision of enough detail to reveal evidence directly relevant to a clinician. Given the discrete and non-quantifiable feature of nutrition habits, these examples cannot be simply applicable for designing a feedback screen of a mobile-phone based self-help tool for T2DM. However, the concepts of time perspective and open space for individual users to find their own genuine patterns should be kept in mind for making feedback intuitive and informative.

9.3.5Rich learning materials, especially about foods

As described in 6.1.2, experiences of feeling uncertain about which category to record nutrition habits manifested the latent needs for information about foods. As also written in 9.2, external knowledge necessary for self-management of T2DM becomes useful in combination with personal experience: the Few Touch application could have been more useful if it had been equipped with rich learning materials that offer such external knowledge at the right timing. Findings by Kanstrup et al. [49] also showed clear needs by participants for "access to information about particular things of importance e.g. the ingredients in food to make more qualified decisions". This finding is also supported by Savoca and Miller's finding [44]. They showed that complex and dynamic processes of behavior change in diet were determined by external knowledge of a recommended diet as well as the patient's experimentally accumulated personal knowledge about the relationships between foods and health. As described in 2.1.3.1, the highest ranked barrier for behavior change in diet is the lack of knowledge about diet. Furthermore, in Trial I, we found that the participants experienced out-of-the ordinary situations where they had much less control over diet in terms of what to eat and when (Multimedia Appendix 5 of Paper 2). Such situations are difficult for people with T2DM to tackle but at the same time opportunities to learn. Instantly accessible rich learning materials especially about foods would be essential for a personal-use based mHealth technology for self-management of T2DM to support users' learning at the right timing. Ideally the materials should come along with a nutrition habit recording system to facilitate learning process.

9.4 Finding 4

R4 was "in which ways can users be involved in evaluation and design of the Few Touch application to ensure its usability?" The fourth finding was the basis to answer R4.

"Usability of the Few Touch application is strongly influenced by individual user's needs and various types of backgrounds both directly and indirectly relevant to the problem domain that the application addresses".

As written in 2.2.1, usability is defined as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [ISO 9241-11: 1998, definition 3.1]" [23]. This definition indicates the dependency of usability on individual users in terms of both their personal backgrounds related to the specified goals and specified context of use. Effectiveness is about how accurately a user can achieve the goal by using the product. Therefore, in the case of mHealth technology, what concerns effectiveness from user perspective is mostly user's specified goals in relation to his/her health status that the mHealth technology is used for. In this research, the goal is supporting daily self-management of T2DM. On the other hand, efficiency is about recourses required to conduct a task by using the product. Therefore, what concerns efficiency from user perspective is mostly user's specified context of use and user's backgrounds that influence his/her resources to conduct a task using the product. In this research, the context of use is in user's everyday life as a general citizen, and the backgrounds are user's characteristics relevant to use of the application including familiarity with it.

Finding 2 was "motivation to use the application is a result of balancing between the expected effort required to use it and the expected benefit, mainly learning about user's T2DM, by using the application". Considering what effectiveness and efficiency mostly concern from user perspective, the factors that determine motivation to use the application are both associated with qualities explaining usability. Results in the two trials indicated actual experiences over expectation determine user's evaluation of usability, especially satisfaction. Here the actual experiences mean results of balancing between obtained benefit by using the application and experienced effort to use the application.

First, the SUS scores given to Diabetes Diary version 2 did not significantly improve from those given to Diabetes Diary version1 in spite of updates of the user-interface designs to improve usability by following established design guidelines. The SUS questionnaire on Diabetes Diary version 1 was administered at Meeting 4, when already six months had passed since the start of Trial I. They experienced benefit out of using it and they were used to the design of it. On the other hand, SUS questionnaire on Diabetes Diary version 2 was administered at Meeting 6 when Diabetes Diary version 2 was introduced. The participants tried version 2 for a short time at the meeting, but they had not experienced any benefit out of using it in their daily life yet. In addition, the two minor updates before Meeting 6 already solved problems they had experienced with the Diabetes Diary version 1. Therefore, updates in version 2 might have addressed relatively minor usability issues for the participants in Trial I, and the new and thus unfamiliar user interface might not be so attractive.

Second, the evaluation regarding satisfaction with design elements of Diabetes Diary version 3 in Trial II was more severe than that of Diabetes Diary version 1 in Trial I (7.2.2). The participants in Trial I were involved in the design process of the Few Touch application. In the case of a tool to support self-management for behavior change, not only usage of a tool in real-life setting but also participation in design process involve participants' empowerment as a patient: they are more motivated to take an active part of treatment and use of the tool as a part of it than before the participation [146]. We received feedback expressing "the Few Touch application as a learning tool until a user understands him/herself" at Meeting 4, only six months after the start of Trial I. Given this fact, the empowerment by participating in the design process would partly explain the enhanced motivation for self-management, and thereby it contributed to the motivation to use the application. Naturally, they could obtain benefit, namely learning effects, by using the application. On the other hand in Trial II, the participants were categorized into three groups and they had different level of needs for self-management and needs for the Few Touch application in their self-management. Therefore, it can be concluded that when seen as the whole group, obtained benefit by using the application was, at average, more in the participant-group of Trial I than that of Trial II. This caused the difference in results of usability evaluation between the groups.

Third, "experienced effort to use the application" means that the effort cannot be known before being experienced. Results from Phase 1 showed that mismatches between design concepts and reality can happen even though the same participants are involved in both design-concept making and a trial. The finding here is supported by an argument by Jensen and Larsen [177]: "some issues will not be apparent before the user has used the service for a while and incorporated it into the daily routine". As written in 9.3.1, integration with everyday life is one of the factors associated with usability of the Few Touch application. This concerns the context of use that varies a lot from a user to another, depending on user's lifestyle as a general citizen rather than people with T2DM.

The finding has three implications to answer R4.

The first is **the importance of involving prospective users with various needs and backgrounds, both directly and indirectly relevant to self-management of T2DM in design process**.

Regarding users' needs and background directly relevant to self-management, it is mainly concerning their understanding about; severity of their T2DM, their motivation and needs for self-management, and their skills in self-management. As found in both trials, user needs regarding self-management differed a lot among individuals. Each user's needs change over time as well. Tailoring intervention to the psychological status including motivation or skills of a patient has been strongly advocated and investigated in many studies [41,43,44,47,270,271]. Therefore, mHealth technology for self-management should also be designed both flexible and robust enough to be capable of being adapted in individual care processes.

Regarding users' needs and background indirectly relevant to self-management, it is mainly concerning familiarity with ICT-use and lifestyle as a general citizen. Factors such as age [235,236,272] and prior experience of a similar interface [236] were known to influence absorption of new knowledge. In any phase of this study, we could not observe any clear influence by age on usability of the application or the prototypes. However, familiarity within ICT-use was found to be highly associated with satisfaction. As written in 9.3.1, integration with everyday life means integration with an entire everyday life, because as the result of Inquiry 1 in Phase 3 showed, users may want to use the tool whenever and wherever. In addition, although lifestyle is strongly relevant to T2DM, background of patients with T2DM could vary a lot including occupation and education. Image-recognition based interface was suggested as a design that can be used by people with low literacy [208]. However, the findings in the pilot usability testing implied that image-recognition based interface is not necessarily perceived as easy by people with high literacy, because they are much more used to reading or recognizing text. In addition, while List View type of user interaction design was a design that most of the participants in the pilot usability testing were used to, Food Browser design was unfamiliar as both search and comparison on a mobile phone. The design principle of "match between system and real world" here well apply if the "real world" means what users are used to in the context of ICT use. A significant change in ICT system must be significantly better [220]. The Food Browser was not inferior to List View in terms of effectiveness, represented by error rate and task completion rate, and efficiency, represented by task completion time, but it was so in terms of satisfaction. Given that the test tasks are of no interest for the healthy volunteer testers, experienced effort to carry out the task, which was not limited to only time as their resource, was major contributor to satisfaction. As Krug's second law of usability [62] says, "it doesn't matter how many times I have to click, as long as each click is a mindless, unambiguous choice", the unfamiliar and new user interface might have been the major factor that deteriorated satisfaction.

Karapanos et al. [273] studied users' engagement with iPhone over time. They argued that a tool engaging many users over long time has "designs that are specific enough to address one single need, but flexible enough to enable the artful appropriation in diverse contexts". Design of a personal-use based mHealth technology for self-management of T2DM involving target users can be carried out efficiently and effectively when the users' lifestyle, familiarity with ICT-use, needs, motivation and skills regarding self-management are diverse. In the case of the Few Touch application, the participants were not selected based on such condition but their back grounds were diverse, as confirmed by results of Trial I. The developed tool resulted in focusing on simple and essential functions for people with T2DM. The Few Touch application was generally found to be easy to use in both trials. In other words, no-use of the application due to anxiety or fear of using the application was not observed, which was the case in other studies [274,275]. As a consequence, the developed tool was considered useful to a greater or lesser extent. A challenge here would be how to incorporate diverse user needs that might be incompatible. Introduction of the notion of "design for me" and "design for us" might help the participants understand their role clearly and give constructive opinions on the design process [276].

The second implication is **the value of pilot usability testing by people without needs for self-management of T2DM to identify usability flaws to fix before testing by target users**.

We recruited healthy volunteers for the pilot usability testing for ethical reasons as written in 1.3.3. Healthy volunteers basically don't have goals to achieve by using the subject artifact, thereby, there is not any benefit out of using it. On the other hand, they are also general citizens that may have some common backgrounds with people with T2DM as general citizens, especially in terms of familiarity with ICT-use. Therefore, effort required to conduct tasks and accompanying satisfaction level are the sole contributors to usability. This implies that pilot usability testing involving healthy volunteers would efficiently and effectively identify usability flaws, when tasks are very simple with clear goals. A challenge here would be specification of tasks. In UCD, it is important to focus on tasks and users throughout the process [277]. When involving healthy volunteers, researchers need to explain well about background of the design. It is also essential to make simple- and fundamental-navigation based tasks that they easily understand. Success of pilot usability testing depends on a lot of factors for test design. People must also check wording of tasks and user interface for testing with preferably different backgrounds for their comprehensibility and error-proneness.

The last implication is **the importance of inclusion of a long-term testing of resulted design by people who participated in design process**.

As we argued in Paper 2 and 3, I would advocate the importance of involving the same participants until a long-term testing before testing on other target users. Because of their empowerment and feeling of ownership, they are motivated to try the designed tool [278]. They will therefore keep using it for a certain period at high probability. In order to find out if the implemented design concepts work out well to achieve their goals in their context of use, namely in their everyday life, the tool needs to be used for a certain period. During this period, they would notice any mismatches and problems that stem from design or specification. In our experience from Trial I and Trial II, participants' feedback to design was quite consistent in both positive and negative ways. It is important to obtain feedback about any problems stemming from the design at an early stage before even users get used to them or lose interest in further engagement.

9.5 Reservations

In addition to the limitations of the research approach, the results had the following limitations.

First, not all the expected data were collected. In Trial I, recorded data on Diabetes Diary 1 by a part of the participants were missing for short period due to different reasons. Although at least 10 of the participants attended in all the meetings, there were three meetings where not all the 12 participants attended. A part of the questionnaire answers were not provided by all the participants in all phases. In a study with small samples, such data deficits require attention in interpretation of the data.

Second, the pilot usability testing could not assess potential advantage and disadvantage of the Food Map design concept by using a mobile phone with its user interaction that enables direct manipulation by fingers on screen. Although we judged that using a desk top browser as a test environment is more advantageous, especially for the purpose of the pilot usability testing, this choice caused the above mentioned limitation.

Because of the focus of this study on studying usage and experiences of mHealth technology from design perspective in HCI field, I suggest the following future works.

First, I will suggest a study involving clinical researchers and a larger sample identifying association between; level and pattern of engagement over period, background of patients with T2DM in terms of both clinical and non-clinical aspects, and effects on clinical outcomes and relevant behavior change. Especially other types of usage of the application; reviewing recorded data, changing goals, and access to information function, would provide better insight regarding engagement with the application.

Second, I will suggest a work about design for and involvement of people with lower motivation for self-management compared to the participants in Trial I and II. From a perspective on design features, it would be essential to minimize the effort required to use a technology. However, more important is the features addressing benefit that users could obtain out of using it. Designing such features would call for more extensive incorporation of health behavior theories and more "push" factors that the Few Touch application is not equipped with. Furthermore, inclusion of people with low motivation for self-management in design process would be quite a big challenge: not only recruitment for participation and inquiry to identify requirements. Users don't necessarily know best about what they primarily want because users are unaware of likely future development of technologies. This would be especially true for people with low motivation for self-management of T2DM and thereby lower needs for technologies to support it. As Grint and Woolgar [279] also state, the important point here is that the researchers and designers need to configure users involving "determination of likely future requirements and actions of users". Borrowing the quote by Kanstrup [149], it is important to "elaborate how to hear and understand end user voices by supporting user negotiations and inquiries and engaging in partly unconscious communication of expressions beyond functionality".

Similarly, impact of user interface design on engagement should be researched. It is indeed regrettable that I needed to discontinue iterative design process and further research of Phase 3.

We consulted a nutritionist regarding the improvement of the information function focusing on diet and nutrition information of food items. Her advices and opinions are summarized in **APPENDIX 16**. Antidiabetic Food Centre at Lund University in Sweden (AFC) runs many research projects focusing on the influence of food intake on blood glucose levels. I stayed at AFC and summarized state-of-the art knowledge in nutrition science to implement as general information about food as well as recommendation information for each food item when applicable. The researchers there provided me with much useful information about mechanisms of blood glucose increase, how to take advantage of GI information, how to compose a meal considering both total nutrition intake and effects on blood glucose increase, and so forth. The knowledge obtained at AFC is also summarized together with information provided by other authorized resources in **APPENDIX 16**.

I developed a web application of a modified List View with food-item images next to its name in the list of items[41]. Detail view of each item was also modified to include information about GI and recommendations and/or useful information from T2DM self-management point of view for each item based on the knowledge (**APPENDIX 16**). A user manual (only in Norwegian) is shown in **APPENDIX 17**.

The results of Phase 3 called for new research projects such as design of user interface of detail view and its impact on understanding and decision making of a user, on further engagement with the application, and on effects in terms of behavior change in nutrition habits.

[41] Available at: http://www2.telemed.no/naoet/matvarekatalog.html

10 Conclusion

In the previous chapter, I discussed each finding in this study by comparing with findings of relevant research. The findings and implications from the findings are associated with the research questions. In this chapter, I will summarize answers to each research question and finally draw conclusion to address the primary research problem.

R1: "how do users use the Few Touch application over time?"

Finding 1 *"There were considerable differences in usage of the Few Touch application in terms of usage pattern and level of engagement, and in addition they changed over time"* answers R1. Results of quantitative analyses of recorded data on Diabetes Diary, which is a software application of the Few Touch application, showed diversity in usage pattern of each function of the application and in degree of usage. They also showed that both usage pattern and degree of usage had changed in the course of the trial period. The ways they changed were also different individually, and there were also cases in which almost no changes were observed and increase in usage was observed. Results of qualitative inquiries explained the heterogeneity and the changes over time. Implication of Finding 1 is that the potential heterogeneity in usage and its change over time need to be considered in a study where a personal-use based mHealth technology is used for self-management of T2DM.

R2: "what are users' motivations for usage of the Few Touch application for their self-management?"

Finding 2 *"Motivation to use the application is a result of balancing between the expected effort required to use it and the expected benefit, mainly learning about user's T2DM, by using the application"* answers R2. The Few Touch application served as a flexible learning tool about user's T2DM: what influences their blood glucose level and how. Expected benefit refers positive user experiences by learning from recorded data and prepared educational materials as well as by goal achievement. Experiences of goal achievement themselves were often improvement of behaviors. Consequence of learning experiences however is decreased effects by further engagement with the application. This causes effort required to use the application to exceed the expected benefit out of using it, which thereby decreases motivation for next use of the application to a certain degree. Required effort is not only physical operations of the application but also mental effort and indirect physical efforts required before reaching the stage where operations of the application take place. Mental effort can be explained as being comprised of the followings: cognitive load to understand information; thinking process for recording data, goal changing, and interpretation of recorded information; and mental stress caused by experiences of problems at use of the application. Experience of problems at use of the application is a consequence of mismatch between user's expectation for user experience and its reality represented by: misbehavior of the application such as failure in data transmission, design of the application that requires more effort than a user expected or can invest mindlessly, and difficulty in integrating the use in users' regular lifestyle.

R3: "what are the factors that contribute to the usability of the Few Touch application?"

Finding 3 *"Factors that reduced effort required for self-management of T2DM while enhancing learning about a user's T2DM seemed positively associated with usability of the*

Few Touch application" answers R3. Five concrete factors associated with usage and usability of the Few Touch application were identified: (1) integration with everyday life, (2) automation, (3) balance between accuracy and meaningfulness of data with manual entry, (4) intuitive and informative feedback, and (5) rich learning materials, especially about foods. The first two factors are for reducing effort required for self-management of T2DM. Especially the first factor is important not to introduce unnecessarily extra effort required to use the application. Automation reduces effort required to use the application and to interpret information, therefore it can generally improve usability unless the automation causes unexpected extra burden. On the other hand, the other factors are mainly for enhancing learning about a user's T2DM.

R4: In which ways can users be involved in evaluation and design of the Few Touch application to ensure its usability?

Finding 4 *"Usability of the Few Touch application is strongly influenced by individual user's needs and various types of backgrounds both directly and indirectly relevant to the problem domain that the application addresses"* made a basis of the three implications that answer R4.

As written previously, users basically used the Few Touch application to learn about their T2DM. Specific goals and required level of self-management activities differed depending on each user's health condition and lifestyle. Furthermore, the same user utilized the application for spontaneous or occasional purposes as well as for regular self-management on daily basis. Being heavily involved in a design process of the Few Touch application empowered the participants to take a more active role in their self-management of T2DM. It increased their motivation for self-management and thereby for using the application. On the other hand, efforts required to use the application and the prototypes of a food-information database module were influenced by user's background as a general citizen, especially previous experiences within ICT-use, rather than as people with T2DM. Such individual needs and backgrounds both directly and indirectly relevant to self-management of T2DM influenced both expectation and actual experiences of benefit by using the Few Touch application and required efforts to use it. User's evaluation on usability of the Few Touch application, especially satisfaction, was determined by actual experiences over expectation regarding benefit out of using it and effort required to use it.

The three implications for design and evaluation of mHealth technology are:

1. The importance of involving prospective users with various needs and background, both directly and indirectly relevant to self-management of T2DM in design process.
2. The value of pilot usability testing by people without needs for self-management of T2DM to identify usability flaws to fix before testing by target users.
3. The importance of inclusion of a long-term testing of resulted design by people who participated in design process.

Considering heterogeneity of users' background and needs, involvement of potential users with various backgrounds and needs throughout an iterative design process will ensure that a resulted design will have high flexibility and usability. Here "throughout an iterative design process" means from an early phase to a long-term testing of a working prototype in real-life setting. Long-term testing in a real-life setting of the users that were involved in the design process is important because it uncovers latent problems that the users were unaware with in design requirement identification process. At the same time, to efficiently discover usability flaws at an early stage of design, the working prototypes should be pilot tested for their usability by people with a variety of background but without the need for the designed artifact. This is because they have low or no motivation to use it and thereby low thresholds to notice usability flaws that will eventually be manifest in the course of engagement over time by real patients.

Primary research problem: "How do users use and experience a personal-use based mHealth technology for self-management of T2DM, and how can its usability be improved?"

The main findings to the primary research problem can be summarized as follows.

In case of a particular personal-use based mHealth technology for self-management "the Few Touch application", users basically used and experienced the technology as a flexible learning tool in terms of self-management of T2DM. Patterns and degrees of usage varied a lot among users and they changed over time depending on each user's needs and background both directly and indirectly relevant to T2DM. This was because motivation for continuation of usage was a result of balancing between expected benefit and effort required to use it. Usability of the technology could be improved by designing it so that it simplifies tedious self-management activities without posing extra effort to use the technology while it enhances the learning process and maximizes its learning effect.

Testing of the technology in real-life setting of the users that had been involved in the design process revealed many usability issues that could not have been addressed in the design process. Perceived usability was generally consistent between users who had been involved in the design process and those who had not. Nevertheless, usability evaluation by users who had not been involved in the design process was more severe than those who had. Design concepts of a module for the technology were made by involving users and by incorporating stakeholders' opinions as well as findings from relevant studies. The users involved in the design process found the user interaction of the module easy when they were shown an animation based demo. Working prototypes that implemented the design concepts were pilot tested to identify usability flaws by healthy volunteers before implementing as a module of the technology in users' mobile phone. This pilot testing identified usability flaws of the design concepts and the reasons for them.

Based on the main findings, I will conclude this study as follows.

As described in Introduction and Background chapters, one of the problems that make it difficult to analyze efficacy of mHealth intervention is obscurity of users' engagement with mHealth technology. This study showed heterogeneity in engagement with a particular mHealth technology, the Few Touch application, among users and its change over time. This study also explained the mechanism of users' engagement with the mHealth technology and associated factors with the engagement. From these results, the study indicated the importance of clarification of engagement with an mHealth technology for self-management of T2DM or an mHealth-based intervention in research studies. The reasons for usage and experience of the mHealth technology in this study differed individually due to different background reasons that are directly and indirectly relevant to self-management of T2DM. Therefore, analysis on only aggregated data about; usage, experiences, and effects of an mHealth technology by group level may pose a risk to hide important information for understanding causality of effects by the mHealth technology. At least as a pilot study, appropriate size of samples should be involved in a trial of an mHealth technology to investigate how and why the technology is or is not engaging to users by utilizing mixed methods research. This will enable to identify factors associated with usage of the technology and how usage and user experience of the mHealth technology influence clinical outcomes. Identified factors should be then used for inclusion criteria of participants and/or grouping of the participants at evaluation of a larger clinical study. This will help researchers reach a solid evidence of an intervention. In addition, this study showed the importance of designing for flexibility and robust usability so that it will make the application engaging to users with heterogeneous needs and backgrounds. Design and development of a personal-use based mHealth technology for self-management of T2DM should include potential users with various needs and background both directly and indirectly relevant to the problem domain that the technology would address throughout the iterative process. To discover design flaws efficiently at an early stage, healthy volunteers with various backgrounds can be also valuable resource for pilot usability testing with simple and fundamental tasks. It is also important to include the participants in design process in a long-term trial where a resulted design is tested for finding any usability flaws that can only be identified by using it in real-life setting before it is tested by people with T2DM in general, especially in a larger user group.

Errata

- In Paper 2 [209], Appendix 4 cites two articles with reference numbers 28 and 29. They are incorrect, and 28 and 29 should be 41 and 42, respectively.
- In Paper 2 [209], Table 4 and Appendix 4 show mean values for the results of questionnaires using Likert scale. This is not appropriate, because the scores given by Likert scale are ordinal.
- In Paper 2 [209], Figure 4 shows updated screen designs at Meeting 6 (when one year had passed since the start of Trial I) but not ones updated at Meeting 4 (nutrition habit recording) and Meeting 5 (tips function). The correct screenshots are shown in Figure 6.11.

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Part II: Collection of papers

PAPER 1

Tatara N, Årsand E, Nilsen H, Hartvigsen G. A Review of Mobile Terminal-Based Applications for Self-Management of Patients with Diabetes. Proceedings of International Conference on eHealth, Telemedicine, and Social Medicine, 2009. (eTELEMED '09), Page(s): 166 – 175, 2009

PAPER 2

Tatara N, Årsand E, Skrøvseth SO, Hartvigsen G. Long-Term Engagement with a Mobile Self-Management System for People with Type 2 Diabetes. JMIR Mhealth Uhealth 2013;1(1):e1

PAPER 3

Tatara N, Årsand E, Bratteteig T, Hartvigsen G. Usage and Perceptions of a Mobile Self-Management Application for People with Type 2 Diabetes: Qualitative Study of 5-month Trial. Studies in Health Technology and Informatics. 2013;192:127-31

PAPER 4

Tatara N, Årsand E, Hartvigsen G. Patient-user involvement for designing a self-help tool for Type 2 diabetes. Proceedings of Therapeutic Strategies A Challenge for User Involvement in Design: Workshop in conjunction with NordiCHI2010, ISSN 0105-8517, Pages: 53-55, 2010

PAPER 5

Tatara N, Bratteteig T. Making it Easy is not so Easy: Interaction Design with Text and Image on a Small Screen. submitted to CHI 2014

Part III: Appendices

Appendix 1

A list of publications not included in collection of papers

Tatara, N., 2009. Designing mobile patient-centric self-help terminals for people with diabetes, in: Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services. ACM, Bonn, Germany, pp. 1–1.

> This paper presents the original research plan for this study, quite much in line with the first submission of research proposal. The direction changed drastically and this paper does not include any results from this study, therefore I don't include this paper in the dissertation.

Årsand, E., **Tatara, N.**, Østengen, G., Hartvigsen, G., 2010. Mobile phone-based self-management tools for type 2 diabetes: the few touch application. J Diabetes Sci Technol 4, 328–336.

> This paper is basically based on parts of dissertation by Årsand E. I contributed to making questionnaires regarding usability of the Few Touch application and a part of data analysis.

Årsand, E., **Tatara, N.**, Hartvigsen, G., 2011. Wireless and Mobile Technologies Improving Diabetes Self-Management, in: Handbook of Research on Mobility and Computing: Evolving Technologies and Ubiquitous Impacts. IGI Global, pp. 136–156.

> This book chapter is basically based on parts of dissertation by Årsand E and Paper 1. I contributed to the survey of mobile self-management diabetes systems.

Lee, E., **Tatara, N.**, Arsand, E., Hartvigsen, G., 2011. Review of mobile terminal-based tools for diabetes diet management. Stud Health Technol Inform 169, 23–27.

> The work is conducted as background of master thesis of Lee E. whom I was a co-supervisor of in the autumn of 2010. The manuscript was returned with conditional acceptance requiring major revision from a conference MIE 2011. Due to conflicts between the deadline for submission of the master thesis and one for resubmission of the manuscript, I conducted an analysis of all the included paper from scratch to revise almost the whole manuscript.

Årsand, E., Frøisland, D.H., Skrøvseth, S.O., Chomutare, T., **Tatara, N**., Hartvigsen, G., Tufano, J.T., 2012. Mobile health applications to assist patients with diabetes: lessons learned and design implications. J Diabetes Sci Technol 6, 1197–1206.

I wrote the section “8. Nutrition Information for Type 2 Diabetes” in Results chapter of this paper. As explained in the beginning of Chapter 8, results of “Inquiry 3” is very briefly presented in this section.

Chomutare, T., **Tatara, N.**, Arsand, E., Hartvigsen, G., 2013. Designing a diabetes mobile application with social network support. Stud Health Technol Inform 188, 58–64.

I contributed to this study by conducting Mann-Kendall test to see trend of blood glucose level of each participant in the course of the trial period of the mobile application used in this study.

APPENDIX 2

SUMMARY TABLE OF A SURVEY OF RESEARCH ARTICLES ABOUT MHEALTH FOR SELF-MANAGEMENT OF DIABETES

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Intervention period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Tsang	2001	Not specified		Use of diabetes monitoring system (DMS) on a handheld device that can also be used as a channel to communicate with a HCP	Unclear. In Methods chapter, participants' use is described as follows: "(p. 48) Each meal averaged 10 records. Patients usually transmitted the data once every two days" in the context of data size.	Hand-held computer (CV8300, Vtech, Hong Kong)	Installed software Diabetes Monitoring System (DMS) with 24-hour access to a hospital and with a food database.	3 months (12 weeks)	20	1	p. 48 "Because he defaulted during follow up"	"Frequency of use (transmissions/week)" is shown only as answer to a questionnaire (p. 49)
Ferrer-Roca	2004	Not specified		Transmission of blood glucose level and body weight by WAP protocol of a mobile phone to a diabetes management system with both automatic and manually made feedback (by a doctor)	No info.	Mobile phone (capable of working with WAP protocol, participant's own mobile phone) (p. 278)	To access a website using WAP protocol (p. 278)	9 months (Not all the participants used the system for 9 months due to gradual recruitment)	12	4 (that could not be contacted for the exit interview)	No info.	"None of patients used the WAP interface" (p. 280). There are brief description about difference in usage of web site via PC over time (monthly) and among individuals (p. 280, Figure 4-6)
Ferrer-Roca	2004	Not specified		Transmission of blood glucose level and body weight by SMS to a diabetes management system with both automatic and manually made feedback (by a doctor)	Sending "daily measurements (e.g. of body weight and blood glucose levels)" "when appropriate (e.g. daily)" (p. 282)	Mobile phone (participants' own mobile phone)	To send SMS (p. 282)	8 months	23	No info.	#N/A	The following is the only description about engaement: p. 283 "There was an average of 33 SMS server messages per month from the 23 patients. There was a reduction of reporting activity during a holiday period. "
Larizza	2006	Not specified		Use of multi-channel telemedicine support by physician (M2DM), SMS and smart modem (Roche Acculink modem) is used for a mobile device part	Periodic sending of blood glucose data by using a smart modem. (p. 80) Frequency of data trasmission is not clearly determined.	Mobile phone (model not specified, ownership is unclear but most probably partiaipant's own mobile phone)	To receive SMS	12 months (56 weeks)	38	8	No info. (p. 81 "In most cases drop outs left the study very soon and didn't use the system at all")	Engagement of all the participants in each center for the whole period of the interventions was assessed in the form of sum of the transmitted blood glucose data, averaged number of transmitted blood glucose data per person, and averaged number of web visit + interactions per week. Reasons for difference between the two medical centeres are not investigated. The number of SMS sent to participants is not shown. (p. 81)
Mamykina	2008	Not specified	Newly diagnosed	Use of MAHI (Mobile Access to Health Information) system as a channel of communication with HCPs	MAHI was used as a diary and a experience sampling tool to capture anything that disrupts regular activities. When a participant used a blood glucose meter, MAHI prompted him/her to record the reasons for using the glucose meter and the context of usage by capturing voice notes and photographs.	Mobile phone (Nokia N80)	Installed software on a mobile phone (Java)	5 months	25	1	due to health complications (surgery) (p. 482) One other (not included in the number of dropouts) completed study but was not available for the exit interview and post-study questionnaire.	Engagement is explained qualitatively regarding how they perceived MAHI using quotes in both positive and negative manners. Great individual difference in usage was found. The reasons for lack of engagement are explained as; technophobia mainly due to lack of usability of the provided phone, time conflicts, and low level of personal interest. Regarding quantitative perspective of engagement: the total number of records per participant; the total and average number of data divided into types, are shown for the whole study period (Table 1 and Figure 3).

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Interventi on period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Lee	2009	Not specified		Participants send their blood glucose data using mobile phone or IP sharing instrument to a U-health service center where doctors assess the data when they visited out-patient clinic.	blood glucose measurements: before breakfast, 2-hours after (breakfast?) meal, before sleep, and in the event of any symptoms of hypoglycemia (p. 196)	Mobile phone with Zigbee for data transmission from a blood glucose meter (model not specified, provided from the researchers) (p. 194)	To send blood glucose data using web service (p. 194)	3 months ("July to October, 2005", p. 194)	20	3	p. 196 "due to a large difference in data between the existing blood glucometer and the one provided during the service, troublesome defects with the mobile phones, and individual reasons"	Engagement is summarized in the averaged frequency of data transmission per day per participant (2.13+-0.49 times) (p. 196-7). The rate of transmission loss of blood glucose data was 22.03%, nearly 90% of this is for unkown reason but assmed to be problems related to communication. (p. 196) There is no description about no-measurements by the participants.
Hanauer	2009	Not specified	Young adult Treated with insulin	Two-way text messaging system to encourage increased blood glucose monitoring using Computerized Automated Reminder Diabetes System (CARDS) (p. 100)	A user is supposed to send blood glucose measure in response to reminder whose timing (time of day and day of week) can be customized by a user. A user can send blood glucose measure at any time as well. Every Sunday, a user get a reminder to view and print blood glucose diaries.	Mobile phone (participants' own mobile phone)	To send blood glucose data and receive a reminder by SMS	3 months	22	4	They never used the system. No reason for non-use is provided. (p. 102)	Engagement is summarized in the form of "average number of blood glucose results per user by study month submitted to CARDS" in Figure 2. It shows a decline in usage for both phone and e-mail groups over time. They also clarify that in the last (3rd) month of the study, there were only 5/18 users in the phone group continued to submit blood glucose measurements. Users and non-users, who never used the system, were compared with their baseline characteristics by a statistical analysis. They did not find difference between phone and E-mail group regarding the tendency in being users or non-users. Table 2 summarizes engagement in detail for the whole 3-month period in the form of average per participant. (p. 102-3)
Istepanian	2009	Not specified		Sending blood glucose values to a server, viewing accumulated measurements and to contact clinical research team for clinical and technical support (p. 5130)	Measuring blood glucose between 4 and 9 times / week (p. 5131)	Mobile phone (Motorola A1000)	To send blood glucose data, view accumulated blood glucose data and to contact clinical research team for support (p. 5130)	Unclearly described as "7.5 (5.0) months (p. 5131)"	72	No info.	#N/A	Engagement is summarized as the total number of blood glucose readings sent (4099) for the whole period (7.5(5.0) months). The transmission rate of blood glucose reading (in average "1.8[1.1]/person/week") was significantly less than expected (P=.0001)

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Intervention period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Rotheram-Borus	2012	Not specified	Woman	Use of mobile phone to receive reminder messages and to send a report regarding their behavior daily as well as a platform for communication with peers. (p. 359-60)	Daily report to a question about behavior by text message. Regarding communication with peers, frequency is not specified. (p. 360)	Mobile phone (provided, model not specified)	To receive and send SMS and to call	3 months (12 weeks)	22	0	#N/A	Engagement is summarized as weekly average of: the number of responses to a question given daily; and message exchange between peers (buddies) (123), calculated for the whole period of the intervention. They analyzed the trend of messaging in terms of weekdays for both ad-hoc messaging and responses to a question. By dividing the participants at the median split of the number of texts, they analyzed association with the amount of texting and clinical outcomes/behaviors over time (Figure 1,2, p. 362)
Kumar	2004	T1DM	Child, Adolescent	Use of diabetes management software on PDA (intervention group used DiaBetNet game in addition) # Data was transmited to a server, and HCPs could view the data, but no feedback was given	Monitor blood glucose levels 3 or 4 times daily, transmit blood glucose values from a meter to a PDA wirelessly and enter insulin dose and carbohydrate intake into the PDA daily (p. 447). Participants in intervention group are supposed to access the DiaBetNet game daily and transmit the data to the central server wirelessly.	PDA (Visor™ Platinum, Handspring™, Mountain View, CA)	Installed software on PDA (AccuChek Pocket Compass® software, Roche Diagnostics Corp., Indianapolis, IN) and DiaBetNet software (game)) p. 447.	1 month (= 4 weeks)	40 (intervention (=game) group: 19)	3 (who did not transmit their data at all, p.448)	p. 451 "one participant who lived outside the range of the wireless network, another who withdrew for family reasons, and a third who never attempted transfer"	Frequency of daily blood glucose measurements during the intervention period was compared between intervention (with game) and control (without game) groups by histogram showing histogram of participants according to median number of daily measurements. No information about use of game (DiaBetNet), information about change in frequency of blood glucose measures or data entry of other information (insulin dose and carbohydrate intake).
Vähätalo	2004	T1DM		Use of WellMate® System on a mobile phone as a basis for regular communication with HCPs	Test blood glucose values and send the results via the mobile phone. Participants in intervention group received 25 strips per week while those in control group received 10 strips which is the normal practice in the Turku Health Centre for people with T1DM.	Mobile phone (Nokia 6110 GSM phone)	Installed software on a mobile phone (WellMate system)	12 months	102	No info. (it is probable that dropouts are merged into "inactive group")	#N/A	Engagement is explained as: average of transferred blood glucose reading per week (9.1) per participant for the whole intervention period; and distribution of the participants who sent more readings than the number of provided strips (4%) per week. Factors associated with difference in engagement between individuals are investigated and statistically analyzed. No change in level of engagement over time is reported briefly. (p. 192-3)

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Intervention period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Gibson	2005	T1DM	Young adult	Use of mobile diabetes management software as a virtual coach. Intervention group additionally had proactive nurse support via telephone (in response to real-time blood glucose test results) and an extra histogram display of blood glucose readings for the last two weeks on the phone.	Measure blood glucose, answer to three questions about insulin dose, diet and exercise prompted at measurement, and (automatically) send them to a server. (Farmer et at.. 2005 " A real-time, mobile phone-based telemedicine system" shows that the participants were initially encouraged to use theirblood glucose monitor at least 4 times a day - befor each meal and bedtime.)	Mobile phone (Motorola T720i)	Installed software on a mobile phone (Custom Java software), phone call by diabetes specialist nurse.	9 months	93	No info.	#N/A	Engagement is reported as a figure that shows how mean numbers of readings per week calculated for all the participant in each group change in the course of the study period at an interval of one week. Proactive nurse support via telephone kept participants' motivation for data uploading for 9 months as shown graphically and statistically the difference in weekly mean number of submitted blood glucose measures among participants in each arm, namely intervention group and control group.
Farmer	2005	T1DM	Young adult	Use of mobile diabetes management software as a virtual coach. Intervention group additionally had proactive nurse support via telephone (in response to real-time blood glucose test results) and an extra histogram display of blood glucose readings for the last two weeks on the phone.	Measure blood glucose, answer to three questions about insulin dose, diet and exercise prompted at measurement, and (automatically) send them to a server. (p. 2698) (Farmer et at.. 2005 " A real-time, mobile phone-based telemedicine system" shows that the participants were initially encouraged to use theirblood glucose monitor at least 4 times a day - befor each meal and bedtime.)	Mobile phone (Motorola T720i)	Installed software on a mobile phone (Custom Java software), phone call by diabetes specialist nurse.	9 months	93	12	No info.	Engagement is explained in the form of: total blood glucose readings sent from each group (I:29765, C:21,400); mean and SD of the number of weeks in which at least 7 blood glucose tests were taken among each group (I:27.3+-11.8 and C:18.8+-11.1, difference 8.4 [95% CI 3.7–13.1], P 0.001); and the week when median number of blood glucose readings sent in each group differred significantly (week 36, I: 11, Interquartile range (IQR) 1-28 and C:0 IQR 0-7)
Rami	2006	T1DM	Adolescent	Use of VIE-DIAB system by which mobile phone (SMS and WAP) and computer (web browser) are used as a channel to send diabetes-relevant data to HCPs for automatic and manually tailored feedback by SMS (p. 702-3)	Participants were instructed to measure at least 4 glucose values per day and were advised to send their data (date, time, carbohydrate intake, and insulin dosage divided into short- and long-acting insulin) everytime they measured a blood glucose value or at least once daily. (p. 702)	Mobile phone (Nokia 3510, pre-paid phone card was provided)	To send data by SMS/WAP and receive SMS	3 months	36	0	#N/A	Description about engagement is only the followings: p. 703 "Nine patients (25%), despite weekly attempts of motivation via SMS, sent only <50% of the required four daily blood glucose values. Comparing the metabolic control of this subset of patients to that of patients who sent >50% of the required four daily blood glucose values, we could not see a statistically significant difference."

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Intervention period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Benhamou	2007	T1DM	Adults Treated with continuous subcutaneous insulin infusion	Intensive coaching using mobile phone as a channel to send blood glucose data transmission and receiving SMS advice weekly in addition to GlucoNet® software (France Telecom R&D, Maylan, France) on PDA for self-management. SMS feedback was given only in Intervention period (p. 221-2)	p. 221 "to download (upload?) blood glucose values at weekly intervals during 1 year, and to download the quality of life questionnaire every 3 months within 1 week before of after the visit at the clinic"	PDA (Palm m515®, Palm OS 4.1) and a mobile phone capable of infra-red communication and GPRS data transmission (Siemens S45i)	Mobile phone: to receive SMS and to transmit data from PDA to a investigator. PDA: Installed software on PDA (GlucoNet software®, quality of life DQOL queationnaire software (Avails Telemedicine, Basel, Switzerland)	12 months (cross over, sms and no-sms for 6 months each)	30	2	Reported as "unknown" (p. 223 "with only two patients interrupting data transmission between the 10th and the 12th months during the no-SMS phase for unknown reasons.)	The participants who completed the study (n=28) were well engaged with transmitting data (weekly blood glucose values and QoL questionnaire every 3 months) on time as requested with an exception that one did not for 3-weeks due to neglect. No statistically significant difference in the number of blood glucose measurements per day was found between SMS- and no-SMS periods (p. 224, the whole section of "Adherence") p. 222 "Adherence was determined from the server as the average number of blood glucose tests performed by the patients during the week preceding each visit. As this period may induce a greater adherence, frequency of SMblood glucose was also compared during the 30 days preceding V2, V4 and V6."
Jensen	2007	T1DM		Use of DiasNet Mobile as a self-monitoring tool	No info.	Mobile phone (smartphone) (Nokia 7710)	Installed software DiasNet Mobile	3 months (, where the user stopped using the service.)	1	#N/A	#N/A	Usage pattern in terms of data entry of blood glucose, carbohydrate intake and insulin dosage and viewing data is analyzed according to time of the day (Figure 8), day of a week (Figure 7), and in the course of the study period at daily basis (Figure 6). (Note: unit for the y-axis in these figures is unclear) It was found that during most of the period the usage is concentrated in small chunks of 3 to 4 consecutive days in the beginning of the week. Usage peak was found at meal times and the system was rarely used during 8-14. It also provides with observation of navigation: many sessions with multiple inputs. (p. 680)
Kollmann	2007	T1DM		Use of mobile diabetes management system Diab-Memory as a self-monitoring tool	Track daily blood glucose measurement (3 times a day) and to register injected basal and bolus insulin doses, content of carbohydrates in meals, physical activities and symptoms of hypoglycemia.	Mobile phone (Nokia 7650)	Installed software on a mobile phone(Java 2 Mobile Edition)	3 months	10	0	#N/A	Engagement of all the participants for the whole period of the interventions was assessed in the form of sum and average +- SD. Adherence rate was 85% from the number of cumulative days on which at least three blood glucose values were sent. The total number of SMS reminder, which was snet in case less than 3 blood glucose measurements were sent, was shown, but no information is given regarding the number of data sent after receiving the reminder.

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Intervention period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Franklin	2008	T1DM	Young adult	Use of SMS as a channel of virtual coaching based on SCT plus P2P support for better blood glucose control. Participants receive daily message plus weekly reminder of their personal goal. (p.2)	Participants were encouraged to send in messages containing information or questions related to their diabetes self-management (p. 2) No concrete prescription about frequency.	Mobile phone (pay-as-you-go mobile phone and 10 GBP phone card)	To send and receive SMS	12 months	64	4 (who did not send a SMS at all)	No info.	Well described in Holtz et al. 2012 (below is a copy: "Technology use: 1,180 messages were submitted during the study period. Five subjects used the system the majority of the time (52% of all messages). Female subjects sent more messages not regarding diabetes. Unprompted submission of blood glucose was most common message type. Responses to requests for personal experience and tips accounted for 40% of incoming messages as well as asking questions and ordering supplies. Subjects did not request that an outside (of the study) person receive texts regarding the subjects' status."
Gomez	2008	T1DM	Treated with continuous subcutaneous insulin infusion	Use of PDA-based Personal Assistant (PA) that communicates with insulin pump and continuous glucose monitor for insuling control (HCP can view and change therapy regimen)	No info.	PDA (iPAQ hp2210) and a module for GPRS communication (AudioVox RTM 8000) (p. 6)	Installed software on PDA (Java) (P. 6)	6 months	4	0	#N/A	Only description about engagement is as follows: p. 7 "The pattern of system usage varies between individuals but all of them registered and sent data to the hospital on a regular basis".
García-Sáez	2009	T1DM	Treated with continuous subcutaneous insulin infusion	Use of PDA-based Personal Assistant (PA) that communicates with insulin pump and continuous glucose monitor for insuling control (HCP can view and change therapy regimen)	p. 398 "patients used the PA and the telemedicine services to send monitoring data (blood glucose measurements, insulin doses administered, diet and other additional events) to the physician in charge." "To reinforce the PA usage, an automatic SMS message was sent to the patient's cellular terminal after each therapy change". Frequency of usage (data sending) is not prescribed in Methods chapter but in Discussion chapter as "they had instructions to send data (blood glucose and insulin doses administered to the TeleMedicine Central Server at least once per week".	PDA (iPAQ hp2210) and a module for GPRS communication (AudioVox RTM 8000) (p. 395)	Installed software on PDA (Java) (p. 395)	1 month	10	0	(Questionnaire was answered by 9/10 participants)	Engagement is reported in the form of weekly average and SD per participants according to types of usage (functions, what kinds of data were recorded, data viewing, etc.) (p. 398 Figure 5). The participants sent 6.32+-3.1 insulin data per week, which means almost everyday (p. 399-400). In addition there is a description indicating no change in usage patterns over time (p. 399). Individual difference is reported in Discussion as "all the patients used the PA to register and send data to the hospital on a regular basis, although the pattern of system usage varied between individuals (p. 400)".

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Intervention period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Rossi	2009	T1DM		Use of Diabetes Interactive Diary (DID), carbohydrates and insulin bolus calculator as a virtual coach and as a platform of communication with health care professionals via SMS. (p. 20)	Not clearly described, but daily blood glucose measurements at least 3 times per day and data entry regarding diet and physical activity (p. 20-1)	Mobile phone (model not specified, provided by the researchers but participant's own SIM card was used)	Installed software (DID) and for communicating with diabetes specialist by SMS (p. 20-1)	3 months (12 weeks)	Unclear ("50 individuals were recruited" (p. 21), but the values showing simple statistics regarding participants don't correspond to this number)	No info.	#N/A	Engagement is summarized in the form of average (SD) per day per participant regarding: "information on CHO content of the meals (3.1+-1.5); blood-glucose-value recording (4.8+-2.3) ; and advice on insulin dose obtained (3.2+-1.3)" and average (SD) number of SMS for the whole study period per participant (from participant: 10.4 +-3.1, from physician in reply: 10.0+-3.4), which indicates that the participants had more or less weekly contact with a physician.
Rossi	2010	T1DM		Use of Diabetes Interactive Diary (DID), carbohydrates and insulin bolus calculator as a virtual coach and as a platform of communication with health care professionals via SMS. (p. 110-1)	Not clearly described, but daily blood glucose measurements at least 3 times per day and data entry regarding diet and physical activity (p. 110-1)	Mobile phone (model not specified, provided by the researchers but participant's own SIM card was used)	Installed software (DID) and for communicating with diabetes specialist by SMS (p. 110-1)	6 months	67	9 (but data were analyzed for all the 67 originally involved participants)	1 was lost to follow-up due to moving to other area 2 found it difficult to use the DID system 2 were not compliant with visiting schedule 4 had difficulties in transmitting messages due to poor mobile network coverage in the area (p. 110, Figure 1)	Engagement is summarized in the form of median (range) number of text messages sent by participants (52; 6-75) and by the physician (39; 22-70) during the whole period of the study. These numbers were reformed into averaged frequency as 2 SMS/week by the participants. The following description "and the physician regularly replied to confirm the therapeutic scheme or to modify the parameters set in the DID (cabohydrate-to-insulin ratio, insulin sensitivity factor, and/or blood glucose target)." implies that there was no change in frequency over time, but this data is not shown. (p. 113-4)

First author	Year	Type of diabetes	Other info. about population	Short description of mHealth intervention	Expected participants' engagement (what to do, how often)	Mobile terminal	What a mobile terminal is used for (web app. / installed app. / sms / others)	Interventi on period	Sample size	Dropouts	Report of reasons for dropouts	Summary of reported engagement
Cafazzo	2012	T1DM	Child, Adolescent	Use of a software "bant" installed on iPhone/iPod touch as a virtual coach to track blood glucose values in the context of meals and physical activities so that it provides a user with a summary of glycemic tontrol at a glance and if necessary it supports decision making on adjustment in regimen. It also encourages blood glucose measurements by giving rewards. It provides a platform for peer communication to share experiences and gain or provide support as well as a platform to share blood glucose results with parents. (p. 4-8)	Not specifically written, but reward is given when 3> blood glucose tests (at maximum 5) across different contexts are performed. (p. 6)	Mobile phone (iPhone 4) for 15 participants and iPod Touch (fourth generation) for 5 participants	Installed software (bant) on a mobile phone	12 weeks	20	2 (and 6 who did not have sufficient baseline data from the meters for the authors to perform the analysis were excluded from the analysis) (p. 8)	It is only explained as "did not complete the full 12-week pilot study" (p. 8)	Frequency of blood glucose measurements is summarized in the form daily average (3.6 times / day) for all the 12 participants analyzed for the whole study period. Engagement in the rewards program is shown by: the total and average number of rewards distributed to patients based on their frequency of measurements (161 rewards in total, 8 rewards per person (N=20)); and distribution of participants based on their frequency of measurements (10/20 participants collected > 10 rewards, 5/20 collected < 10 rewards, and 5/20 collected no rewards, 2 of which were highly adherent but never redeemed the points for rewards) (p. 8) Engagement with the social network function is analyzed in terms of: total and averaged number of posts per participant over the study period; distribution of participants in the level of engagement, which is skewed; and regarding the content (p. 9)
Mulvaney	2012	T1DM	Adolescent	Receiving SMS messages tailored based on personal barriers to adherence. Patients can also add own messages and involve other as part of their support team. (p. 115-6)	Not specifically written, but participants could log-in web site via mobile phone to: change schedule for receiving SMS; search messages associated with their particular goal; add their own messages: and nominate other people as part of their support team, etc. (p. 116)	Mobile phone (participants' own mobile phone)	To receive SMS	3 months	28	5	- technical problems with participants' mobile phone - going to be away - no longer allowed to use the phone	Engagement is summarized in the form of average per perseon, per week, calculated from the data obtained in the whole intervention period. Range is shown together with average for messages received (10, range: 8-12) and website log-ins (3.0, range: 1-8). SD is shown together with average for scheduling of additional messages (5.0, SD: 4.2) and deletion of messages (1.8, SD: 0.9). The contents of messages were analyzed briefly. 9 people, a friend or family member, were nominated by participants to contribute messages to help with diabetes. (p.117, "Website use" section) Regarding engagement with received messages over time, it is very briefly shown in Table 2, in the form of mean (SD) of scores (2.4, SD: 1.8) given to 7-point Likert scale (1: not at all true, 7: very true)-based question "after a while I did not read the messages from SuperEgo" (p. 117)

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Frøisland	2012	T1DM	Adolescent	Use of 2 mobile phone-based programs as a part of diabetes care. One is Diamob application to record photograph of food, postprandial blood glucose prompted by the application according to the time of photographing of food, physical activities, and insulin dosage, as a basis of consultation with a physician. The other is Diabetes Message System to send messages to their providers when they faced obstacles in everyday life and also to receive educational messages. (p.3-6)	2 periods of recording on Diamob, each lasting 3 days, before the consultation. Expected to be 4 times per day. Sending messages using Diabetes Message System when they face obstacles. Frequency is not specified. (p. 3-7)	Mobile phone (smartphone, HTC Touch 2)	Installed software on a mobile phone (Diamob and Diabetes Message System)	3 months	12	1	Personal reasons	Engagement is described briefly as the number of the pictures taken in the form of total for all the participants (691), and mean (50) and range (25-94) per person for the required 6 days. (p.7) Information about the other data (such as insulin dose, physical activity, blood glucose readings, and messages sent to DIabetes Message System) are not explained
Faridi	2008	T2DM	Not insulin treated	Use of Confidant™ mobile diabetes management software as a virtual coach	Daily blood glucose measurement (once, upon awakening) and use of a pedometer during the day. Daily data sending to a server from blood glucose meter and pedometer.	Mobile phone (model not specified, ownership is unclear, but most probably loaned from the researchers)	Installed software Confidant™ mobile diabetes management software on a mobile phone	3 months	15	5 (who "did not transmit information altogether", p. 467)		Engagement is explained as duration in which participants were completely adherent, and they report considerable differences in the duration between individuals. Reasons for non-engagement were identified by focus groups with the participants. The reasons are mainly usability problems of both mobile phones and pedometers.
Forjuoh	2008	T2DM		Use of Diabetes Pilot™ software as a self-monitoring tool	daily data entry (p. 275-6, Results chapter), "as they self-managed their diabetes" (p. 274). Data can include: blood glucose measurements, insulin and other medication dosages and administration times, meals, exercise, test results and other notes. Regarding nutrition, intake of carbohydrates, fat, calories, protein and fiber can be tracked. Note: this is not mentioned in Methods chapter or Forjuoh et al. 2007 which describes methods for this intervention.	Mobile phone (provided, model not specified)	Installed software on PDA ("Diabetes Pilot" software)	6 months	43	25 (refer p. 275 "Study Participants" for more detail)	Burden of daily data entry due to bad usability and time constraints (refer Vuong et al. 2010 p. 2 as well). Frustration with data entry because it is difficult. (Forjuoh et al. 2007, p. 380)	Engagement is explained as the mean (Standard Error, SE) number of days per week on which each feature was used for the last 7 days before 3- and 6-month visit per participant who completed each duration. Therefore it requires caution when interpreting the data, although the frequency of PDA use "did not significantly change at 6-month visit (p. 276)" from the 3-month visit. Baseline characteristics of those who completed the 6-month intervention and those who did not are compared (p. 275 Table 1). No statistically significant difference was found. Number of days in the last 7 days specific features were used (mean and SE among the participants) was reported at 3-month visit and 6-month visit and compared (mean difference and 95% confidential interval).

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Sevick	2008	T2DM		Dietary self-monitoring by PDA-based software BalanceLog® integrated within a behavioral intervention based on SCT	p. 399 "self-monitor their dietary intake" (at least once a day at Week 2 and after Week 3 all meals per day)	PDA (Palm One Tungsten/E2)	Installed software on a PDA (BalanceLog® software by MicroLife)	6 months	74	(together with control group (n=77), 22)	(p. 400) "refused/no show (n=8); scheduling conflict (n=5); unable to contact (n=3); medical reasons (n=2); deceased (n=1); transportation problems (n=1)	Data entry about dietary intake is assessed in averaged number of entered data (as the number of meals) for the whole period (6 month, including the first two weeks when participants were not expected to enter all the meals) and for the all participants in the intervention group. It was found that the data entry was marginal. (p. 406)
Cho	2009	T2DM		Use of diabetes phone to upload blood glucose data to Diabetes centre, view graphs showing the blood glucose data for different periods, and to receive feedback by SMS fortnightly (p. 78, Figure 1)	Daily blood glucose measurement and send the data. The frequency of measurements depends on a participant's condition (if insulin-treated, 3 times; if treated with oral agents, 2 times; otherwise once, at least) (p. 79)	Mobile phone (LG-KP8400 / Gluco Plus)	To send blood glucose data to a web server automatically and receive feedback by SMS (	3 months (p. 78)	38	3	p. 79 "Two patients were withdrawn because of missing laboratory follow-up tests while four patients were withdrawn when they did not send blood glucose data for more than three weeks during the study period." (this includes drop-outs in Internet group as well)	Engagement is summarized in the total number of blood glucose measurements transmitted to a web server during the study (6487), the mean number of days on which participants measured their own blood glucose at least once a day (77, SD 29), and the mean frequency of blood glucose measurements per day (2.1, SD 0.7) which is not statistically different from Internet group (2.4, SD 1.3, p=0.30) (p. 80). 83% (24/29) of the participants (who answered to the questionnaire) replied that they accomplished the tasks as recommended by the doctor (p. 81, Table 2b).
Turner	2009	T2DM	Treated with insulin	Use of a telehealth software (t+ Diabetes) as a virtual coach for decision makings in future self-management. The software provides a user with feedback based on transmitted blood glucose test results, electronic diary to record insulin dose and a facility to transmit blood pressure results and weight. Telehealth nurse can view data and may give feedback if necessary (p. 48)	Participants were encouraged to monitor blood glucose levels a minimum of once a day and adjust their own insulin dose by two units every three days based on self-monitored glucose levels. Once target blood glucose levels were achieved, the frequency of blood glucose tests could be less. Participants were supposed to call telehealth nurse in case of questions or problems. (p. 49)	Mobile phone (provided, model not specified)	Installed software on a mobile phone (t+ Diabetes (t+ Medical, Abingdon, UK))	Not clearly described (HbA1c is compared at 3 months after the start of intervention)	23	No info.	#N/A	Engagement is described qualitatively in the section "Patient's views on the technology". The mean (SD) of blood glucose data transmitted per participant is also shown (160, SD: 93). The participants were originally habituated to measure daily and if necessary additional couple of times. This remained during the study. Regarding phone calls, "the majority of patients called the telehealth nurse with questions at least once during the initial two week". Positive perception with the study was reported expressing feeling of "more in control" and increased confidence regarding insulin titration. (p. 51)

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Sevick	2010	T2DM		Dietary self-monitoring by PDA-based software BalanceLog® integrated within a behavioral intervention based on SCT	Refer Servick et al. 2008: self-monitor dietary intake daily as frequent as they have meals	Refer Servick et al. 2008: PDA (Palm One Tungsten/E2)	Installed software on a PDA (BalanceLog® software by MicroLife) (Refer Servick et al. 2008)	6 months	123	Not clearly written and hard to interpret from the sentence on p. 317 under "Measures" and Table 2	#N/A	Adherence in terms of average among all the participants in the intervention group declined in the course of the 6-month study period. Difference in level of adherence is investigated and the predicting factor of adherence is identified as the level of adherence in the previous phase (period). Suboptimally adherent behavior was the least consistent. p. 318 "Participants entered an average of 11 meals per week in Phase 1, 7 in Phase 2, and 4 in Phase 3." "By the end of the study, approximately 20% of the participants remained adherent."
Noh	2010	T2DM		Use of web-based ubiquious information system (eMOD) for mobile phone to provide real-time diabetes self-management information which is updated repeatedly. (p. 334)	Participants could log in the eMOD system whenever convenient. (p. 334)	Mobile phone (capable with Internet connection)	To access to a website	6 months	24	2	Difficulty with accessing the web site or in using a mobile phone (p. 334)	Total number of access to the eMOD system with breakdown into the combination of a channel used (either computer or mobile phone) and contentes are reported (Table 2). Mobile phone was used for the half of the access (191/351) among which 135 access was to content about "dining out".
Lyles	2011	T2DM		Use of web-based program in which a mobile phone (smartphone) can be used to upload blood glucose values wirelessly and to communicate with care manager through e-mail (on smartphone) in addition to use of a game console to access shared medical records. (p. 564)	Participants were encouraged "to review their medical record, upload glucose readings, and send secure e-mail as needed, responding to participants once daily during business days" (p. 564)	Mobile phone (smartphone with Windows Mobile 6.0 or higher. Participant could choose a model, p. 564)	Installed software to upload blood glucose data and view trends on a mobile phone, to receive e-mail notification, and to communicate with a care manager with e-mails. (p. 564)	3 months	8	0	#N/A	Engagement is summarized in terms of the total number of: blood glucose measurements; uploads; and e-mail conversations with health care provider, at individual level (Table 1). Big individual difference is shown and described in main body and Table 1. 2/8 did not use any function at all. Qualitative analysis of interview identified 5 major themes regarding user experiences with the intervention.
Hussein	2011	T2DM		Use of SMS for consultation with clinicians and/or educators between clinic visits (p. e24)	Consult to either clinicians or educators by SMS at least once in a week (interpreted from description of a reminder sent when no contact was taken for 7 days) (p. e24-5)	Mobile phone (model not specified, ownership is unclear but most probably participants' own mobile phone)	To send and receive SMS to consult	3 months	12	No info.	#N/A	Engagement is summarized as the total number of SMS (633) and average per participant per month (17.5). Decreasing trend in the number of messages is reported (not quantitatively). Distribution of the messages based on their content in percentage is shown and the majority of the messages (64.7%) were home glucose monitoring values for review (p. e25).

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Lim	2011	T2DM	Elderly	Use of h-healthcare which provides patient-specific message generaged by clinical decision support system in response to blood glucose data transfer within 2 minutes in addition to weekly and monthly evaluation of glucose levels for effective glucose control (p. 309-10)	Measure blood glucose at least 8 times per week (> 3 at fasting, > 3 postprandial, and > bed times) and transfer the data by the blood glucose meter's cradle connected to public switched telephone network. (p. 309-10)	Mobile phone (participants' own mobile phone)	To receive messages	6 months	51	2	Inconvenience of frequent testing (p. 310)	Mean (SD) of frequency of blood glucose measurements per week per participant calculated for the whole intervention period (10.5, SD: 5.1) is compared with the value at baseline (3.2, SD: 3.5).
Dick	2011	T2DM	African-American in urban area Treated by either insulin and/or oral medication	Use of SMS to receive personalized messages regarding self-management and to send response regarding their adherence back in order to assist self-management (p. 1247-8)	Send a reply to daily sent reminder about either medication or blood glucose test and weekly sent question about foot care (p. 1248)	Mobile phone (participants' own mobile phone)	To receive and send messages (p. 1248)	4 weeks	19	1 (who did not complete the text messaging portion of the pilot)	Unclear from the description	Engagment is summarized as mean of: the number of exchanged text messages per participant (220); the number of messages requiring response (78) and response rate (80%); and the number of messages responded to a message not requiring response (31.4). Due to skewed distribution of response time, median is used for response time (6.1 minutes). Table 2 (p.1251) shows the breakdown of messages according to sender (participant or the program SMS-DMCare) and contents (p. 1248, 1250, 1251)
Katz	2012	T2DM		Use of WellDoc Diabetes Manager system as an interactive platform for patients and health care providers to track blood glucose and receive real-time feeback and diabetes information (p. 68)	Not specifically written regarding frequency, but participants were instructed to enter all glucometer readings into the phone (p. 68)	Mobile phones (web-enabled, provided together with a low-cost monthly prepaid contract)	To access the WellDoc Diabetes Manager system	56 weeks (1 year)	32	16	9 discontinued because of inability to afford $20/month cell phone payments, 5 for lack of use of the WellDoc system, and 2 changed health plans (p. 68)	Participants were divided into active and inactive (dropouts) groups. They were compared in terms of mean of the number of weeks in which they were followed (56 and 10), average frequency of blood glucose reading per week per participant for the first and last 10 weeks, and average number of weeks in which no blood glucose readings were entered, as well as in the form of proportion against the duration in which they were followed (8.0 weeks as 14% of weeks, 4.8 weeks as 54% of weeks). (p. 68)
Nes	2012	T2DM		Use of 4 features available using a smartphone for Acceptance and Commitment Therapy. 4 features are: Internet program enabling daily data entry; individualized written situational feedback; audio files with mindfulness and relaxation exercies; and the Few Touch application (p. 386)	Making 3 diaries daily in the form of answering to 16-19 questions by choosing predefined alternatives or scoring on a 6-point Likert scale at most of the questions. This includes reporting of blood glucose readings. (p. 387)	Mobile phone (smartphone, Samsung Omnia i 900)	To access to an Internet program to make diary, receive feedback, receive reminder by SMS, for automatic data transmission from a blood glucose meter, and to listen to audio files. (p. 386-7)	3 months	11	(4 "dropped out" before interventi on started)	(due to the conviction that being involved in the intervention would be too time consuming, p. 389)	Diary response rate and feedback read rate through the whole intervention period is shown at individual level and average among the participants (p. 388, Table 2). Use of the audio file is described briefly that "only a few patients used the sound file with mindfulness exercies." (p. 390) Use of the Few Touch application is not explained.

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Vervloet	2012	T2DM		Use of Real Time Medication Monitoring (RTMM), which reminds patients only if they forget to take their pills, to improve adherence to oral medication. Reminder is sent by SMS. (p. 595)	Take medication as prescribed from teh RTMM dispenser. Frequency could vary between 1-3 times per day. (p. 596)	Mobile phone (participants' own mobile phone)	To receive SMS reminders (p. 595)	6 months	56	11	- Irregular working hours (1) - Poor mobile connection (1) - No longer on oral therapy (1) - Disinterest in using the dispenser (1) - The rest (7 participants) stopped without giving a reason	Adherence to oral medication is explained by data about timing of opening dispenser; the number of days without dosing in average and SD; missed dose in average and SD in the form of percentage; and the number of participants who did not open the dispenser for more than 7 days (9-12 days by 7 participants). The number of SMS reminders sent are followed by the timing of opening dispenser. Averaged number, SD, and range of SMS reminders per participant calculated for the whole period of intervention is shown for the whole intervention group and divided participant group based on the prescribed frequency of medication. Two examples of plots showing date and timing of medication intake compared with the time frame within which a participant agreed to take medication are shown to illustrate the great

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Tsang	2001	No info.	Distribution of frequncy of use (transmission/week) in the form of answer to a questionnaire (p. 49, Table 2)	No info.	No info.	No info.	For the whole period of the intervention only	No info.	p. 49 "The average numbers of log-ins increased subsequently, after the technical problems had been dealt with."	Questionnaire (p. 49, Table 2, 3)	-Technical problems were experienced and reported by 7/19 participants in the early phase of the study. They were fixed. - The DMS was considered to be easy to use in general (Table 2)
Ferrer-Roca	2004	N/A	(only regarding use of PC)	(No info.)	(No info.)	(No info.)	(monthly)	(No info.)	(p. 280 "Fewer visits tot eh Website in the mongh of December, perhaps because of Christmas")	Telephone interview (p. 279)	(p. 279, Table 2) Preference for SMS (6/8) is shown. Only 1/7 considered s/he had difficulty of readability, but it is not clear if the question meant about Website visited by mobile phones or PCs.
Ferrer-Roca	2004	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	Very briefly reported: p. 283 "a reduction of reporting activity during a holiday period".	Satisfactionary survey with 5-point Likert scale and a qualitative inquiry at two meetings (p. 283, p. 284 Table 2)	- Rather high satisfaction with the SMS system was shown (p. 284, Table 2) - Critisizm on the inability of entering data from the previous days - Difficulty in typing the SMS message by eldery people - Concern about cost hindered young peole reporting after they used pre-paid card.
Larizza	2006	Reported (p. 81, Table 2, 3)	No info.	No info.	No info.	No info.	For the whole period of the intervention only	No info.	No info.	Questionnaire (p. 81, Fig. 2, Telemedicine satisfaction questionnaire)	p. 81, Figure 2 shows the results of questionnaire, but what the rader shows is unclear (what the percentage means) p. 81 "The overall usability perception was very high; moreover, it did not significantly change over time."
Mamykina	2008	N/A	Reported: Figure 3	No info.	Reported, but it is not clearly indicated the correspondence between the reasons for low-level of engagement and actual level of engagement	No info.	For the whole period of the intervention only	No info.	No info.	Qualitative interview (p. 482)	Usability issues with the mobile phone (Nokia N80) were reported (phone menus, small size and high sensitivity of buttons)

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Lee	2009	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	Not clearly described but "satisfaction score (10 points)" is used (p. 196)	By the satisfaction scores, blood glucose meter and service was scored 8.59 and 9.01 out of 10 points respectively. Technical problems with the meter and mobile phones are reported: short battery life of the meter (4 weeks);difficulty with operating mobile phones; discomfort due to errors.
Hanauer	2009	N/A	Reported (but not only phone group but together with E-mail group): (p. 102) "Females were more likely to be users than males (P=0.04), regardless of the communication modality, with 86% of females compared with 56% of males using the system.	Reported: see "Difference between individuals"	No info.	Reported (but not only phone group but together with E-mail group): Table 1 shows baseline characteristics of the participants according to user status (users and non-users)	Monthly (p. 103, Figure 2)	No info.	In Discussion, the authors inferred that the drop in use in the 2nd and 3rd month might be due to summer months (p. 103)	p. 100 "final questionnaire concerning their use of CARDS"	p. 103 Left column: participants' preference on cell phone to receive reminders (50%) compared with e-mail (17%). suggestions including incorporating CARDS to pump or a meter, "having a healthcare provider call if the participant did not submit BG measurements for several days"
Istepanian	2009	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	No info.	#N/A
Rotheram-Borus	2012	N/A	(The participants were divided into high- and low-texters by splitting at the median number of texts)	No info.	p. 362 "High-texting women appear to be those who have higher BMI, who perhaps used texting to replace walking"	Associations between clinical outcomes/behaviors and engagement level (high- or low-texting) are investigated (p. 362, Figure 1, 2)	For the whole period of the intervention only	No info.	No info.	No info.	#N/A

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Kumar	2004	Reported: - Difference in the total number of transmitted BG values (I:1662, C:1471 p <.001) - Difference in proportion of participants who checked BG levels a median of 4> times a day (I:78% and C:68%, statistic significance is not reported) - No difference in frequency of data transmission regarding insulin dose and carbohydrate intake (p. 448-9)	Reported by histogram regarding distribution of the participants according to the median number of BG measurementsper day. (p. 450, Fig. 2)	Reported: see "Difference between arms" (p. 448-9)	Reported: p. 452 "the current pilot investigation cannot confirm whether the graphical display of insulin, carbohydrates, and BG levels or the DiaBetNet guessing game, or both, provides the motivation for behavior change"	No info.	For the whole period of the intervention only	No info.	No info.	survey questions (p. 448)	p. 449 "Youths' and parents' reports regarding satisfaction with the technologies indicated that both Game and Control Groups adapted equally and readily to the new platforms including the glucose monitor with infrared data transmission and the PDA software."
Vähätalo	2004	N/A	Reported: those with technical background transferred on average 1.4 (1.0) measurements per day whereas the other transferred 1.1 (0.6) per day (P=0.166) (p.193).	Reported: see "Difference between individuals"	No info.	Investigated. but only minor level of trend was shown that ones with technical background transferred slightly more BG measures than the others. (p. 193)	For the whole period of the intervention only	No info.	No info.	No info.	No info.

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Gibson	2005	reported: Figure 2 Mean number of readings received from patients in each group, during each week of their participation in the trial.	No info.	Reported: "The mean number of weeks in which no BG measurement was received was significantly different between the intervention group (3.9 weeks) and control group (11.4 weeks): p < .0001.	Reported: proactive nurse support appears to be essential in maintaining compliance in taking a reasonable frequency of BG readings	No info.	weekly	No info.	Reported: "Figure 2 shows that the number of readings perceived per patient each week decreased during the trial in the control group, but was sustained in the intervention group. Similarly, the significant between-group difference in the number of weeks for which no readings were received implies that nurse support discourages patients from stopping their use of the system altogether"	No info.	No info.
Farmer	2005	Reported: see "Summary of reported engagement"	No info.	Reported: see "Summary of reported engagement"	Reported: p. 2701 "A key element of our intervention was the telephone support by the diabetes specialist nurses".	No info.	weekly	No info.	No info.	Questionnaire at the final 9-month clinic visit (p. 2698)	Technical problems: - inability to transmit data due to temporary problems of GPRS (48 occurrences in intervention and 11 in control group) - difficulties with the cable linking the meter and phone - damage and theft of mobile phones - need to replace batteries.
Rami	2006	No info.	Reported: see "summary of reported engagement".	No info.	Technical problems with GPRS connection that hindered data transmission are reported but its relevance to the 9 participants is unclear. (p. 703)	No info.	For the whole period of the intervention only	No info.	No info.	Questionnaires (5-point Likert scale) (p. 703-4)	-26/36 participants reported experience of technical problem with GPRS connections for data uploading. The problem occured especially at weekends. -Entering and sending values took about 1 minute or less, but the majority still rated this as too time consuming. -Most participants thought that the VIE-DIAB system was useful for their diabetes management.

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Benhamou	2007	Reported: No statistically signigicant difference in adherence (the number of BG values transmitted to the server) was found (p. 224)	Reported: - 1 interrupted for 3 weeks in no-SMS period	Reported: see "Difference between arms" (p. 224)	No info.	No info.	1 month (30 days) (p. 224, "Adherence")	Reported: (p. 224) "When measured during the 30 days preceding V2, V4 and V6, no statistical difference was observed in either group, although a trend was noticed in the SMS to no-SMS group between V2 and V4, where SMBG frequency increased from 3.96 ± 1.60 to 4.93 ± 1.26 tests per day (difference 0.97, IC95 [–1.96–0.02], P = 0.054). "	No info.	19-item satisfaction survey	p. 223 "From the satisfaction survey, 81% of patients judged the device as very easy or moderately easy, 19% as moderately complex, none as very complex. Technical errors occurred in rare occasions, related with incidental clock unsynchronization between the glucose meter and the PDA, needing technical intervention (< 10 occurrences)."
Jensen	2007	N/A	N/A	N/A	N/A	N/A	daily	No info.	No info.	A debriefing interview (p. 679)	Technical problem of the BG meter (p. 680)
Kollmann	2007	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	Questionnaire, 7/10 returned completed quesetionnaires (p. 7 Table 2)	- Diab-Memory software was found to be easy to use and learn, and the service was helpful - the navigation and the data entry were practical for regular daily use. - the data acquisition procedure took 3 minutes at average. - Data transmission error due to lack of GPRS connectivity occurred in 3.5% of all cases.
Franklin	2008	No info.	Reported: as a wide variety in the number of submitted messages. 5 participants contributed to 52% of messages and 2 sent BG readings very regularly. (p. 4-5)	Reported (p. 5 section "Association Between Messaging and Patient Characteristics")	No info.	Investigated: Female sent significantly more messages unrelated to diabetes. Otherwise no factors were identifed as associated.	For the whole period of the intervention only	No info.	No info.	By messages categorized into "technical messages" (p. 6)	7% (86/1180) of messages were about technical problems. 55 messages were about difficulties with message transmission and cost. Problems highlighting failures in message personalization were also reported.

First author	Year	Difference between arms	Difference between individuals (not predefined arms)	Quantitative (statistical) analysis to assess difference in engagement between groups / individuals	Qualitative analysis for reasons of difference in engagement between groups / individuals	Factors associated with difference in engagement are investigated when difference between individuals are reported	Granularity of reported level of engagement over time	Quantitative (statistical) analysis for change in level of engagement over time	Qualitative analysis for reasons of change in level of engagement	Usability evaluation (data collection methods)	Usability evaluation (problems reported / satisfaction)
Gomez	2008	N/A	See "Summary of reported engagement"	No info.	No info.	No info.	See "Summary of reported engagement"	No info	No info	No info.	p. 7 "Main technical difficulties came from the mobile GPRS communication and the use of the PDA: 1) GPRS connection failed when very high amounts of data were transmitted (e.g. data from several months); 2) the limited GPRS connection coverage in some suburban areas and; 3) PDA battery consumption during data transmission.
García-Sáez	2009	No info.	Only as description "the pattern of system usage varied between individuals (p. 400)" in Discussion	No info.	No info.	No info.	For the whole period of the intervention only	No info	Briefly reported: "Patients' behavior did not change along the intervention phase (p. 399)"	Online questionnaire with 4-point Likert scale (p. 399)	p. 399 "In general, all patients had a positive opinion of the functionalities and utility of the system. Although some patients did not think that the system could help to reduce the number of acute problems, it is important to notice that all the patients considered the system easy to learn and they would recommend it for diabetes care."
Rossi	2009	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	Questionnaire ("specifically developed", p. 21)	Carbohydrates counting was considered to be most useful followed by insulin bolus calculation, food diary, physical activity recording and food exchange function (P. 21-2). Slowness of the software and the lack of some food int eh list and pictures were pointed out as problems. (p.22)
Rossi	2010	N/A	In the form of range of the number of text messages, the results show the difference among the participants.	No info.	No info.	No info.	For the whole period of the intervention only	No info.	No info.	No info.	(Considred to be done in the study by Rossi et al. 2009)

First author	Year	Difference between arms	Difference between individuals (not predefined arms)	Quantitative (statistical) analysis to assess difference in engagement between groups / individuals	Qualitative analysis for reasons of difference in engagement between groups / individuals	Factors associated with difference in engagement are investigated when difference between individuals are reported	Granularity of reported level of engagement over time	Quantitative (statistical) analysis for change in level of engagement over time	Qualitative analysis for reasons of change in level of engagement	Usability evaluation (data collection methods)	Usability evaluation (problems reported / satisfaction)
Cafazzo	2012	N/A	Reported for engagement with the rewards program (see "summary of reported engagement")	No info.	No info.	No info.	For the whole period of the intervention only	No info.	No info.	Survey in paper form (p. 4)	Satisfaction was high (14/16 who answered the survey would continue to use the system) The remaining 2 wanted the system to be integrated with their insulin pump (p.9)
Mulvaney	2012	N/A	In the form of range of the numbers of text messages and log-ins, the results show the difference among the participants.	No info.	No info.	No info.	For the whole period of the intervention only	No info.	Reasons for not using the website were explained as: no need because the system does in the way they like; "it was another thing to log into"; or being busy (p. 117)	Interviews (p. 116)	Generally usability and satisfaction were rated highly. The participants considered that the system was motivating enough, SMS modality was appealing, helpful in their self-management both practically and psychologically. They wanted social network functions to be improved. (p. 117)
Frøisland	2012	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	SUS questionnaire and semistructured interview	10 participants who reported positive experience with the 2 mobile applications gave high SUS score (mean 81, SD 10) while 2 others gave 30. Availability of consultation with text message was appreciated and preferred to phone calls. Short and immedicately relevant message contents were preferred. Cumbersomeness of use of DIabetes Message System due to need to remember a code to get access and a simple SMS based consultation is preferred. Technical failure regarding data transmission from BG meter to the mobile phone was reported. (p.7-9)

First author	Year	Difference between arms	Difference between individuals (not predefined arms)	Quantitative (statistical) analysis to assess difference in engagement between groups / individuals	Qualitative analysis for reasons of difference in engagement between groups / individuals	Factors associated with difference in engagement are investigated when difference between individuals are reported	Granularity of reported level of engagement over time	Quantitative (statistical) analysis for change in level of engagement over time	Qualitative analysis for reasons of change in level of engagement	Usability evaluation (data collection methods)	Usability evaluation (problems reported / satisfaction)
Faridi	2008	N/A	Reported Refer the first paragraph of section "Uptake, utilization and focus groups".	No info.	No info.	No info.	Qualitative description only. Refer the first paragraph of section "Uptake, utilization and focus groups".	No info.	Repoprted Refer the second paragraph of section "Uptake, utilization and focus groups".	Focus group	Usability problems with a mobile phone for uploading data and a pedometer were reported. Participants reported that if the system was improved they would prefer using it over usual care.
Forjuoh	2008	N/A	Reported: who completed and did not complete the 6-month study Refer Table 1 (p. 275).	Reported: Refer Table 1 (p. 275).	See the "Report of reasons for drop-outs" and p. 275-6 for more detail	Investigated, but no statistically significant difference was found with regard to the factors they investigated.	Every 3 months (at 3-month and 6-month visit regarding use of specific features)	Reported: refer Table 2. No statistically significant difference was found in terms of level of usage between 3-month and 6-month point for all features. Data requires caution to interpret due to different sample between 3-month and 6-month visits.	No info.	p. 278 "Data from preliminary analysis of an accompanied user feedback session using volunteers from among the study participants" Note: not clearly described in Methods section	(p. 276) 75.10% of participants reported being comfortable with the use of their PDA (scored 4> on 7-point Likert scale) at 3-month visit and this trend did not change significantly at 6-month visit. '- Loss of data due to participant's failure to properly save entered data - Difficulties with data entry so choosing to enter all activities in a book (=misleading reports) - The application was open to error - The PDA was not straightforward nor user-friendly (Forjuoh et al. 2007, p. 381; Vuong et al. 2010, p. 2)
Sevick	2008	N/A	Reported: 12 participants entered less than 10% of the number of expected meals (p. 406)	No info.	Difficultiy using the PDA, especially elderly people without experience and with fine-motoric problems (p. 406). Not clearly described whether or not the reason is for the 12 participants who gave up using PDA.	No info.	For the whole period of the intervention only	No info.	No info.	p. 406 "an investigator-developed 5-point Likert scaled instrument regarding the acceptability of PDA self-monitoring"	Participants agreed that they understood the usefulness of PDA-monitoring (87.9%), that entering foods into the program was easy (84.8%), that feedback graphs were easily interpreted (69.7%), and that they would continue to use the PDA for self-monitoring after the study concluded (82%).

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Cho	2009	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	Questionnaire (p. 79)	Table 2a shows that majority was satisfied with the medical service by mobile phone, but the total number of subjects (29) does not correspond to the number of those who completed the study (35).
Turner	2009	N/A	No info.	N/A	N/A	N/A	(The duration of the intervention is unclear)	No info.	No info.	(Not evaluation but technical problems were reported by phone call to the telehealth nurse (p. 51))	(Technical problems such as phone transmission or application errors were normally resolved by the telehealth nurse or application supplier's front-line support team, p. 52 Table 2)
Sevick	2010	N/A	Reported: (Figure1 and Table 2 on p. 319.)	N/A. The participants were divided according to the level of adherence per week.	No info. (only factor analysis)	Reported: (Table 3 and 4 on p. 320-1)	weekly	No info. (Change in adherence over time is not investigated at individual level)	Only in discussion: Assumed to be less value in continuing monitoring after being aware of and made necessary dietary modifications (p. 322). (Change in adherence over time is not investigated at individual level)	No info.	No info.
Noh	2010	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	No info.	No info.
Lyles	2011	N/A	Reported (see "summary of reported engagement)	No info.	Reported in the Results, "Qualitative themes", however, the participant's ID for quotes look contradictive. (p. 566-7)	No info.	For the whole period of the intervention only	No info.	No info.	Semistructured interview (p. 564)	-Uploading BG data was considered genrally easy, but 3/8 participants were frustrated with its difficulty -Smartphones were perceived diffitult to use (p. 566)

First author	Year	Difference between arms	Difference between individuals (not predefined arms)	Quantitative (statistical) analysis to assess difference in engagement between groups / individuals	Qualitative analysis for reasons of difference in engagement between groups / individuals	Factors associated with difference in engagement are investigated when difference between individuals are reported	Granularity of reported level of engagement over time	Quantitative (statistical) analysis for change in level of engagement over time	Qualitative analysis for reasons of change in level of engagement	Usability evaluation (data collection methods)	Usability evaluation (problems reported / satisfaction)
Hussein	2011	N/A	No info.	N/A	N/A	N/A	Monthly but only in the following description "it was observed that the first month had the highest messages and there was a trend of fewer inquiries in the second and the third month" (p. e25)	No info.	Reported briefly, see "Granularity of reported change in engagement over time".	Questionnaire (p. e25)	SMS consultation was generally considered to be helpful in self-management, motivating, and saving cost and money while feeling sequre (p. e25)
Lim	2011	N/A	No info.	N/A	N/A	N/A	For the whole period of the intervention only	No info.	No info.	No info.	No info.
Dick	2011	N/A	Reported regarding response time (p. 1248)	No info.	No info.	No info.	For the whole period of the intervention only	No info.	No info.	Interviews with 8 questions about thier satisfaction with the pilot using a 6-point Likert scale and open-ended survey questions (p. 1248)	Generally participants considered the text messaging satisfactory, easy to learn than expected. More variation in message contents and more control about message scheduling were requested, but part of the participants wanted to rely on a person to help them manage their schedule. Participants felt that frequent messages were necessary at beginning but less after routine was established. (p. 1252)
Katz	2012	N/A	Reported: see "Summary of reported engagement"	No info.	Explained as reasons for drop-outs, see "Report of reasons for drop-outs".	No info.	Regarding active group: the first and the last 10 weeks (among 56 weeks)	No info.	No info.	No info.	No info.

First author	Year	Difference between arms	Difference between individuals (not predefined arms)	Quantitative (statistical) analysis to assess difference in engagement between groups / individuals	Qualitative analysis for reasons of difference in engagement between groups / individuals	Factors associated with difference in engagement are investigated when difference between individuals are reported	Granularity of reported level of engagement over time	Quantitative (statistical) analysis for change in level of engagement over time	Qualitative analysis for reasons of change in level of engagement	Usability evaluation (data collection methods)	Usability evaluation (problems reported / satisfaction)
Nes	2012	N/A	Reported, refer p. 388, Table 2	No info.	No info.	No info.	For the whole period of the intervention only	No info.	No info.	Questionnaire (5- and 3-point Likert scale) and 2 semi-structured interviews, at halfway through and after the completion of the study (p. 388)	Smartphone: some usability problems were reported, but the majority considered it user friendly. It was considered uncomfortable to bring the provided smartphone along their own mobile phone. Diary: Table 5 (p. 390) shows the evaluation of the intervention structure, and it illustrates that most of them considered that the structure was acceptable. However, they missed a variation in the questions and wanted to be free of obligation on weekends. Technical problems: Data transmission errors from a BG meter to the mobile phone was frequently reported. Participants were frustrated when entered diary data dissapearred due to technical errors.
Vervloet	2012	Difference between SMS group (intervention) and no-SMS group who used the same dispenser is compared (Table 2)	In the form of range of the number of SMS reminders, description and figures that shows two contrasting examples of adherence over the study period (p. 587-600)	Investigated and reported: Association between user experience and the number of SMS reminders (the number of SMS did not differ between participants with positive experiences and negative experiences but participants who reported high awareness received significantly more SMS than those who did not (P=0.03) (p. 600-1)	No info.	Investigated: Difference in adherence was analyzed according to: the prescribed frequency of medication intake (compared in terms of the reminded rate and how quickly responded to the reminders); and experiences with the system (in terms of the number of reminders received) (p. 600-1)	Two participants whose timings of medication intake are illustrated histrorically. Otherwise data are calculated for the whole intervention period	No info.	No info.	Questionnaire (p. 596)	Generally the SMS reminders in case of forgetting was appreciated (82.9%), considered to be supporting in medication use (75%), and useful (65.7%), part of the participants considered it disturbing (20.6%) and 6 participants (18.2%) answered that they don't react to the reminders.

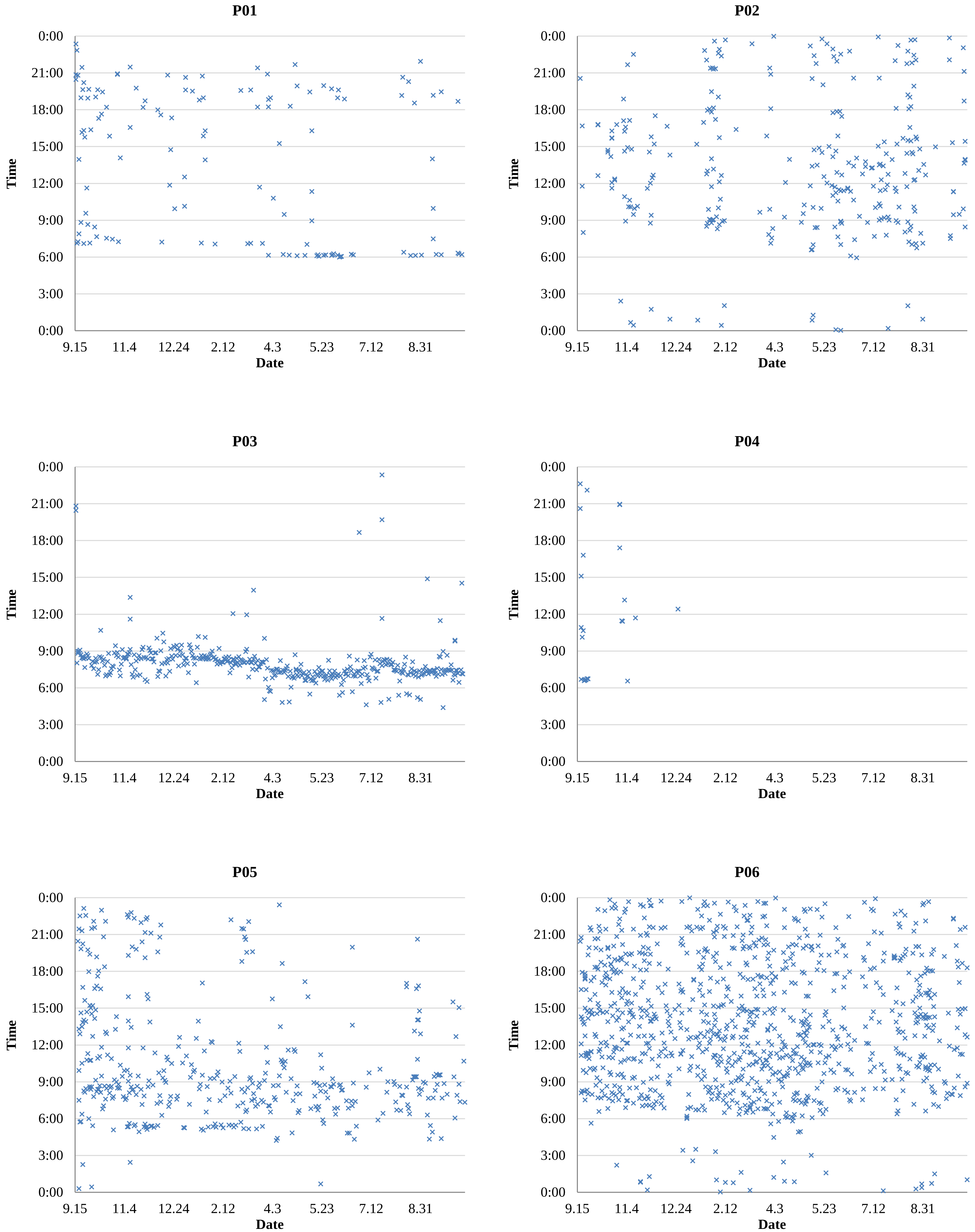
First author	Year	Engagement with specific components (or functions / features), if applicable	Report (or at least investigation) of reasons for enagement / non-engagement with specific componetns (or functions / features), if applicable
Tsang	2001	N/A	N/A
Ferrer-Roca	2004	(use of PC Web browser is explained in detail)	p. 279 Table 2 "Preference for SMS: yes (n=6), no (n=2)
Ferrer-Roca	2004	N/A	N/A
Larizza	2006	Table 2 shows the average number of web visits and interactions per week, but it is unclear what "interactions" mean. No explanation about Table 2 in main body. Table 3 shows the number of data (BG and insulin) sent by participants.	p. 83 (Success and Failure Factors of the M2DM service) "We believe that our system was well accepted by users thanks to the great flexibility of the multiaccess architecture that offers the possibility of providing a user-tailored telemedicine system for diabetes management. The presence of easy-to-use devices and the exploitation of different technologies (PSTN, Internet, GSM, etc.) for the access to the service are aspects certainly appreciated by the users. ... The analysis of the questionnaires (NB: 26/30 answered)delivered to patients not only showed the feasibility of this approach, but also the acceptability of the multi-access concept by all users involved."
Mamykina	2008	p. 482 Table 1	No info.
Lee	2009	N/A	N/A
Hanauer	2009	p. 102 Table 2 Comparison of 3 months of CARDS use between e-mail and cell phone users p. 103 Figure 2. Average number of BG results submitted by users per month (by two arms, phone group and e-mail group)	No report about other specific components (shown in Table 2) than the number of BG results submitted. Regarding "CARD usage" represented by the number of BG results submitted, the decline is inferred as due to summer months (p. 103)
Istepanian	2009	No info.	No info.
Rotheram-Borus	2012	Frequencies of responses to a daily given question and ad-hoc messaging between peers (buddies) are reported. See "Summary of reported engagement".	No info.
Kumar	2004	p. 448 "The number of transmitted BG values differed significantly between the two groups (intervention and control) p. 449 "There were also no differences between groups in daily insulin dosing or intake of carbohydrates as entered into the PDA database and transmitted via the wireless modem" p. 450 Figure 2 a: A histogram of the median number of glucose values checked per day in the Game and control groups.	No info.
Vähätalo	2004	N/A	N/A
Gibson	2005	N/A	N/A
Farmer	2005	N/A	N/A
Rami	2006	No info.	N/A
Benhamou	2007	p. 223 "All patients at V2 filled the questionnaire. However, several patients neglected to answer the questionnaires at 3-month intervals and were not reminded to do so in the absence of an adequate procedure, the DQOL database is being left unchecked until the completion of the trial."	No info.
Jensen	2007	Refer Figure 6-8 on p. 680. p. 681 "the user did not use the graph functionality very often".	Regarding increased use of BG functionality: due to technical problems with Bluetooth enabled BG-meter that automatically transferred data, the user needed to manually enter BG values after a couple of weeks (p. 680) Regarding little use of graph functionality: due to little novelty or utility for the user as an experienced patients of T1DM (p. 681)
Kollmann	2007	p. 6 Table 1 (more utilization of mobile phone than desktop PC for data transmission) (section "Feasibility", p. 9) "Although the patients also had the option of using a Web portal for data input, over 90% of values were transmitted via mobile phone. The remaining 10% of values were entered via the Web portal mainly by two patients who used the Internet access at their work."	Reported: Web portal via desktop was used by two participants who used Internet access at their work. (p. 9)
Franklin	2008	#N/A Contents of messages were analyzed.	N/A
Gomez	2008	No info.	N/A
García-Sáez	2009	p. 398 Figure 5. p. 399 "The functionalities of the PA application preferred by patients according to their usage were: downloading insulin data (6.32±3.1 per week), viewing the personal logbook (7.54±6.4 per week) and synchronizing the PDA with the TMCS(Telemedicine Central Server) (7.98±4.3 per week). "	No info.
Rossi	2009	Refer "Summary of reported engagement"	No info.
Rossi	2010	Description about participants' engagement with DID system is limited to the number of text messages and no information is given about what types of data were recorded and how often.	N/A

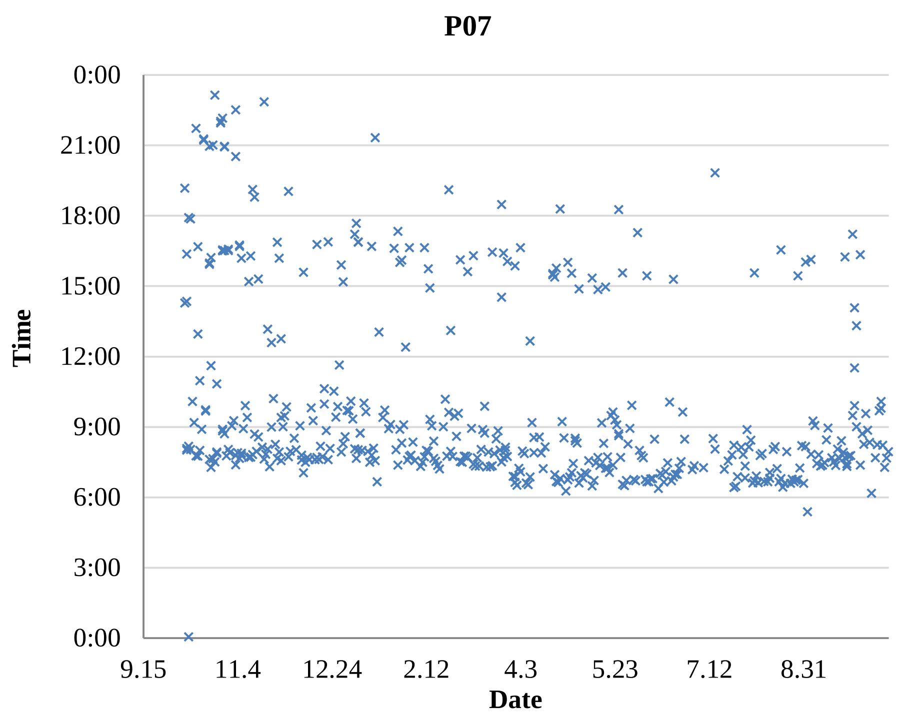
First author	Year	Engagement with specific components (or functions / features), if applicable	Report (or at least investigation) of reasons for enagement / non-engagement with specific componetns (or functions / features), if applicable
Cafazzo	2012	Frequencies of BG measurements, engagement with the rewards program and the social network function are explained, see "summary of reported engagement". Information sharing with parents is not explained.	No info.
Mulvaney	2012	Frequencies of message receiving, website log-ins, message creation, scheduling for additional messages, and deletion of meessages are explained, see "summary of reported engagement".	No info.
Frøisland	2012	Only regarding the number of pictures of food is reported, engagement in terms of data entry of other types of data and messages exchange with providers are not given.	No info.
Faridi	2008	No concrete description about utilization of each component (glucose meter and pedometer) in spite of the following description: p. 466 "Utilization was measured in the intervention group by mining the data collected by the NICHE server to obtain information about the utilization of separate components."	Usability problems of each component (mobile phone's user interface and a pedometer) were reported. Refer the second paragraph of section "Uptake, utilization and focus groups".
Forjuoh	2008	p. 276 Table 2 Number of Days in last 7 Days Specified PDA Feature Used to Assist with Self-Care Activity Monitoring (at 3- and 6-month visit, mean and standard error, mean difference and 95%CI)	p. 278 "patients used the graphics feature of the PDA to visualize trends in their blood glucose levels to replicate behaviors and practives that led to better glycemic control" p. 278 "with apparent improvement in their glycemic control, they reportedl chose to use their PDAs less often to record their blood sugar readings and medications."
Sevick	2008	N/A	p. 406 "No participant was lost due to difficulties experienced with the PDA self-monitoring (although not all participants used the PDA consistently)" p. 407 "A third challenge was participants who had difficulty using the PDA to monitor their foods. These individuals were typically elderly people, who had no experience with computers, and/or had problems with fine motor skills ... Only 12 participants 'gave up' on the PDA, and entered less than 10% of their expected meals. When this occurred, participants were, nevertheless, encouraged to remain in the study"
Cho	2009	N/A	N/A
Turner	2009	BG measurements frequency remained as once daily or more if necessary during the intervention period as it was before enrollment in the intervention. "A mean (SD) of 160 (93) BG readings were transmitted per patient" Contact to teleheatlh nurse was taken by the majority of participants during the initial 2 weeks. (p. 51)	No info.
Sevick	2010	N/A	N/A
Noh	2010	Reported according to a channel used to access and contents accessed, see "Summary of reported engagement" (Table 2, p. 355)	No info.
Lyles	2011	The number of BG measurements, uploads, and e-mail communications for the whole intervention period are explained at individual level in Table 1, p. 566	Reported in the section "Qualitative themes", with quotes with participant's ID. However, it is not totally clear about association with the level of engagement and the described user experiences as its reasons.
Hussein	2011	N/A	N/A
Lim	2011	(Only the frequency of BG measurements)	No info.
Dick	2011	(In terms of contents of messages, it is reported, refer p. 1251, Table2)	No info.
Katz	2012	N/A	No info.
Nes	2012	p. 388 Table 2 shows diary response rate and feedback read rate at individual level. p. 390 "Only a few patients used the sound file with mindfulness exercies."	(Questionnaire answer regarding agreement with motivational effect of the sound file with mindfulness exercises is highlighted (p. 389) due to the number of participants who negatively answered (3/10) more than to the other questions (1/10, including both scored 4 and 5) (p. 390, Table 4), but it is not written as associated with the result of use of the file)
Vervloet	2012	N/A	N/A

APPENDIX 3

DISTRIBUTION OF TIME POINTS WHEN BLOOD GLUCOSE MEASUREMENTS AND NUTRITION HABIT RECORDINGS OCCURRED ON THE DAY ALONG TRIAL DURATION IN TRIAL I (PHASE 1)

Distribution of time points when blood glucose measurements occurred on the day along trial duration (Trial I)

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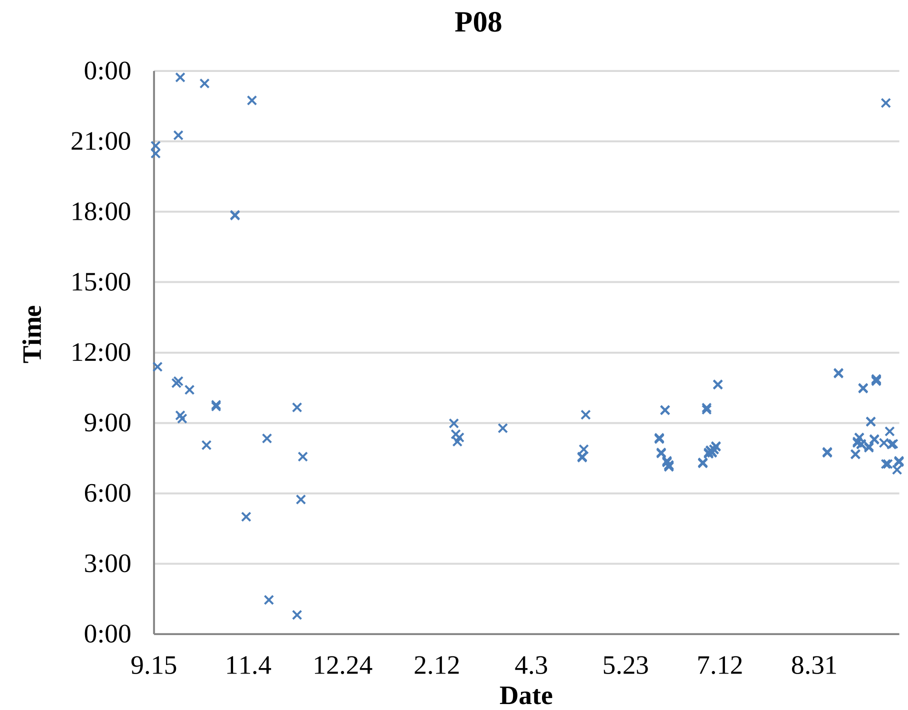
7.12
8.31
Date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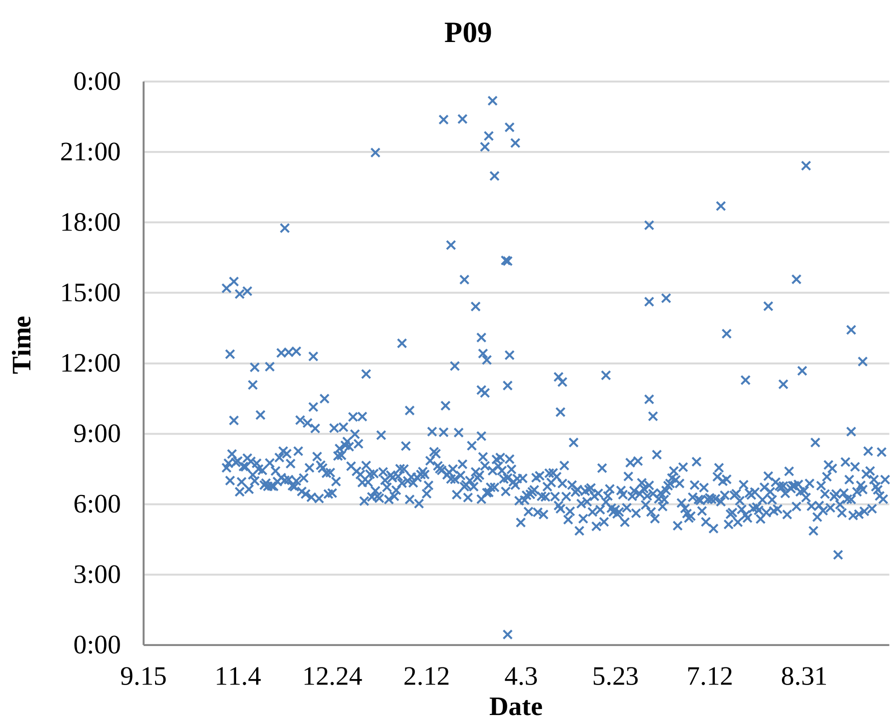
7.12
8.31
Date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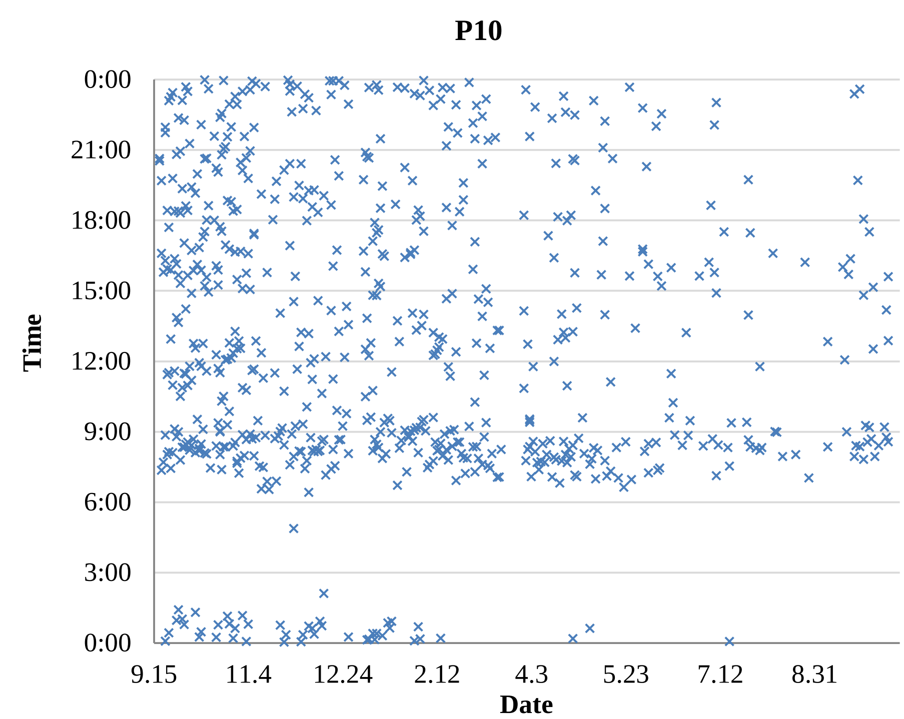
Date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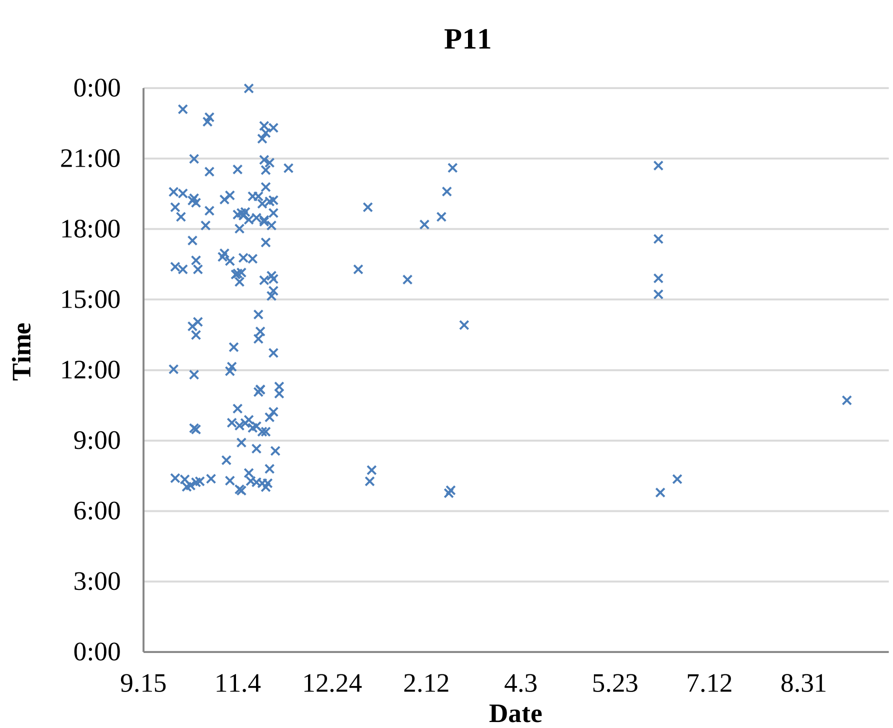
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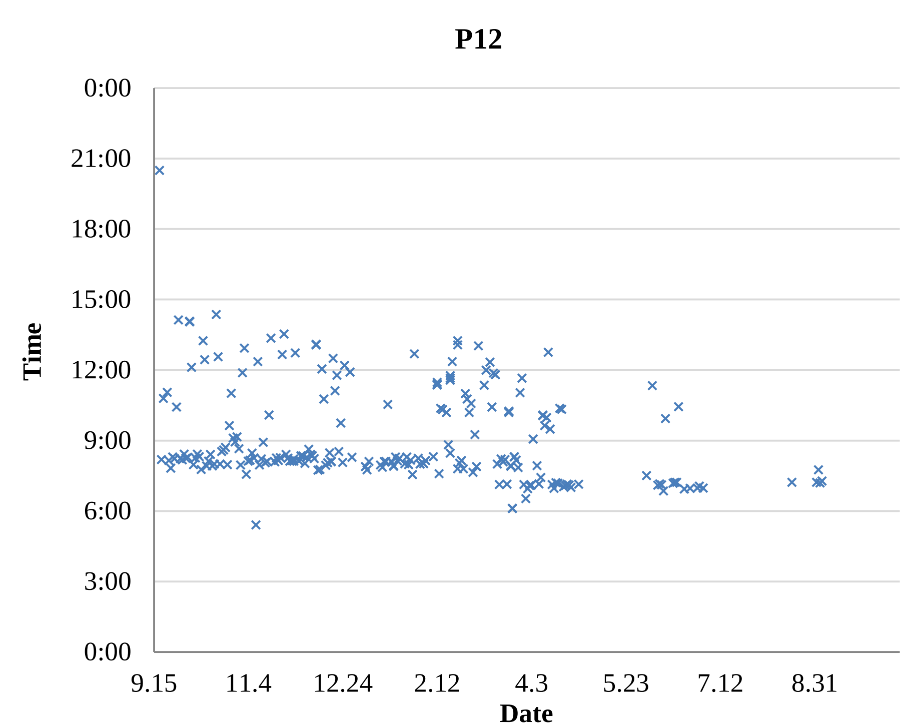
Date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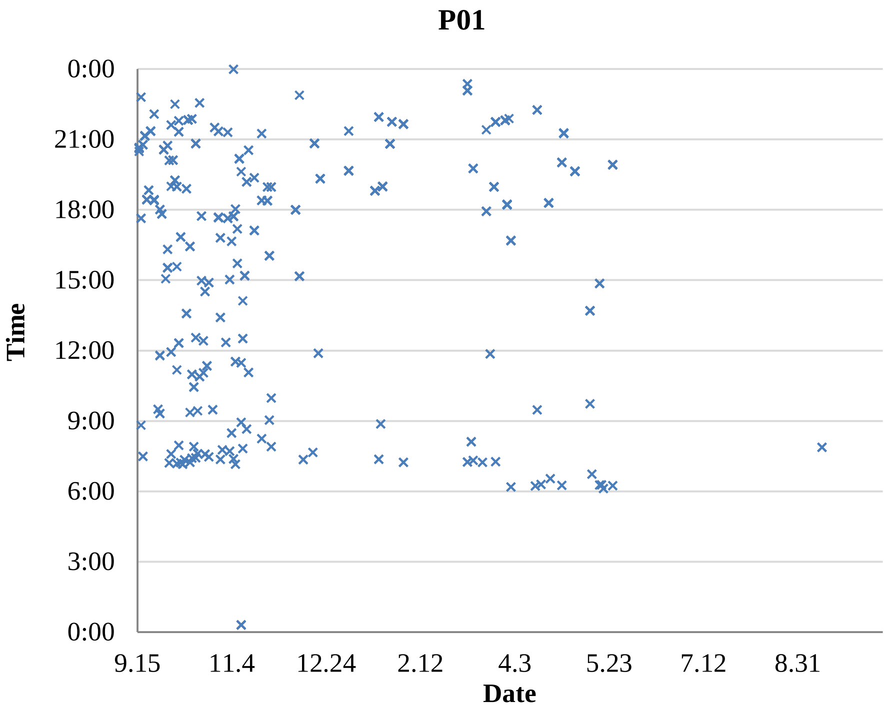
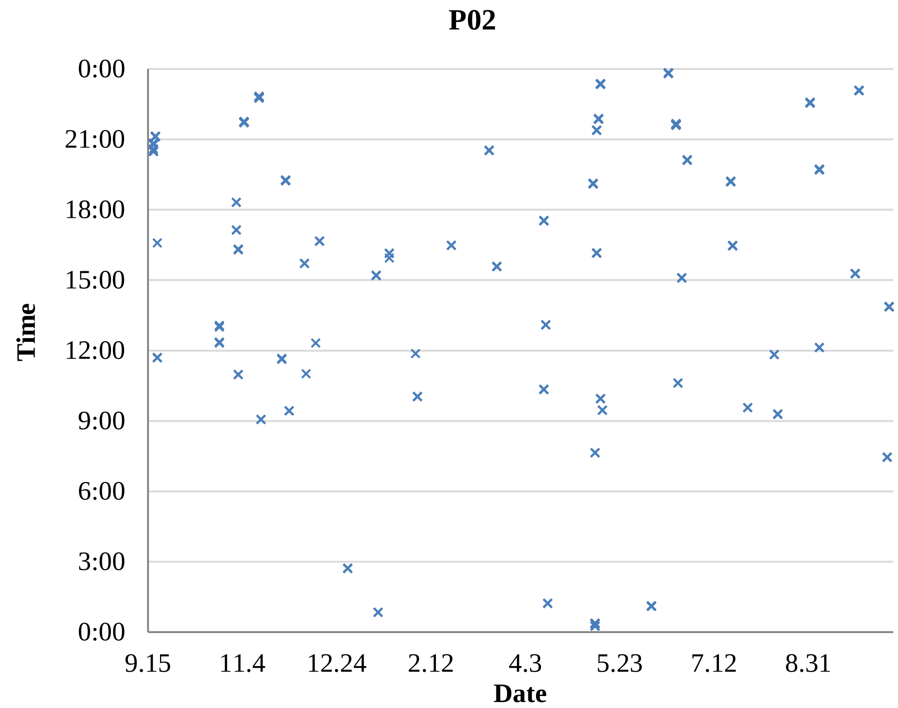
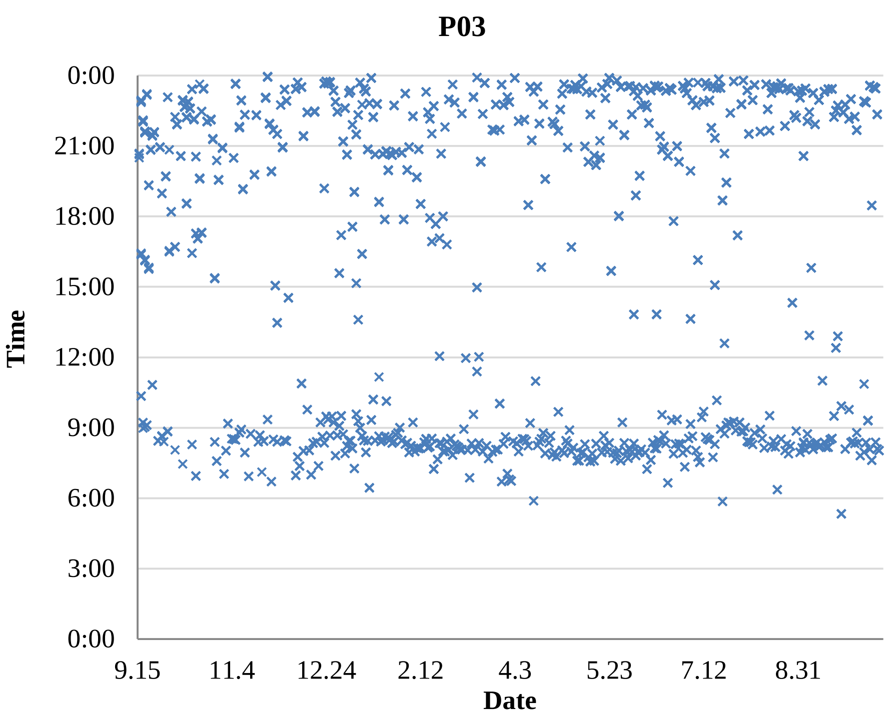
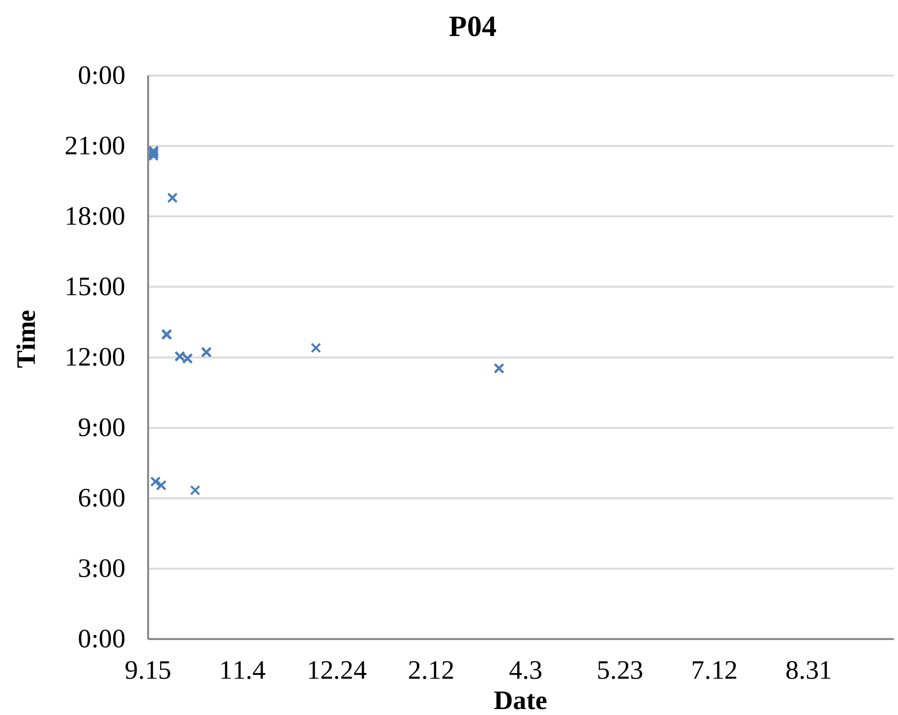
7.12
8.31
Date

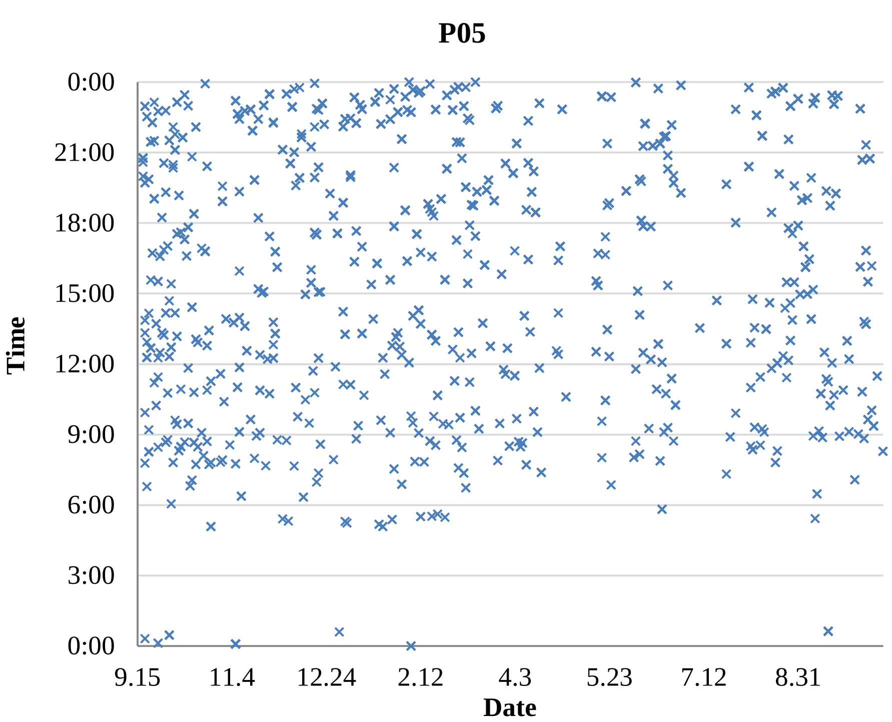
Distribution of time points when nutrition habit recordings occurred on the day along trial duration (Trial I)

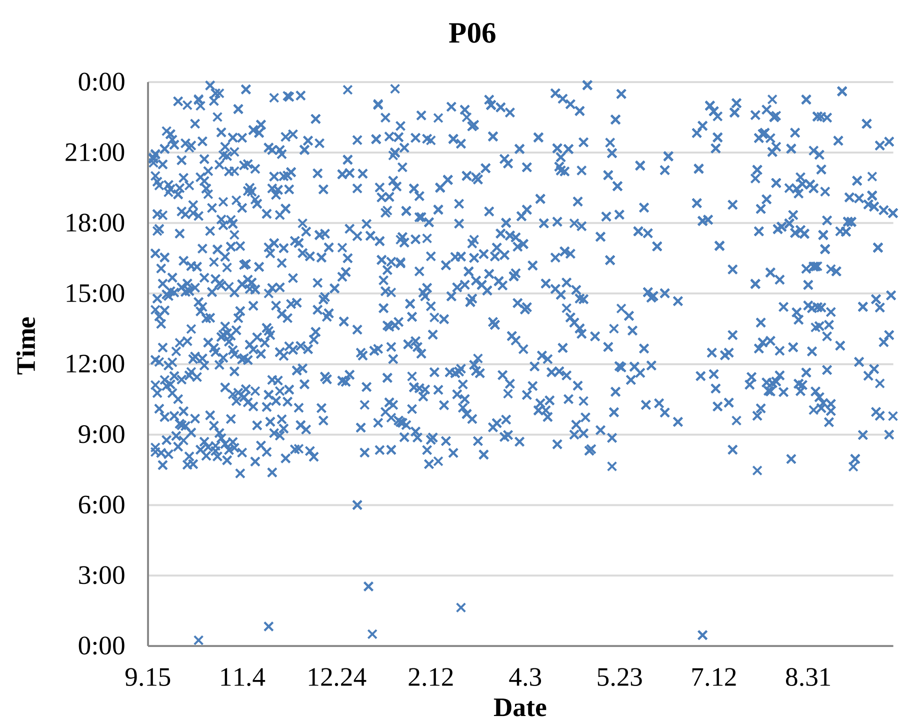


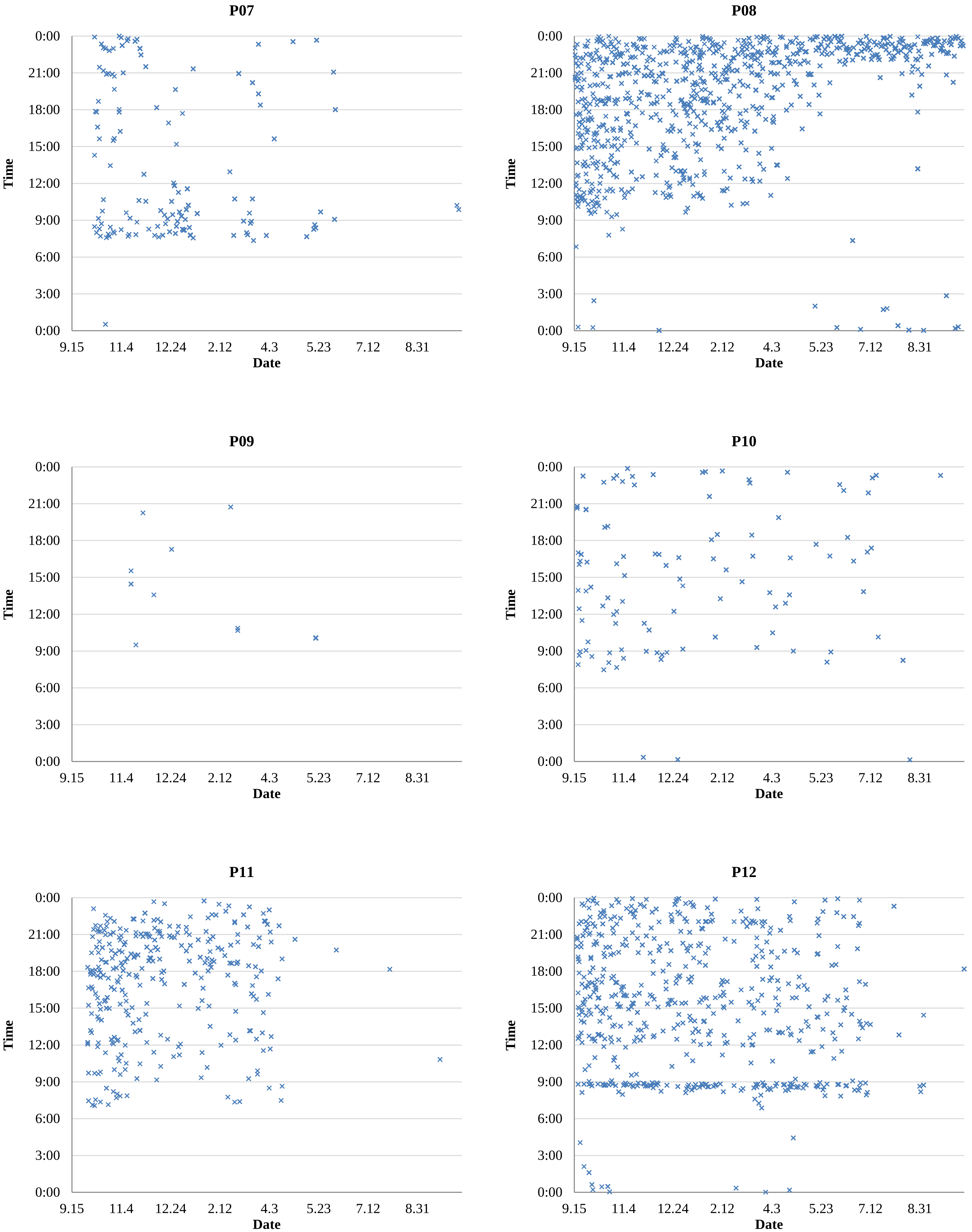











P07
P08
P09
P10
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Time
0:00
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18:00
21:00
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Date
9.15
11.4
12.24
2.12
4.3
5.23
7.12
8.31

APPENDIX 4

QUESTIONNAIRE TO PARTICIPANTS IN TRIAL II (PHASE 2)

Although I am the main contributor to designing this questionnaire, Eirik Årsand gave advices on both the contents and the amount of questionnaire and administration of it. Translation into Norwegian was supported by Hilde Gaard, a project leader of Motivation with Mobile, and John-Fredrik Solberg, a master student of Business Creation and Entrepreneurship (BCE) at University of Tromsø. Solberg and Päivi Salminen, also a master students of BCE, suggested inclusion of question 7.

Questionnaire to participants in ”Motivation with mobile”

This is a questionnaire to you who have participated in Diabetes Union’s motivation group in Harstad in autumn 2010 and spring in 2011, where Norwegian Centre for Integrated Care and Telemdicine has introduced Diabetes Diary and automatic transfer of blood glucose data to a mobile phone in the motivation group.

The purpose of this questionnaire is to get to know if the self-help tool you have used has led to any change in your self-management of diabetes. The self-help tool was developed with a group of people with Type 2 diabetes, and we have tried improving iteratively with feedback we received. In order to develop such tools that can function well for as many people with diabetes as possible, it is important that we get feedback from you who have not involved in the design process.

The answers will be handled anonymously. On the left shoulder corner, there is a number. This number is used only for analysis of the result with the usage data of the self-help tool.

Thank you for your help!

1. Date

2. Age

3. Gender

❒ Male
❒ Female

4. How many years has it been since you were diagnosed as having Type 2 diabetes?

year

5. Are you using insulin for your treatment now?

❒ Yes
❒ No

6. Are you using oral medication for your treatment now?

❒ Yes
❒ No

7. Have you kept track of your diabetes before you received this electronic diary? If so, how did you do?

❒ Yes, with paper-based diary
❒ Yes, but it is not with any tool or such thing
❒ Yes, with computer program. Which? (____)
❒ No
❒ Others

BLOOD GLUCOSE

8. Do you use the blood glucose sensor system (data transfer to the Diabetes Diary on the mobile phone) **in the last month?**

❒ Yes, at every measurement
❒ Yes, often but not all the time (at average more than every 2nd – 3rd times)
❒ Yes, sometimes (at average more than every 4th – 5th times)
❒ Yes, but seldom
❒ No, not anymore (I used it before)
❒ No, I have never used it

9. Have you experienced any problems with the blood glucose sensor system **after you got it updated in November 2010?**

❒ Yes
❒ I don't remember
❒ No

a. If you answered "Yes", what were the problems?

❒ Data transfer error from the meter to the mobile phone
❒ Blood glucose data disappeared after they were transferred to the mobile phone.
❒ Others

b. If you answered "Yes", does it work without any problem?

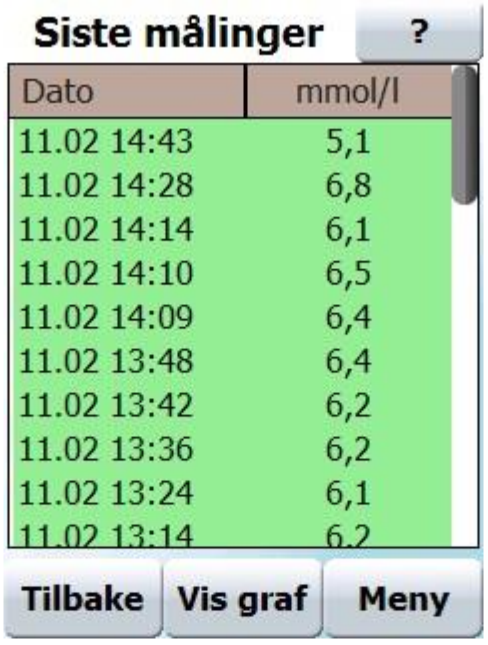
❒ Yes, now I have no problem
❒ I don't know
❒ Partly, or no (Please take kontakt to researchrs from NST afterwards)

c. If you answered "Yes", did you stop using the blood glucose sensor system due to the problems?

❒ Yes
❒ No

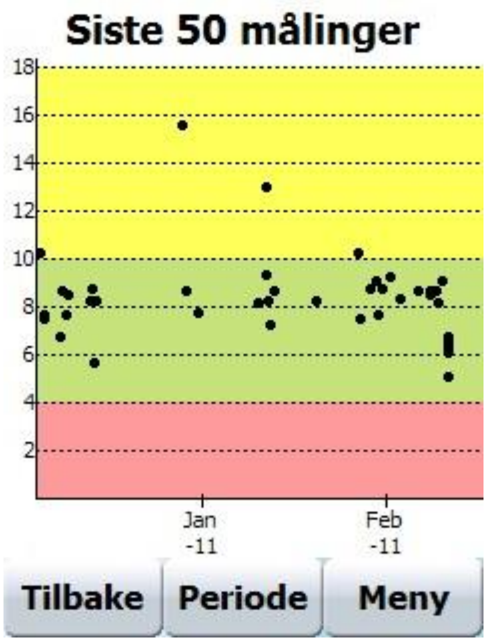
10. When do you see each page of Blood glucose pages in the Diabetes Diary **in the last month**? Mark all the alternatives that apply.

a. ”Last measurement” (the list)



❒ At every measurement
❒ When you want to see relationship with diet or physical activity
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ When you want to know trend
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ I don’t see this page so often anymore
  When did you see it before?
  ❒ At every measurement
  ❒ To see relationship with diet or physical activity
  ❒ To know trend
❒ I have never seen this page
❒ Others

b. ”Last 50 measures” (the graph)



❒ At every measurement
❒ When you want to see relationship with diet or physical activity
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ When you want to know trend
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ I don’t see this page so often anymore
  When did you see it before?
  ❒ At every measurement
  ❒ To see relationship with diet or physical activity
  ❒ To know trend
❒ I have never seen this page
❒ Others

11. Approximately how many timed do you measure blood glucose level per week **in the last month**?

Times / week If less frequent than weekly, how often? ______________________

a. If you measure irregularly, please specify when you measure. (ex. When you travel, or one week continulusly every month)

12. Is it more or less frequent **than before you received the self-help tool**?

❐ Much more frequent (more than doubled)
❐ Little more frequent (less than doubled)
❐ Neither
❐ Little less frequent (more than half)
❐ Much less frequent (less than half)

13. Why do you think the frequency changed or did not change? Mark all the alternatives that apply.

❒ Because with the tool, I have become more conscious about how I conduct self-management of my diabetes.
❒ Because the tool was motivating enough for me to measure blood glucose level oftener than before.
❒ Because with the tool, I learned about myself well enough and I don't need to measure so often as before anymore.
❒ Because the tool did not work out in the way that I come to measure blood glucose level oftener or less frequently.
❒ Because the frequency has been sufficiently high from before.
❒ Others (please write the reason)

14. Are you satisfied with **how often you measure blood glucose level now**? (Do you think that you measure sufficiently often with regard to blood glucose control?)

❐ Very satisfied
❐ Satisfied
❐ Neither
❐ Unsatisfied
❐ Very unsatisfied

15. In which degree do you agree that **the blood glucose system** motivates you enough for better self-management **in total (measure blood glucose level sufficiently often, have healthy dietary habit, and be more physically active)**?

❐ Totally agree
❐ Agree
❐ Neither
❐ Disagree
❐ Totally disagree

16. How satisfied are you with the blood glucose sensor system in the self-help tool?

❐ Very satisfied
❐ Satisfied
❐ Neither
❐ Unsatisfied
❐ Very unsatisfied

17. Is there anything you like about the blood glucose sensor system?

	Very well	Well	A little	Not especially	Don’t like it
The you don’t have to write down blood glucose values anymore					
That you get the blood glucose values on the mobile phone immediately					
That blood glucose values are easily accessible on the mobile phone					
The list of the blood glucose values					
That the graph of blood glucose values is easy to get overview of the trend of the blood glucose level					
The option to change the period to show the graph					

Annet:

18. Do you have any opinions about how the **Blood glucose sensor system** could have been improved?

INFO FUNCTION

Tips-part

19. Do you read the tips of the Diabetes Diary on the mobile phone **in the last month**?

❐ Ja, ofte (daglig – 2,3 ganger i uka)
❐ Ja, av og til (ukentlig – månedlig)
❐ Ja, men sjelden
❐ Nei, ikke lenger (Leste den før)
❐ Nei, jeg har ikke brukt i det hele tatt

20. In which degree do you agree that the tips have been useful and good to learn about diabetes?

❐ Totally agree
❐ Agree
❐ Neither
❐ Disagree
❐ Totally disagree

21. Which types of tips did you think the most useful? Mark all the alternatives that apply.

❐ Physical activity
❐ Blood glucose
❐ Definition
❐ Diet
❐ Sickness

22. In which degree do you agree that the **tips** motivate you enough for better self-management **in total (measure blood glucose level sufficiently often, have healthy dietary habit, and be more physically active)**?

❐ Totally agree
❐ Agree
❐ Neither
❐ Disagree
❐ Totally disagree

23. In which degree do you agree that you **actually have improved** how you conduct self-management of your diabetes after you read the tips?

❐ Totally agree
❐ Agree
❐ Neither
❐ Disagree
❐ Totally disagree

24. How satisfied are you with the tips part with regard to blood glucose control?

❐ Very satisfied
❐ Satisfied
❐ Neither
❐ Unsatisfied
❐ Very unsatisfied

25. Is there anything you like about the tips part?

	Very well	Well	A little	Not especially	Don't like it
That the tips are useful					
That the tips are concise and easy to read					
That the tips are motivating					
That they are easily accessible on the mobile phone					

Others:

26. Do you have any opinions about how the **tips part** could have been improved?

	Totally agree	Agree	Neither	Disagree	Totally disagree
Updating the tips					
With richer contents of the tips					
Possibility to connect to internet for more information					
The tips must be tailored depending on a user's blood glucose level					
With more motivating / encouraging contents					

Others:

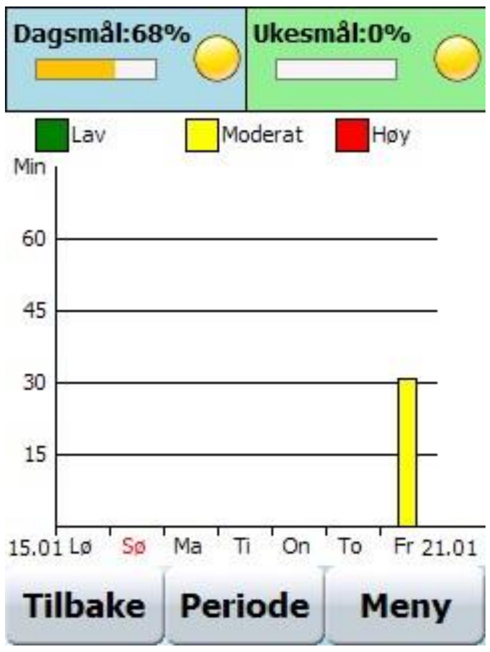
PHYSICAL ACTIVITY

27. Do you record the time you spend on physical activity by using the physical activity recording system in the Diabetes Diary in the last month?

❒ Yes, every time I do physical activity
❒ Yes, often. But not all the time (at average more than every 2nd-3rd times)
❒ Yes, sometimes (at average more than every 4th – 5th times)
❒ Yes, but seldom
❒ No, not anymore (I used it before)
❒ No, I have never used it

28. When do you see the "Status"-page of the physical activity recording system **in the last month**? Mark all the alternatives that apply.

❒ When you want to see relationship with blood glucose level
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ When you want to see if you have reached the goal
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ To get overview of how active you have been
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ I don't see it often anymore (I saw it before to see relationship with blood glucose level)
❒ I don't see it often anymore (I saw it before to see if you have reached the goal)
❒ I don't see it often anymore (I saw it before to get overview of how active you have been)
❒ I have never seen this page
❒ Others



29. How often do you do physical activity at average?

❒ Approximately every day or oftener than 3 times per week
❒ 1-3 times per week
❒ 1-3 times per month
❒ Seldom
❒ Never
❒ Others (please write how often or when you do physical activity if you do irregularly)

30. Is it more or less frequent **than before you received the self-help tool**?

❒ Much more frequent (more than doubled)
❒ Little more frequent (less than doubled)
❒ Neither
❒ Little less frequent (more than half)
❒ Much less frequent (less than half)

31. Why do you think the frequency changed or did not change? Mark all the alternatives that apply.

❒ Because with the tool, I have become more conscious about that physical activity influences the blood glucose level.
❒ Because the tool was motivating enough for me to do physical activity oftener than before.
❒ Because with the tool, I learned about myself well enough and I don't need to do physical activity so often as before anymore.
❒ Because the tool did not work out in the way that I come to do physical activity oftener or less frequently.
❒ Because the frequency has been sufficiently high from before.
❒ Others (please write the reason)

32. Are you satisfied with the frequency now?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

33. How long do you do physical activity every time at average?

❒ More than 1 hour
❒ 31 minutes – 1 hour
❒ 16 – 30 minutes
❒ Less than 15 minutes
❒ It depends on which type of physical activity it is (please specify how long for each type)
❒ Others (please write why)

34. Is it longer or shorter **than before you received the self-help tool**?

❒ Much longer (more than doubled)
❒ Little longer (less than doubled)
❒ Neither
❒ Little shorter (more than half)
❒ Much shorter (less than half)

35. Why do you think the length changed or did not change? Mark all the alternatives that apply.

❒ Because with the tool, I have become more conscious about that physical activity influences the blood glucose level.
❒ Because the tool was motivating enough for me to do physical activity longer than before.
❒ Because with the tool, I learned about myself well enough and I don't need to do physical activity so long as before anymore.
❒ Because the tool did not work out in the way that I come to do physical activity longer or shorter.
❒ Because the length has been sufficiently long from before.
❒ Others (please write the reason)

36. Are you satisfied with the length now?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

37. Have you changed the goals for physical activity?

❒ Yes, I have changed both weekly and daily goals
❒ I have changed only weekly goal
❒ I have changed only daily goal
❒ I don't remember
❒ No, I have not changed goals

38. How do you think about the function for goal changing? Mark all the alternatives that apply.

❒ Motivating for me to become more physically active
❒ I have not changed the goals (or I don't remember) but I think it is a good possibility to have
❒ I could not find any effect by changing the goals
❒ I need a help to set a goal that fits me
❒ Others (Write how you think)

39. In which degree do you agree that the **physical activity recording system** motivates you enough for better self-management **in total (measure blood glucose level sufficiently often, have healthy dietary habit, and be more physically active)**?

❒ Totally agree
❒ Agree
❒ Neither
❒ Disagree
❒ Totally disagree

40. How satisfied are you with the physical activity recording system in the self-help tool?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

41. Is there anything you like about the physical activity recording system?

	Very well	Well	A little	Not especially	Don't like it
That the smiley icons are motivating					
The graph					
That it is possible to record after the physical activity has been done (not like a step counter that you cannot record if you forget to attach it on you)					
That it is possible to record different types of intensity					

Others:

42. Do you have any opinions about how the physical activity recording system could have been improved?

DIET

43. Do you record food and drinks by using the nutrition habit recording system in the Diabetes Diary in the last month?

❒ Yes, every time I eat or drink
❒ Yes, every day at the end of the day
❒ Yes, often. But not all the time (at average more than every 2nd-3rd times)
❒ Yes, sometimes (at average more than every 4th – 5th times)
❒ Yes, but seldom
❒ No, not anymore (I used it before)
❒ No, I have never used it

44. When did you **see the "Status"-page of the nutrition habit recording system** in the last month? Mark all the alternatives that apply.

a. "Status-1" (Total records on the day and in the week, goals and smileys at goal achievement)

❒ When you want to see relationship with blood glucose level
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ When you want to see if you have reached the goals
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ To get overview of how you have eaten on the day or in the week
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ I don't see it often anymore (I saw it before to see relationship with blood glucose level)
❒ I don't see it often anymore (I saw it before to see if you have reached the goal)
❒ I don't see it often anymore (I saw it before to get overview of how you have eaten)
❒ I have never seen this page
❒ Others

b. "Status-2" (List of total records on the all types of foods and drinks)

❒ At every measurement
❒ When you want to see relationship with blood glucose level
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ When you want to see if you have reached the goals
  How often does it happen?
  ❒ Often (daily or several times per week)
  ❒ Sometimes (about once weekly)
  ❒ Seldom
❒ To get overview of how you have eaten on the day or in the week
  How often does it happen?

- ❐ Often (daily or several times per week)
- ❐ Sometimes (about once weekly)
- ❐ Seldom

❐ I don’t see it often anymore (I saw it before to see relationship with blood glucose level)
❐ I don’t see it often anymore (I saw it before to see if you have reached the goal)
❐ I don’t see it often anymore (I saw it before to get overview of how you have eaten)
❐ I have never seen this page
❐ Others

45. Do you think that you have now better or worse overview of what you eat daily **than before you received the self-help tool**?

❐ Much better overview
❐ A little better overview
❐ Neither
❐ A litte worse overview
❐ Much worse overview

46. Approximately how much fruits, vegetables and berries do you eat every day (at average)? (incl. fresh, prepared, frozen, dry and canned fruits and vegetables)

❐ More than 600 gram (corresponding to more than 4 portions of fruits, vegetables or berries)
❐ 300 – 600 gram (corresponding to 2-4 portions of fruits, vegetables or berries)
❐ 0 – 300 gram (corresponding to 0-2 portions of fruits, vegetables or berries)
❐ I don’t eat fruits, vegetables or berries

47. Is it more or less **than before you received the self-help tool**?

❐ Much more (more than doubled)
❐ A little more (less than doubled)
❐ Neither
❐ A little less (more than half)
❐ Much less (less than half)

48. Why do you think the amount changed or did not change? Mark all the alternatives that apply.

❐ Because with the tool, I have become more conscious about that diet influences the blood glucose level.
❐ Because the tool was motivating enough for me to eat more fruits, vegetables or berries than before.
❐ Because with the tool, I learned about myself well enough and I don’t need to eat fruits, vegetables or berries so much as before anymore.
❐ Because the tool did not work out in the way that I come to eat fruits, vegetables or berries more or less.
❐ Because the amount has been sufficient from before.
❐ Others (please write the reason)

49. Are you satisfied with the amount and frequency of eating fruits, vegetables or berries now?

❐ Very satisfied
❐ Satisfied
❐ Neither
❐ Unsatisfied
❐ Very unsatisfied

50. Approximately how often do you eat **meals with low carbohydrate content** (at average)? (ex. fish-, chicken-, meat dishes, with little (less than or about a third of the dish) carbohydrate oriented food like potatoes, bread, rice, couscous, pasta, etc.)

❐ 3 times or more per day
❐ 1 – 2 times per day
❐ 4 – 6 times per week
❐ 1 – 3 times per week
❐ 1 – 3 times per month
❐ Seldom or never

51. Is it more or less frequent **than before you received the self-help tool**?

❐ Much more frequent (more than doubled)
❐ Little more frequent (less than doubled)
❐ Neither
❐ Little less frequent (more than half)
❐ Much less frequent (less than half)

52. Approximately how often do you eat **meals with high carbohydrate content** (at average)? (ex. pasta, rice or other dishes with much (more than half of the dish) carbohydrate oriented food)

❐ 3 times or more per day
❐ 1 – 2 times per day
❐ 4 – 6 times per week
❐ 1 – 3 times per week
❐ 1 – 3 times per month
❐ Seldom or never

53. Is it more or less frequent **than before you received the self-help tool**?

❐ Much more frequent (more than doubled)
❐ Little more frequent (less than doubled)
❐ Neither
❐ Little less frequent (more than half)
❐ Much less frequent (less than half)

54. Why do you think the frequency of having main meals with low/high carbohydrate content changed or did not change? Mark all the alternatives that apply.

❐ Because with the tool, I have become more conscious about that diet influences the blood glucose level.
❐ Because the tool was motivating enough for me to eat main meals with low carbohydrate content instead of main meals with high carbohydrate content than before.
❐ Because the tool did not work out in the way that I come to eat main meals differently from before.
❐ Because the frequency of having main meals with high carbohydrate content has been sufficiently low from before.
❐ Others (please write the reason)

55. Are you satisfied with the frequency of having main meals with low carbohydrate content?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

56. Have you changed the goals for nutrition habit?

❒ Yes, I have changed all the goals
❒ I have changed only the following goal
Please mark all the alternatives that apply
❒ Low carb. snack per day
❒ Total daily meals
❒ Maximum number of high-carb. meals per week
❒ I don't remember
❒ No, I have not changed goals

57. How do you think about the function for goal changing? Mark all the alternatives that apply.

❒ Motivating for me to eat more healthily
❒ I have not changed the goals (or I don't remember) but I think it is a good possibility to have
❒ I could not find any effect by changing the goals
❒ I need a help to set a goal that fits me
❒ Others (Write how you think)

58. In which degree do you agree that the **nutrition habit recording system** motivates you enough for better self-management **in total (measure blood glucose level sufficiently often, have healthy dietary habit, and be more physically active)**?

❒ Totally agree
❒ Agree
❒ Neither
❒ Disagree
❒ Totally disagree

59. How satisfied are you with the nutrition habit recording system in the self-help tool?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

60. Is there anything you like about the nutrition habit recording system?

	Very well	Well	A little	Not especially	Don't like it
That the smiley icons are motivating					
That it is easy and simple to record					
That it is possible to record drinks as well					

Others:

61. Do you have any opinions about how the nutrition habit recording system could have been improved?

	Totally agree	Agree	Neither	Disagree	Totally disagree
If it was possible to record foods and drinks more in detail					
With a calculating function (ex. Calorie, amount of carbohydrates)					

Others:

THE SELF-HELP TOOL in total (Diabetes Diary on the mobile phone and automatic data transfer of blood glucose values from the meter) and YOUR DIABETES

62. Do you use the self-help tool when you consult to your doctor?

❒ Yes, every time
❒ Yes, but not every time
❒ I used it before, but not anymore
❒ No, not at all
❒ I have not been to a doctor since I received the self-help tool

a. If you answered "Yes", do you think that the relationship between you and your doctor has changed?

❒ Yes, it has been better
❒ Yes, it has become worse
❒ No, it has not changed

63. How satisfied are you with how you manage your diabetes now?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

64. Do you think that you are more satisfied or unsatisfied with how you manage your diabetes **than before you received the self-help tool**?

❒ Much more satisfied
❒ More satisfied
❒ Neither
❒ More unsatisfied
❒ Much more unsatisfied

65. Why do you think so? Mark all the alternatives that apply.

❒ Because I could get control over my diabetes with the tool.
❒ Because with the tool I discovered that I did not manage my diabetes well enough.
❒ Because the tool was not useful enough for me to manage my diabetes well enough or better than before.
❒ Because I have been satisfied with how I manage my diabetes from before.
❒ Others (write the reason)

66. How satisfied are you with your knowledge about your diabetes?

❒ Very satisfied
❒ Satisfied
❒ Neither
❒ Unsatisfied
❒ Very unsatisfied

67. Do you think that you are more satisfied or unsatisfied with your knowledge about your diabetes **than before you received the self-help tool**?

❒ Much more satisfied
❒ More satisfied
❒ Neither
❒ More unsatisfied
❒ Much more unsatisfied

68. Why do you think so? Mark all the alternatives that apply.

❒ Because I could get to know more about my diabetes with the tool.
❒ Because with the tool I discovered that I did not know about my diabetes well enough.
❒ Because the tool was not useful enough for me to get to know more or less about my diabetes than before.
❒ Because I have been satisfied with my knowledge about my diabetes from before.
❒ Others (write the reason)

69. In the course of the last months you have used the tool, do you think that **anything has been improved due to this self-help tool**? Mark all the alternatives that apply.

❒ Medication
❒ HbA1c
❒ Blood glucose control (average of blood glucose values)
❒ Others (please specify)

70. In the course of the last months you have used the tool, do you think that **anything has become worse due to this self-help tool**? Mark all the alternatives that apply.

❒ Medication
❒ HbA1c
❒ Blood glucose control (average of blood glucose values)
❒ Others (please specify)

71. How useful do you think the self-help tool has been for you to control your diabetes? Mark the place in the scale which describes it the best.

Not useful at all |__|__|__|__|__|__|__| Very useful

72. Do you think that the **self-help tool in total** has been useful for you with regard to the followings? Mark a place that describes the best for each item.					
	Totally agree	Agree	Neither	Disagree	Totally disagree
To measure BG sufficiently often					
To get confirmation about how you conduct self-management					
To understand relationship between blood glucose level and nutrition habits or physical activity					
To reflect (think over) what you have eaten before					
To become more conscious about what to eat					
To become more conscious about how to eat (when and how much)					
To eat more healthily					
To involve family to healthier meals					
To reflect (think over) how physically active the participant has been					
To plan physical activity					
To be motivated to be more physically active					
To be more consicous about daily activity (house holding work, take stairs instead of taking a lift, etc.)					
To learn about yourself as to diabetes					
To focus more on how you conduct self-management of diabetes					
To feel calm and become less worried					
To feel that you do not have a bad consciousness					

Others:

73. In which degree do you agree that the following functions would increase your motivation **to use the self-help tool**? Mark a place that describes the best for each item.					
	Totally agree	Agree	Neither	Disagree	Totally disagree
Reminder for blood glucose measurement					
Reminder for nutrition habit recording					
A wearable physical activity sensor (e.g., step counter, accelerometer)					
Tips that pop up on the mobile phone screen automatically					
Data transfer to general practitioner on regular basis					
Data transfer to general practitioner when the data is alarming					
Feedback delivery on mobile phone from healthcare professionals					
Platform of communication with patient peers for message exchange, data/goal sharing					
Automatic feedback based on measurements and personal medical data					
Use of own mobile phone					

Questionnaire to participants in ”Design study Type 2 Diabetes”

This is a questionnaire to you who have participated in Design study Type 2 Diabetes[1].

The purpose of this questionnaire is to get to know if the self-help tool you have used had any problems with the user interface. In order to develop such tools that can function well for as many people with Type 2 diabetes as possible, it is important that we get feedback from you.

The answers will be handled anonymously. On the left shoulder corner, there is a number. This number is used only for analysis of the result with the usage data of the self-help tool.

Thank you for your help!

- Date

74. How satisfied or unsatisfied are you with the followings of the Diabetes Diary? Mark a place that describes the best for each item.

	Very satisfied	Satisfied	Neither	Unsatisfied	Very unsatisfied
Size of the mobile phone					
Size of display					
Battery life of the mobile phone					
Reaction time of Diabetes Diary					
Button size of Diabetes Diary					
Color use in Diabetes Diary					
Text legibility					
Ease of interpreting blood glucose graph					
Ease of interpreting physical activity graph					
Simplicity of nutrition habit recording					
Ease of interpreting feedback on nutrition habit					
Simplicity of change goals for nutrition habit					
Simplicity of change goals for physical activity					
Simplicity of navigation in Diabetes Diary					

[1] Trial II was named as ”Design study Type 2 Diabetes” in the informed consent.

Appendix 5

Questionnaire for Inquiry 1 and Inquiry 2 (phase 3)

Questionnaire about "tips" and "information search" function (9th June 2009)

At the last user meeting, many of you requested more information under "tips", especially about food, picture of food, GI (Glycaemic Index), calorie, carbohydrates, fat, etc. In addition the following information was also requested; information about physical activity (training, what types of training is good, etc.), blood glucose level, and diabetes in general

We want to improve the tips function by answering to users' request, which means your request. When the function includes much information, we must make it in the way that it can be efficiently used.

Therefore we need more information from you. Please answer to the following questions. If there is anything unclear, please ask one of us.

Date: __________ **Initial:** ___________

1. "Tips" which you **don't** search; What types of information do you want to receive?
   Mark the place which is the most appropriate one for you and also write an alternative regarding how you would like to receive the information:

	Do you want?			HOW? a = At preset time b = When you press "Tips" button c = Another way, please write concisely
	Yes	Neither/ I don't know	No	
General information about Food				
General information about Physical activity				
General information about Sickness				
General information about Blood glucose				
Others				

2. ”Tips/ information” you want to search;
   If you answer ”yes”, please choose appropriate alternatives from the list below about when you want such information.

	Do you want?			WHEN?
	Yes	Neither/ I don't know	No	(see the alternatives below)
General information about Food				
General information about Physical activity				
General information about Sickness				
General information about Blood glucose				
Information to show the others				
Picture of a food item in an amount that contains 10 gram of carbohydrates				
Amount of carbohydrates in a normal portion of a food item				
GI – Glycaemic Index				
Nutrition contents of a food item				
Reference book about diabetes				
Others				

Alternatives for WHEN:

A. When you see ”Blood glucose ” measures
B. When you see ”Stepcount” graph
C. When you see ”Nutrition habit” status
D. When you record nutrition habits
E. When you do grocery shopping, cook, are at a restaurant, etc.
F. Whenever (no special situation, time or place)
G. Other situations (describe consicely)

3. Do you think it would be a good idea if it is possible to book mark tips or information you want to come back to read later?

Yes:____ No: ____ I don't know: ______

4. Do you think it would be a good idea if tips have a link to connect to a web page on Internet where you will find more information?

Yes:____ No: ____ I don't know: ______

5. To search information simply and quickly, how do you want tips/information part of the Diabetes Diary to be organized?

   Which category do you want at the top level? Please choose **four** of the items listed below and put the Post-it at a cell in the top row of the table.

   Then put Post-its of categories you want to have under each category set at the top level, at the second or third row (You don't have to use all the categories and you can use the same category more than once to put different places).

   a. Food
   b. Physical activity
   c. Disease
   d. Diabetes in general
   e. Blood glucose
   f. Information to show others (e.g. acute information, foods that are not recommended to eat)
   g. Picture of a food item in an amount that contains 10 gram of carbohydrates
   h. Glycaemic Index (GI)
   i. Amount of carbohydrates in a normal portion of a food item
   j. Nutrition contents of a food item
   k. Reference book about diabetes
   l. Quiz about diabetes
   m. Bookmarks
   n. List of items in alphabetical order
   o. Search by word with manual typing/writing
   p. Others – write your own category on a Post-it™

Appendix 6

Post-test questionnaire for the usability testing (phase 3)

In the questionnaire, the word "Food Map" is used instead of "Food Browser".

Post-testing questionnaire

Please answer the following questions by marking ”x” in the appropriate box, and by writing freely.

1. Which user interface did you like better than the other? And what is the biggest reason for it?

   ☐ List View ☐ Food Map

   Reason:

2. Which user interface did you think more efficient to search a food item? And what is the biggest reason for it?

   ☐ List View ☐ Food Map

   Reason:

3. Which user interface did you think more efficient to compare nutrition amount among several food items? And what is the biggest reason for it?

   ☐ List View ☐ Food Map

   Reason:

APPENDIX 7

INVITATION TO USABILITY TESTING (PHASE 3)

Invitation to usability testing

Thank you for accepting to be a participant of usability testing of ”Food Browser”.

We are developing food information database, “Food Browser”, as a part of the Few Touch Application, which is a smart-phone based self-help tool for people with Type 2 diabetes. This is because we got feedback from our patient users that they want more information about food.

“Food Browser” contains nutrition information of around 200 food items. This is not a big number, but we assume user interface-design for searching food items and presentation of information would influence usability of the application.

In this usability testing, therefore, we would like to ask you to conduct a certain tasks on two different user interfaces, and assess these two user interfaces by answering questionnaires. We simultaneously measure time to complete each task, in order to compare two user interfaces in terms of efficiency.

This testing is an initial assessment of concepts of the user interface designs, so we will conduct this testing on desktop browser, but not on smart phone.

The tasks are mainly divided into two parts for each user interface: Search tasks and comparison tasks.

Search tasks are for example, to find out how much carbohydrate 100 g of strawberry has.

Comparison tasks are for example, to find out which has the most carbohydrate in 100 g of the following food items: Corn, carrot, or banana.

In the beginning of tasks with each user interface, there will be an explanation and a tutorial, so please do not worry.

The objective of this usability testing is purely assessing usability of the two user interfaces, and not testing your ability, knowledge or skills in conducting tasks.

You have right to quit the testing without any reasons.

The data obtained from testing are going to be handled anonymously and used only for the research purpose.

If you have any questions, please contact to Naoe Tatara (naoe.tatara@telemed.no) .

APPENDIX 8

DESIGN PROFILE FOR THE FEW TOUCH APPLICATION (PHASE 1)

Design profile for FewTouchApplication

ver. 1.0

Naoe Tatara

6/15/2009

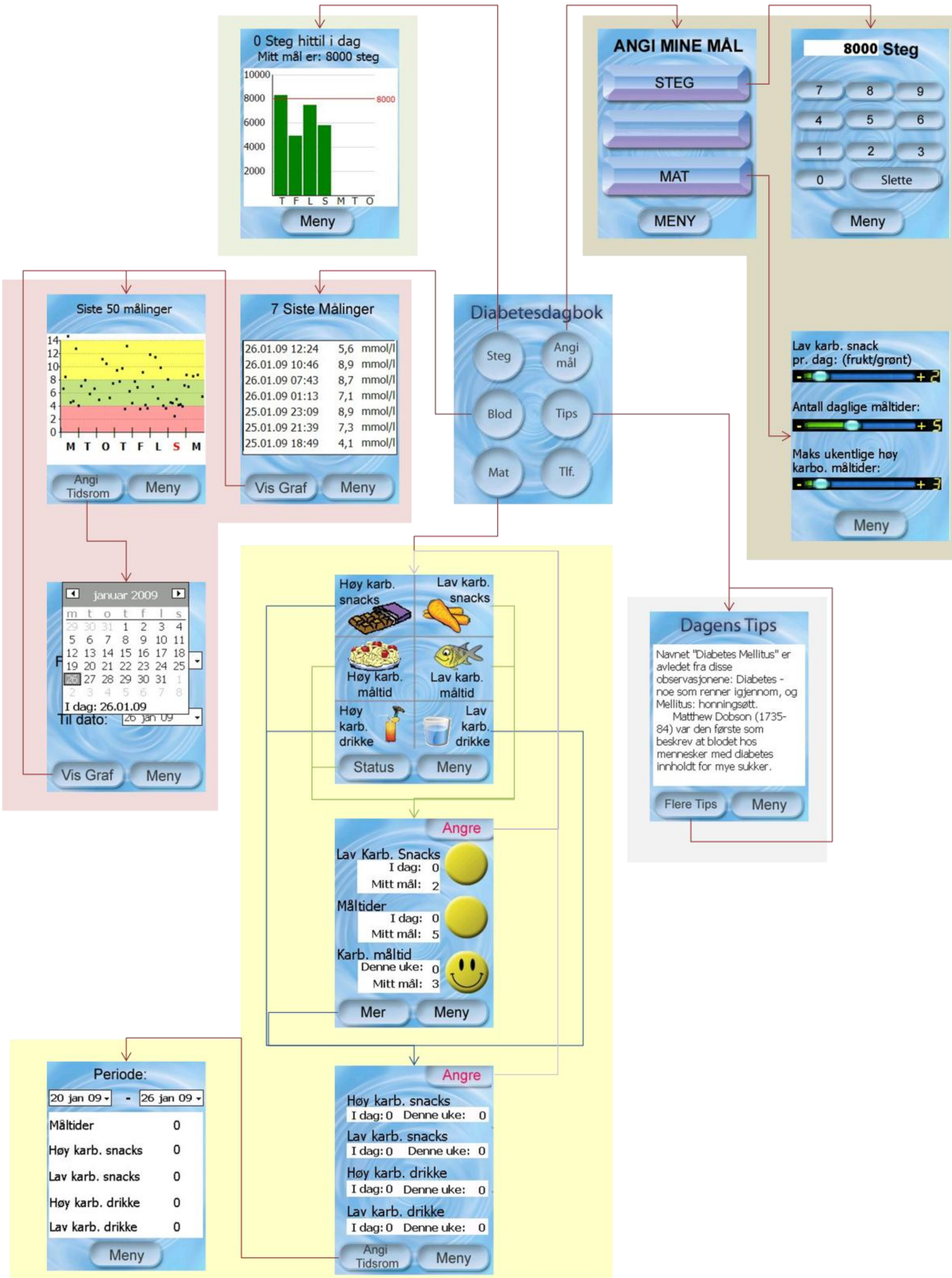
This document describes basic rules to follow in graphical user interface design of FewTouchApplication. The information structure and functions are specified elsewhere, and thus this document basically refers the specifications that are used for the version under user-testing by 12 real-patient users since October 2008.

Preface

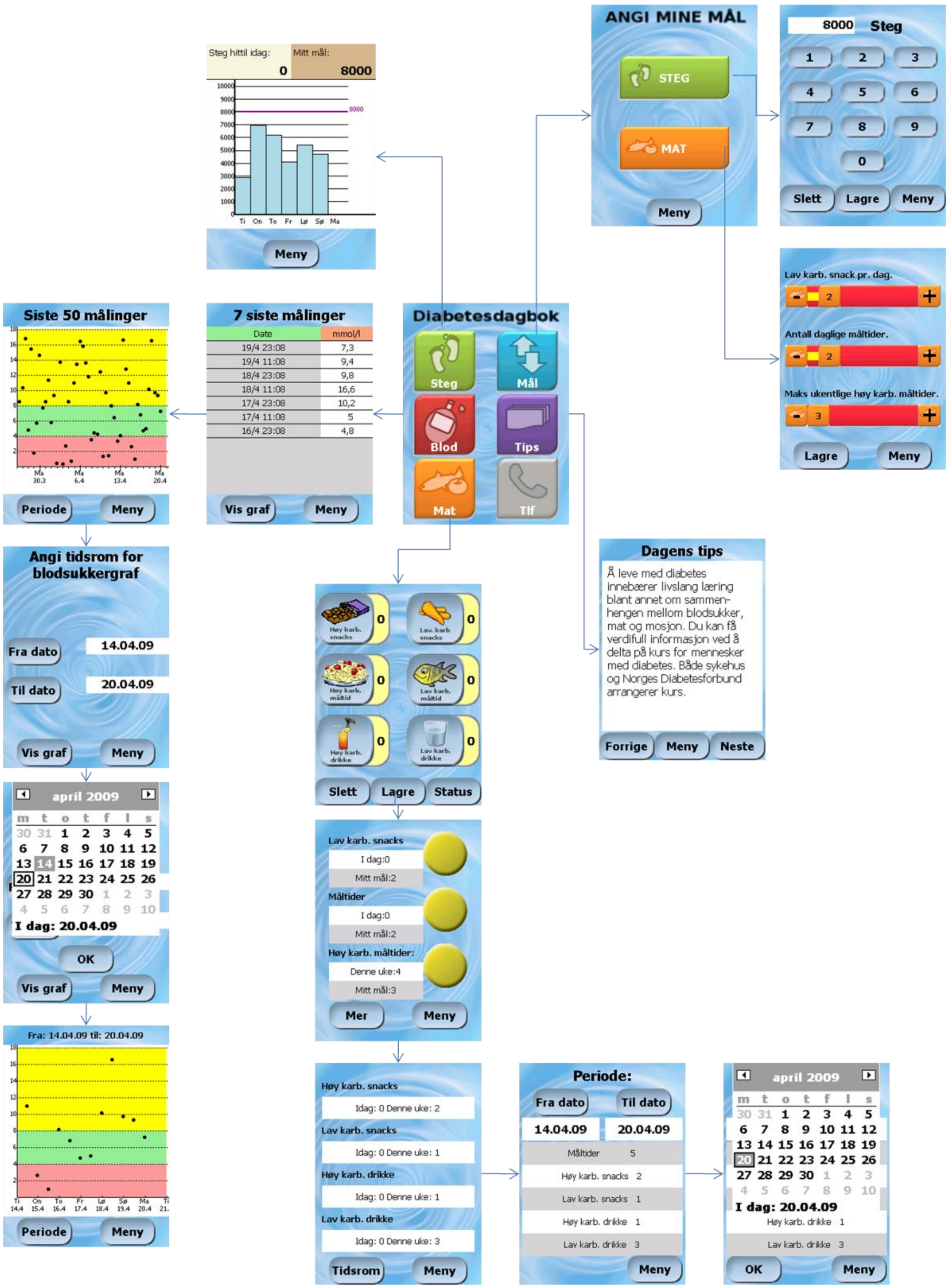
- This design profile gives basic rules to follow in graphical user interface design of FewTouchApplication
- This design profile is based on the version under testing by real patient users from September 2008 and their opinions
- Size of elements, such as buttons and font, are specified in physical length unit, due to variety of mobile phones as terminal.
- Every element is subject to change depending on the change in any requirements

Contents

Screen transition diagram of ver. 1



Screen transition diagram of ver. 2



Color usage (Through application)

Description

- Basic font color is black (exceptions will be identified separately with purposes and reasons) [1]
- Contrast between text and background
  - Color of back ground should keep more than 50% brightness contrast with text [2]
  - Color text letters have 4.5:1 contrast ratio with the background [3]
  - Combination of colors for text and background should be checked with accessibility tool, for example [4] or others introduced in [5, 6]
- For background, use NST's profile color (Pantone 284, 100% of the color still can keep safe contrast between text in black)[7] with gradient
- Colors can be used as secondary aid for
  - distinguishing information
  - identifying and grouping
  - prioritizing

  Therefore information must be delivered by other means (such as text, image, or feature of graphical element) as primary means [1-3]

Rationale

In order to keep high legibility, it is important to keep high contrast between colors of text and back ground. Black is recommended to be used for wider range of lightness of background than white, thus it is more applicable for other design issues.

Given the age of people with Type2 diabetes, consideration for vision characteristics of old age people is necessary.

Rationale for contrast ratio (4.5:1) refers [8]

Background that have soft focus, color gradients, and other distance cues appear to recede behind the more sharply defined content in front of it [9].

Blue is felt to be the color that is least forceful and disturbing because the human eye does not perceive this color so intensively [2].

Supporting material

1. Richard Jackson, Lindsay MacDonald and Ken Freeman, ”Computer Generated Color: A Practical Guide to Presentation and Display” (p. 149, P. 152, p.153)

2. ”Designing for Small Screens” (p. 117, p. 155)

3. W3C ”Web Content Accessibility Guidelines (WCAG) 2.0” Guideline 1.4 (http://www.w3.org/TR/WCAG20/#visual-audio-contrast)

4. “ColorSelector : Fujitsu” (http://www.fujitsu.com/global/accessibility/assistance/cs/)

5. W3C “G18: Ensuring that a contrast ratio of at least 4.5:1 exists between text (and images of text) and background behind the text” (http://www.w3.org/TR/2008/NOTE-WCAG20-TECHS-20081211/G18)

6. W3C “Understanding Success Criterion 1.4.1” Use of Color (http://www.w3.org/TR/UNDERSTANDING-WCAG20/visual-audio-contrast-without-color.html)

7. “Retningslinjer for NSTs grafiske profil” (http://www2.telemed.no/design/nst_profilhandbok_lo_res.pdf)

8. W3C “Understanding Success Criterion 1.4.3” Contrast (Minimum) (http://www.w3.org/TR/UNDERSTANDING-WCAG20/visual-audio-contrast-contrast.html)

9. “Designing Interfaces” (p. 291)

Navigation (Through application)

Description

- Except top page, set navigation area at:
    - the bottom area (from bottom line to 7mm high above) for portrait orientation
    - the right area (from right edge to 10mm left) for landscape orientation
- Place ”Menu” button as always as possible
    - It should be always at
        - right most for portrait orientation
        - top most for landscape orientation
- Place ”Back” button where is deeper than one step from top page as always as possible
    - It should be always at
        - left most for portrait orientation
        - bottom for landscape orientation
- Place ”Cancel” (=Undo) button that set the changed values back to the original values (not “default” but the values before any value changing operation is done) where user can enter values

Rationale

In order to minimize time and steps (screen transition, button press) to use on application and to make it easy to navigate from one category to another and to end using application, every page should have “Menu” button to go back to the top page of the application, unless unavoidable cases or special purpose. [1]

For the same purpose, every screen that is deeper than 2nd level of depth from top page should have “Back” button, unless unavoidable cases or special purpose.

In addition to the same purposes above, in order to provide a user a control locus and easy reversal of actions, “Cancel” button should be where a user can enter data or set values. [2]

When the device allows both orientations (portrait / landscape), first of all, ergonomics needs to be considered. For ensuring easy operation, the application should be operated by only one hand and by thumb. Secondly, the amount of information should be kept regardless orientation of screen. Therefore, it needs to be avoided that the changing orientation makes it impossible to place texts and/or values in the same font size. Lastly, distortion of contents may influence different look and feel, which is against the principle of consistency.

Supporting material

1. J Gong, P Tarasewich, “Guidelines for handheld mobile device interface design“ DSI 2004 (http://www.ccs.neu.edu/home/tarase/GuidelinesGongTarase.pdf)

2. Ben Schneiderman, Catherine Plaisant, “Designing The User Interface” (p. 75)

Buttons (Through application)

Description

- Buttons should keep width at least more than 10 mm [1-3], and height at least 7 mm unless unavoidable case or special purpose
- Every corner of a button should be rounded with a small radius (as default, 1 mm) so that the longest label on buttons can be afforded in the button area without wrapping text
- Buttons should look clickable [4]
- Buttons should have different brightness, or/and saturation, or/and color hue from background
- Buttons that are at same level of meaning, function, or hierarchy should have a certain degree of consistency in outlook
    - Buttons in navigation area (for basic page transition)
    - Functional buttons (for changing, entering values, etc.)
- Place buttons with same function at same place through the application
    - On the device that allows changing orientation (portrait / landscape), keep this consistency within the same orientation
- Keep consistency in button positioning for buttons with same meaning at certain degree through the application, considering consistency with conceptual model in real life and OS where applicable and appropriate
    - Left (low, minus, old)
    - Right (high, plus, new)
- Buttons will be made by Niklas

Rationale

For enhancing accuracy and efficiency of navigation at the same time, button size should be large enough but not too large so that the small screen can afford necessary number of buttons. [3] recommends 15 x 15mm as a smallest size for buttons on touch screen, whereas [1,2] shows results of high enough (95%)accuracy with 9.2 mm and 11.5 mm respectively by young subjects.

Consistency is one of the most important design principles [5-7]. Consistency of positioning buttons with users' conceptual model enhances discoverability, and aesthetic integrity increases usability [8].

The low of similarity maintains that elements with similar properties are perceived as belonging to a group or unit [3].

Supporting material

1. Pekka Parhi, Amy K. Karlson and Benjamin B. Bederson , “Target Size Study for One-Handed Thumb Use on Small Touchscreen Devices” Mobile HCI 2006
2. Keith B. Perry and Juan Pablo Hourcade “Evaluating One Handed Thumb Tapping on Mobile Touchscreen Device” Graphics Interface 2008
3. ”Designing for Small Screens” (p.127, p. 140)
4. Scott Weiss “handheld usability” (p. 70)
5. Ben Schneiderman, Catherine Plaisant, “Designing The User Interface” (p. 74)
6. Enrico Bertini, et al “Appropriating Heuristic Evaluation Methods for Mobile Computing” Handbook of Research on User Interface Design and Evaluation for Mobile Technology
7. J Gong, P Tarasewich, “Guidelines for handheld mobile device interface design“ DSI 2004 (http://www.ccs.neu.edu/home/tarase/GuidelinesGongTarase.pdf)
8. Apple Inc. “Human Interface Design Principles” Chapter 3 (http://developer.apple.com/documentation/userexperience/Conceptual/AppleHIGuidelines/XHIGIntro/XHIGIntro.html)

Font (Through application)

Description

- Font size for contents should keep the largest size(size on screen is about 2 x 2 mm) that is offered at “Settings>System>Screen>Text size”, and the second largest size (size on screen is 1.5 x 1.5 mm) at least when unavoidable

- Title of a page should be distinctive from contents

    - Font size for title of a page should be basically two size larger and at least one size larger than the font size used for contents [1]

- Font type should be consistent with the default font type of the device

Rationale

Considering the results of usability questionnaire by 12 real-patient users that used the FewTouchApplication for 6 months since October 2008, they were satisfied with text legibility on the application. The smallest size used in the application should be kept at least in order not to reduce legibility.

Other descriptions are supported by principles of consistency and discoverability.

Supporting material

1. “Designing Interfaces” (p. 107)

Margin (Through application)

Description

- Margin on right/left side should keep at least more that the width of the font used unless unavoidable case or special purpose
- Margin on right/left side should not be unnecessarily too large

Rationale

In order to make it easy to perceive corresponding items or units with a common meaning as they are meant, the elements should be placed considering proximity [1].

Supporting material

1. ”Designing for Small Screens” (p. 140)

Calendar (Through application)

Description

- Calendar should appear with "OK" button
- The "OK" button should be included in the (looking) same area with calendar
- Calendar area
    - Background color: white
    - Borderline: bold (eg. 3px), dark gray (eg. R127, G127, B127; easily distinctive color from the page where the calendar show up)

Rationale

Following to the law of proximity, the "OK" button that attributes to calendar should be close to the calendar [1]. (Preferably in the same area that enhance the perception of proximity)

Following to the law of figure / ground states, where there is overlap between elements, the foreground should be brighter and the area should be clearly separated [1].

Supporting material

1. "Designing for Small Screens" (p.140, p. 142)

Table and Graph (Through application)

Description

- Tables
    - Tables should have same width unless there is no elements beside a table
    - Width of tables should be decided by the one that is the widest through the application
    - Tables should have same row height
- Graph
    - Background color of graph area: white
    - Graph area should use whole width of the screen

Rationale

Following to the law of proximity, corresponding items should be placed as close as possible. On the other hand, it is also important to keep consistency in outlook of the same graphical design element. Therefore, Width and row height of tables should be kept same whereas keeping proximity as much as possible [1].

Graphs may have many data points and labels to show the values of gridlines. Therefore, in order to keep legibility, the area of screen should be fully used [1].

Supporting material

1. ”Designing for Small Screens” (p.140)

Top page

Description

- Use icons that satisfy following features
    - With illustrations that express the corresponding function well
    - With same degree of abstraction for every icon
    - With the text explanation
    - Size of 15 x 15 mm or bigger
    - Without using color coding
- The icons will be made by Niklas.

Rationale

For the top level of the hierarchy, icons are recommended to be used for enhancing easy and quick operation [1].

The icons should have a perceptual immediacy that allows it to be recognized at a glance [2]

To avoid confusing a user and to achieve visual consistency, the icons used should have same degree of abstraction [1, 2].

For satisfying accessibility, the contrast between text and basic background color used in icons are checked by color check tool [3].

The colors used for labeling icons should be associative with conceptual model [4,5].

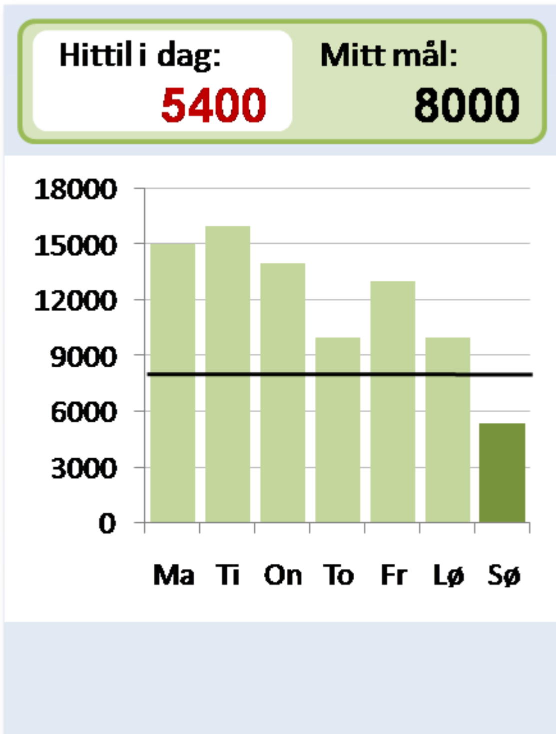
Supporting materials

1. ”Designing for Small Screens” (p.125, p. 124)
2. Kevin Mullet, Darrel Sano, “Designing Visual Interfaces” (p. 175)
3. “ColorSelector : Fujitsu” (http://www.fujitsu.com/global/accessibility/assistance/cs/)
4. Richard Jackson, Lindsay MacDonald and Ken Freeman, ”Computer Generated Color: A Practical Guide to Presentation and Display” (p. 172)
5. Jean Bourges “Color Bytes: Blending the Art and Science of Color” (pp. 20-71)

"Steg"

Description

- See the image below. (background image should be replaced by a new one)



- Title area: "Hittil i dag" (black, one size larger than font size used for contents, on top, left aligned) and the number of steps for "Hittil i dag" (Dark red (R192, G0, B0), three size larger than font size used for contents, at bottom, right aligned) is shown in a white box with round corners, that is inside and left side of a larger light green (R:215, G228, B189) box with round corners and green outline (R155, G187, B89). And "Mitt mål" (Black, one size larger than font size used for contents, on top, left aligned) and the number of steps for "Mitt mål" (Black, three size larger than font size used for contents, at bottom, right aligned) are located on the right side in the light green box.

- Use bar graph to show the data for the last 7 days

  - Width of data points (bars) should keep 80% of the corresponding area (between grid lines on X-axis) and the bars should be centralized.

  - Data points for "today": use darker color than the other 6 days (R119, G147, B60)

  - Data points for the other 6 days: use brighter color than "today" (R195, G214, B155)

  - Gridlines for Y-axis: use bright gray (R191, G191, B191) in thin line width (1px)

- Goal line: use black bolder line width than gridlines (2px)

Rationale

The number of steps for “Hittil I dag” is the most important information on this screen, and it should be clearly distinctive and eye catching. On the other hand, the number of steps for “Hittil I dag” should be comparable with the number of steps for “Mitt mål”. Therefore, the two numbers should be in same font size and in different color. As the basic color for the text is black, the number for “Hittil I dag” should be in dark red, which is the color that draws attention [1].

As the numbers for “Hittil I dag” and “Mitt mål” are in the same level of concept, which is “the number of steps”, they should be grouped and the number of steps for “Hittil I dag” and its title should be highlighted. Therefore, “Hittil I dag” and the number of steps for it should be in a white box inside a light green box that afford both “Hittil I dag” and “Mitt mål”.

In order to keep consistency, the goal line should be drawn in black, which is the same color for the number of steps for “Mitt mål”, and in bolder line to be distinctive clearly from the gridlines.

In order to make it easy to understand the values that the bars express, gridlines for Y-axis should be seen. Therefore, the data points (bars) should have gap between them. And in order to reduce unnecessary information, data points (bars) should not have outlines.

Supporting materials

1. Jean Bourges, ”Color Bytes” (p.38)

"Blod" – "7 siste målinger"

Description

- Use table
    - For header row ("Dato og tid" and "mmol/l")
        - Background color: bright gray (R191, G191, B191)
        - Font: bold, black, and same size as the contents
        - Positioning of text: centralized
    - For data rows
        - Background color: white
        - Positioning of values:
            - Date and time: centralized
            - Blood glucose values: right aligned
        - Format of values:
            - Date and time: "dd.mm.yy hh:mm" (show every value, even if it is 0)
            - Blood glucose values: "x,y" (show the first decimal, even if it is 0)
    - For grid line, use darker gray than the background color of heading row (R127, G127, B127)
    - Column width should be adjusted so that the column for the blood glucose values has the minimum width that can be set considering necessary margin for header (mmol/l) part

Rationale

Important information should have high contrast, and heading and values should be distinctive. In this screen, the measurement data are more important than headers, so the header rows should have gray back ground, which has no meaning than make this row distinctive from the data rows. And as another way to make header distinctive from data row, the font for header should be bold.

Position of the same digit should be aligned across rows in order to make it easy to understand the information and compare values. For the same reason, the date and time should be expressed in the way that the values for same meaning (day, month, year, hour, and minute) are aligned across rows.

"Blod" – "Siste 50 målinger"

Description

- Background color of graph:
    - Zone 0 mmol/l – 4 mmol/l: R255, G153, B153
    - Zone 4 mmol/l – 8 mmol/l: R198, G227, B125
    - Zone 8 mmol/l – : R254, G255, B91
- Graph type: scatter without connection
- Data point:
    - Color: black
- Gridline:
    - Use dash thin (1px) line
    - Color: black

Rationale

Same for the ones mentioned in "Color".

“Blod” – “Angi tidsrom for blodsukkergraf”

Description

- Positioning:
    - “Fra dato” : left side
    - “Til dato” : right side
    - Buttons are above white box showing date
- Format of date should be “dd.mm.yy”
- Outlook of buttons for “Fra dato” and “Til dato” should be differentiated from the buttons in navigation area

Rationale

Button height is less than width, so in order to ensure accuracy and following to the conceptual model and consistency with the same function in “Mat” function, the positioning of “Fra dato” and “Til dato” should be left and right.

“Mat” – Status page with smiley feedback (second depth from top page)

Description

- See the image below (background image and buttons should be replaced by a new one)

- Use tables to show the data for each category
  - Background color of rows:
    - “I dag” and corresponding values: white
    - “Mitt mål” and corresponding values: light green (R:215, G228, B189)
  - No outline or border line should be used
- Positioning:
  - Label for each table : closer to the corresponding table than the one above (bottom aligned)
  - “I dag” and “Mitt mål” : right aligned
  - Values (numbers for “I dag” and “Mitt mål”): right aligned

- Smiley and blank smiley: bottom aligned with a corresponding table, with a margin between the table and the smiley in approximately same amount as the margin between values and edges of a table

Rationale

In order to make it easier to perceive corresponding elements (label for table, table, smiley for it) as a group, they should be placed more closely than to the other elements, according to the law of proximity.

To keep a certain level of consistency with “Steg” screen, which has the same concept showing values for the day against goal, the background color combination should also be same.

In order to make it easier to compare the values for “I dag” against the values for “Mitt mål”, the values should be right aligned.

“Mat” – Status page for snacks and drinks (third depth from top page)

Description

- See the image below (background image and buttons should be replaced by a new one)

- Use tables to show the data for each category
  - Background color of rows:
    - “I dag” and corresponding values: white
    - “Denne uke” and corresponding values: bright gray (R191, G191, B191)
  - No outline or border line should be used
- Positioning:
  - Label for each table : closer to the corresponding table than the one above (bottom aligned)
  - “I dag” and “Denne uke” : right aligned
  - Values (numbers for “I dag” and “Denne uke”): right aligned

Rationale

In order to make it easier to perceive corresponding elements as a group, they should be placed more closely than to the other elements, according to the law of proximity.

In order to differentiate the values for “I dag” and values for “Denne uke”, use different background color for the cells. The values and label “I dag” use white background through this application, therefore the background color for “I dag” should follow this. For “Denne uke”, use bright gray since gray itself has no meaning for it.

“Mat” – Status page for snacks and drinks (fourth depth from top page)

Description

- See the image below (background image and buttons should be replaced by a new one)

- Use tables to show the data for each category
  - Background color of rows: white
  - For grid line, use darker gray (R127, G127, B127)
  - Right aligned

Rationale

The values shown on this screen are all total number of registered food habit during the set period, and not the purpose is not compare values for the same category (like “I dag” against “Mitt mål” or “I dag” against “Denne uke”). Therefore, each line should be shown equally in outlook and same background color should be used. The values can be different according to the period set; therefore the background color should be white.

In order to make it easy to see each line, the table should use grid line. Grid line should not have the same strength in outlook as the header (category name) or values, therefore, the color of grid line should be brighter than black.

“Mål” – “Steg”

Description

- Use numerical buttons (0 - 9), “c” (clear) button, and “standard” button
- The order of numerical buttons should be same as the physical numerical keys of the mobile terminal(top row 1, 2, 3, middle row 4, 5, 6, and bottom row “c”, 0, “standard”)
- Background color for the number of steps set is white

Rationale

The numerical keys on a device that is supposed to be operated by a thumb are arranged from top left to bottom right (such as mobile phone, remote controller of TV). This application is supposed to be operated by a thumb, and in order to keep consistency between the key arrangement of the mobile terminal, the numerical buttons should follow the “top left to bottom right arrangement”.

“c” button is widely known as “clear” by general calculator.

According to the results of 5th user meeting in March 2009, the default values for goal should be given.

“Mål” – “Mat”

Description

- See the image below (background image and buttons should be replaced by a new one)

- Use “+” “-“ buttons, and “standard” button for each item

Rationale

The values for these goals will not be big number like steps, and the change in values will not be so big either considering the meaning of each item. By having standard buttons following user needs from the 5th user meeting in March 2009, “+” and “-“ buttons will be enough for setting values.

“Tips”

Description

- Title should be “(the name of category) tips”
- Heading and contents of tips should be in white box
  - The width of the white box: 4 px (2px on both left and right side) less than screen width
    - Can it be whole width as same as graphs? By the concept of maximize available area in the small screen
  - The height of the white box: 2px above from the navigation button area to the 2 px below the title area
- Color of heading: red (R255, G0, B0)
- Size of white box for heading and contents should be kept same through the all tips
- “Forrige” and “Neste” button should have left and right arrow texture as background of the text in light color respectively

Rationale

In order for the user to understand what the content of tips is about immediately, title should have category name of the tips and heading should be saliently shown.

Arrow is generally used symbol to express “go (right arrow)” and “back (left arrow)”, therefore by including the texture of the arrows on buttons, it can be easier to perceive the role of buttons.

APPENDIX 9

DESIGN GUIDELINE FOR THE FEW TOUCH APPLICATION (PHASE 1)

Design guideline for ”FewTouch Application”

2. Sep 2010 Ver. 0.2

Naoe Tatara

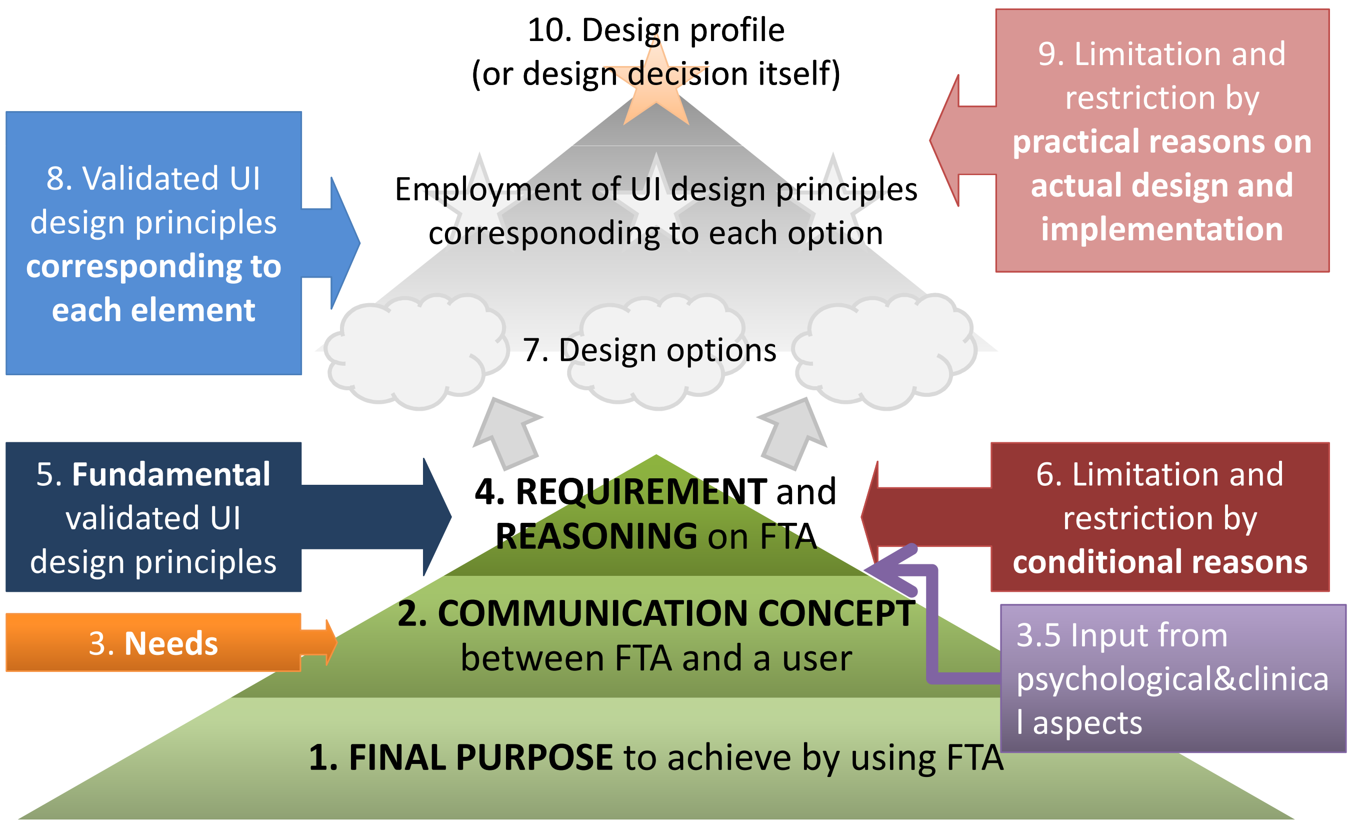
Version

version	date	description
0.1	5 Mai 09	The first draft based on discussion with Niklas and Eirik
0.1.1	14 Mai 09	Addition of minimum re-design part
0.2	2 Sep 10	Change in the concept diagram and some important parts

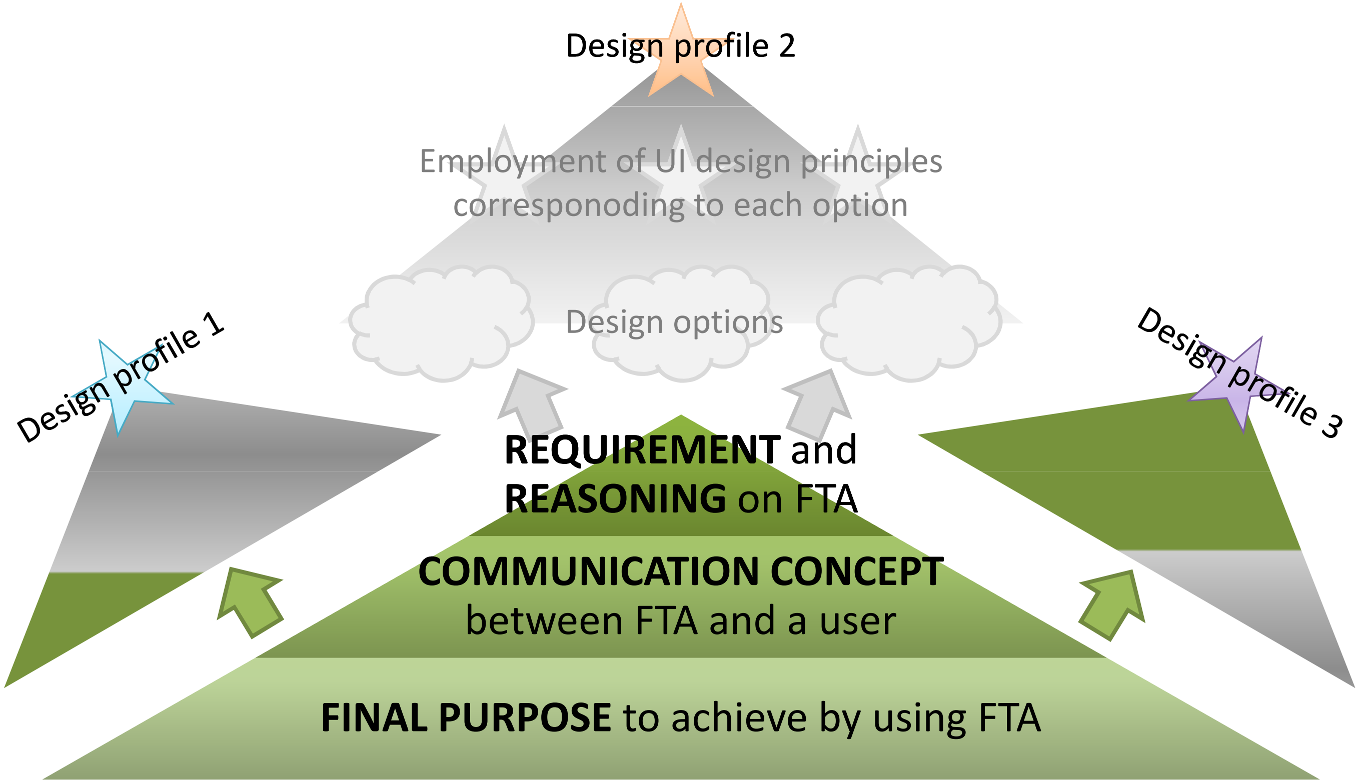
Purpose of design guideline

- To build a solid foundation that design of the ”FewTouch Application” (later than this, simply called ”FTA”) is based on
- To give information about validated principles in user interface (UI) design taking characteristics of target population into consideration
- To know limitations and restrictions by practical reasons
- Based on these above, to make definitive general/specific design profile that the actual design of FTA can refer as a rule

Concept diagram of design guideline



Practical way of design guideline is made



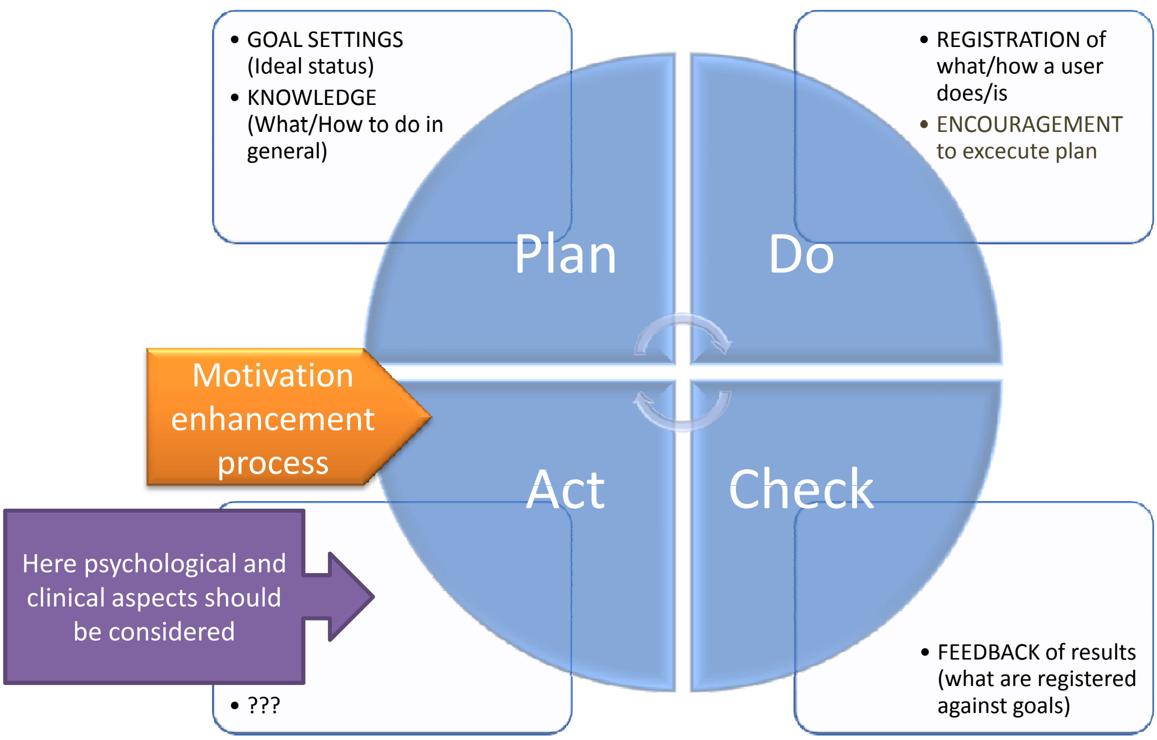
1. Final Purpose

1. Good health
2. Success in self-management of diabetes
3. Improvement in lifestyle
   - Eat food in healthy way
     - Know what is healthy/unhealthy food for a user and understand why
     - Know what is healthy way to eat and understand why
     - Know the influence of what/how to eat on user’s health condition and understand why
   - Be active enough in appropriate way
     - Know what/how to do in order to ”be active” and understand why
     - Know the level of ”enough” of activeness for a user and understand why
     - Know the influence of activeness (or even the way to be active) on user’s health condition and understand why

2. Communication concept (definitive assumption)

- Motivate a user to improve life style
- Help a user to take "PDCA (Plan, Do, Check, and Act) cycle" in self-management
- Let a user to gain and/or enhance self-efficacy in self-management
- Let a user use FTA in a way they like

PDCA cycle and what FTA helps (functions)



3. Needs for characteristics

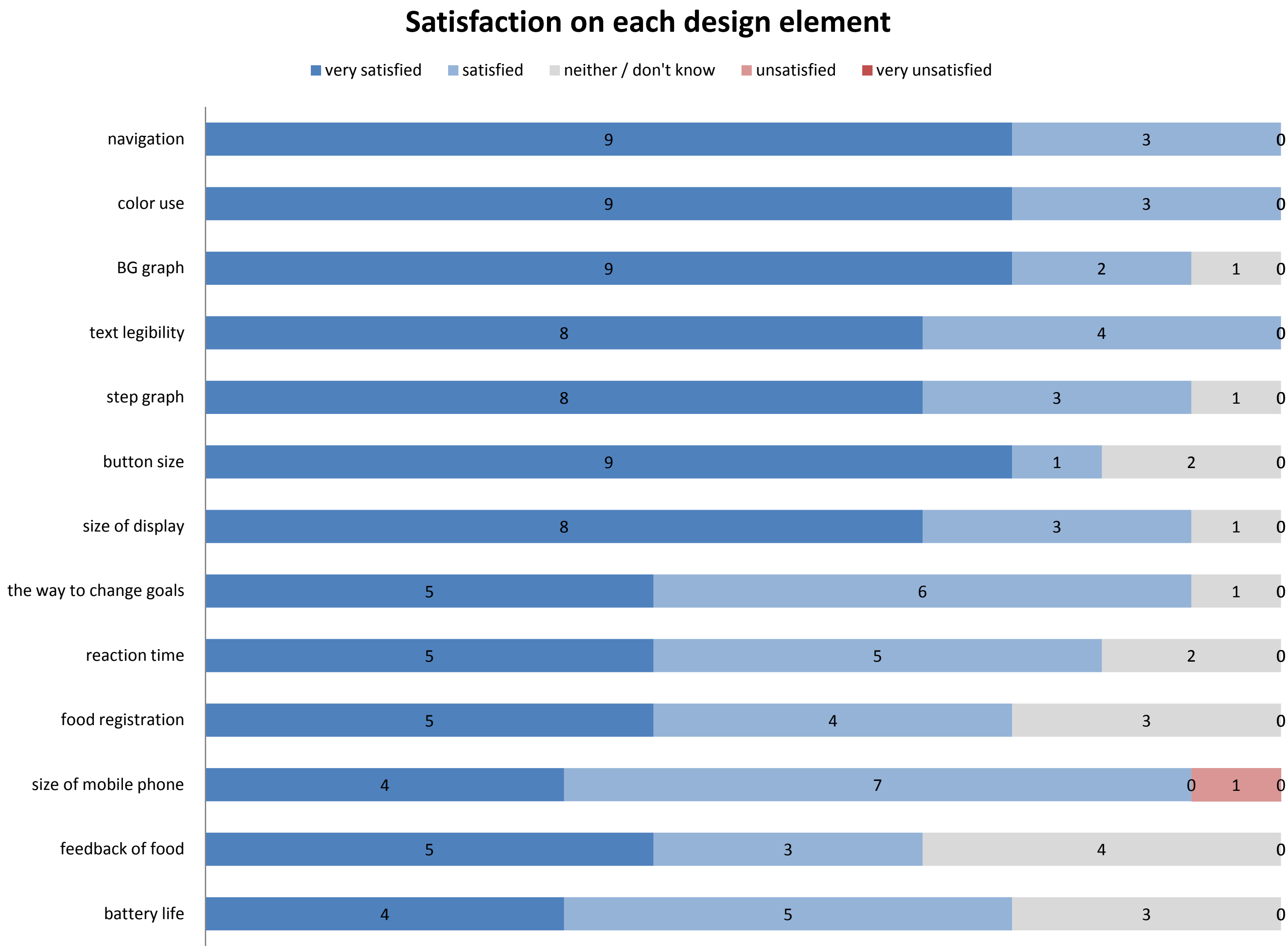
According to users' opinions and the review of other relevant studies...

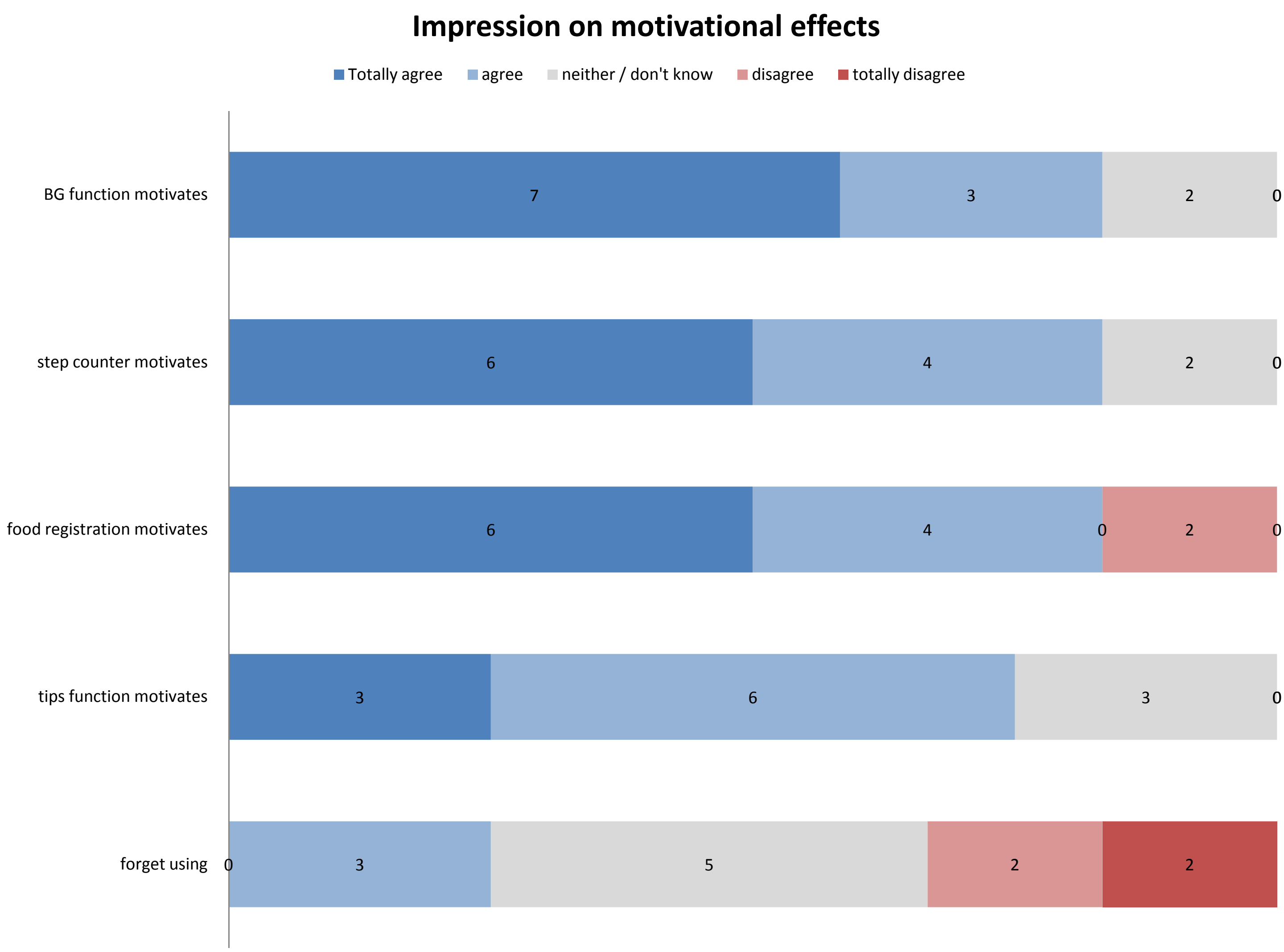
- Attractive
- Exciting
- Intuitive
- Informative (rich)
- Clear (meaning)
- Accurate
- Error less
- Easy
- Quick
- Unobtrusive
- Automatic
- Flexible
- Modest (user should have control)
- Active (attention-grabbing)
- Interesting
- Useful

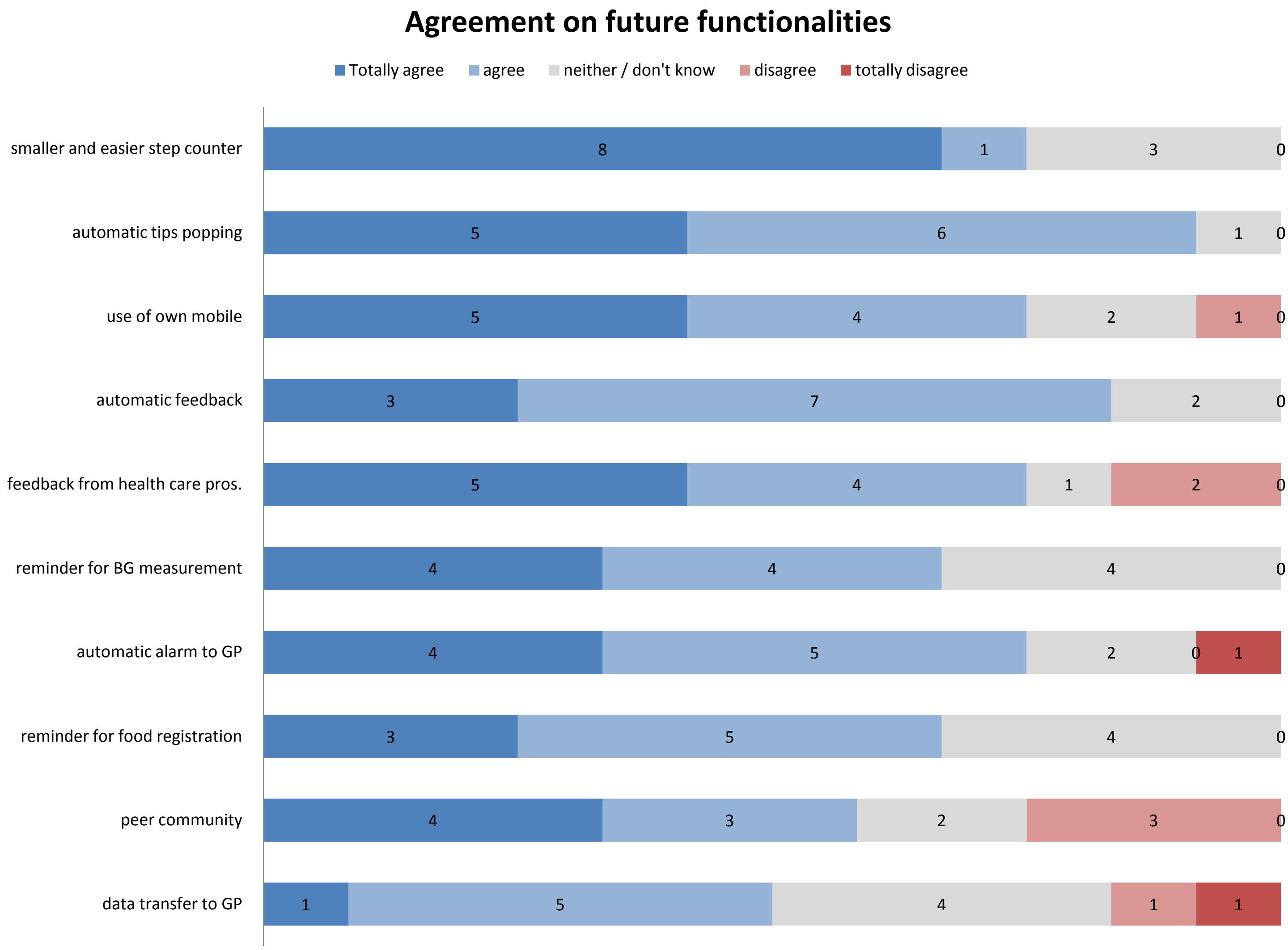
3. Needs for functions in addition/instead

According to users' opinions and the review of other relevant studies...

- GOAL SETTING
  - General recommendation and individual setting
  - Goal for total achievement
- KNOWLEDGE BASE
  - Access to what a user needs
    - Categorized structure, pictures, values (GI)
  - Pointer for richer knowledgebase
  - Timely popping up as a reminder
  - Calculator of glycemic load of food
- REGISTRATION (food habit, activity, and BG values)
  - More than one registration (category, number) at a time (for food) Done already
  - More category/level for food registration
  - Registration of fasting blood glucose
- FEEDBACK (food habit, activity, BG values, and total)
  - Visual or numerical feedback for total or relationship between Food, activity and BG level
  - Calorie intake/consumption
  - Message about food consumption (as caution alarm)
  - Displaying steps for more than a week
  - (Display on a step counter)
- ENCOURAGEMENT
  - Trigger for an actual execution of plan


Satisfaction on each design element
very satisfied
satisfied
neither / don't know
unsatisfied
very unsatisfied
navigation 9 3 0
color use 9 3 0
BG graph 9 2 1 0
text legibility 8 4 0
step graph 8 3 1 0
button size 9 1 2 0
size of display 8 3 1 0
the way to change goals 5 6 1 0
reaction time 5 5 2 0
food registration 5 4 3 0
size of mobile phone 4 7 0 1 0
feedback of food 5 3 4 0
battery life 4 5 3 0


Impression on motivational effects
Totally agree
agree
neither / don't know
disagree
totally disagree
BG function motivates 7 3 2 0
step counter motivates 6 4 2 0
food registration motivates 6 4 0 2 0
tips function motivates 3 6 3 0
forget using 0 3 5 2 2



4. Detailed requirement on total system

- Menu structure
  - Requires as few touches as possible through total use (efficient and effective use)
  - Allow users to go back and to cancel actions

  [discussing points]

  - Grouping (hierarchy) concept in context of use
- Others

4. Detailed requirement on each function

- Goal setting
- Food habit
  - Communication Concepts are : Help users to eat
    - more fruits and vegetables
    - less high carbohydrate foods
    - by more times than fewer times
- Steps
- BG measurement
- Tips
- Others

4. Reasoning

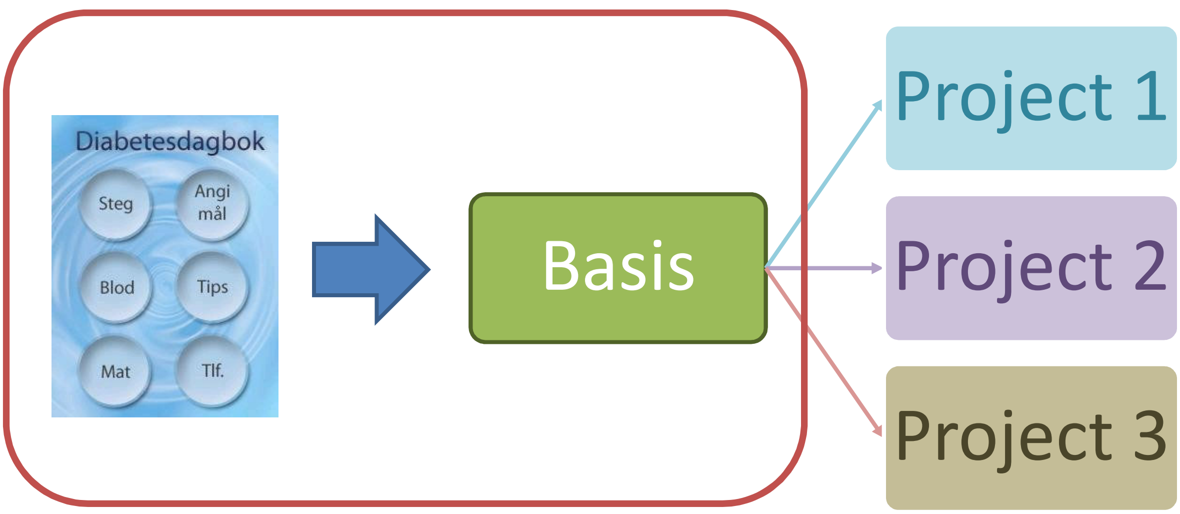
- Target population (User profile): People with Type2 diabetes (or Type1, or prevention of Type2?)
  - Age (middle age ~ elderly)
    - Vision (eyesight, color weakness)
    - Dexterity
    - Hearing ability
  - Social aspects
    - Job
    - Family
  - Other diseases (which might influence on diabetes self-management or technical aspects of application)
  - Education and knowledge
  - Technical skills and experiences
  - Experiences of other means for the same purpose
  - Psychological aspects
- Context in use
- Validated knowledge (in general, other relevant studies) in Type2 diabetes
- Users' opinions based on experience of FTA

5. Fundamental validated UI design principels

1. Keep consistency with: itself (regardless device, especially for control parts), platform (the application is on), users' expectation (mental model), and real world
2. Cater to universal usability. (Use only compatible colours with colour weakness, prepare alternative modality for input/output)
3. Be customizable by users. (Allow for personalization)
4. Provide useful, informative and precise feedback.
5. Prevent , manage, and recover from errors.
6. Permit easy reversal of actions.
7. Support internal locus of control.
8. Reduce short-term memory load. (Be discoverable)
9. Provide a clear navigation model.
10. Use familiar language.
11. Make information entry easy. (select > text input)
12. Display information clearly and legible.
13. Use obvious metaphors, explicit and implied actions (inc. direct manipulation)
14. Design for limited and split attention.
15. Design for speed and recovery.
16. Design for top-down interaction (higher level of information first, lower level by users' decision).
17. Design for enjoyment (inc. aesthetic), privacy, and social conventions
18. Provide help.
19. Keep design as simple as possible.
20. Make system status visible.
21. Take ergonomics into consideration.
22. Design for usability (effectiveness (completeness and accuracy), efficiency, and satisfaction) *not clearly mentioned anywhare

6. Limitation and restriction by conditional reasons

- Need to preserve the version used in 6-month testing as much as possible?
- Others?



Agreed (130509)

As minimum re-design

- As a basis of FTA design, the design of the version used for 6-month user test (later on, this version is called ”ver. 1”) should keep its design as much as possible
- The minimum re-design should be based on
  A. User needs
  B. Fundamental validated UI design principles
- Priority for re-design should be considered as
  1. A and B
  2. A but not B
  3. B but not A
- As this is ”minimum” re-design, basic requirements on each function or total structure should keep as they are on ver. 1, unless there are fatal design flaws.

Agreed (130509)

4. Detailed requirement on total system

”Specifications for the total diabetes system 2008- Type 2 diabetes”

- The user should use as few touch as possible to reach each functionality, using the finger (i.e. not needing to use the stylus).
  - Should be kept basically, but frequency of access to each function (screen) should be considered.
  - Ref 1: Button size should keep 15 mm width (and hight, if there are other buttons above or below) and the distances between buttons should keep 5 mm at least. (”Designing for small screens”, 2005)
  - Ref 2: Button size should not be less than 9.2 mm for discrete tasks, according to the error ratio by 20 subjects aged 19-40 (”Target Size Study for One-Handed Thumb Use on Small Touchscreen Devices”, 2006)
- “One day” (from 0:00-24:00) and “one week” (last 7 days including today) shall be the two ~~main~~ basic overview periods for the patient.
  - Should be customizable by a user (according to design principle 3)
- Present the data as visual feedbacks without any interpretations.
- Shall be possibly to search for a specified period to display data for.
  - The way for changing period should be consistent through the system

Additional requirements

- Font size should be as same as the minimum size (capital 2x2 mm) used in ver. 1 at least
  - According to the results from usability questionnaire at 5th user meeting, all users are satisfied with the text legibility of ver. 1.
- All screens should basically have a “menu” button and a “back/cancel” button discretely (design principle 6)
- Colour use should be examined by colour-check tools (design principle 2)

4. Detailed requirement: Tips

- Richer contents, especially
  1. food relevant contents (with glycemic index, pictures)
  2. activity relevant contents
- Both categorized structure and ”popping-up” random tips
  – Category (number at a level and depth) needs to be discussed and decided
  – Screen design and navigation on this function should be accordingly decided
- ✘ The following needs by users should be discussed for inclusion as requirements
  – Pointer for richer knowledgebase
  – Timely popping up as a reminder
  – Calculator of glycemic load of food
- If the change above is impossible,
  – At least each tips screen should have ”back” button in addition to ”next” (have been already solved technically) (according to design principle 6)
  – Should have headings (ex. category, keyword) in a larger font so that a user can judge if the information is what she/he needs or not more quickly (according to design principle 12, 15, 16)
  – Colour scheme can be used accordingly but should not be the primary solution instead

✘ Basically, ignore for minimum re-design

4. Detailed requirement: Steps

- ✘ Excerpts from ”Specifications for the total diabetes system 2008- Type 2 diabetes”
  – As a first version, data should be transferred at 22:00 each day. I.e. the Aim functionality for the step count transfer time does not need to be implemented.
  – Even if it is impossible to change the data-transfer time by a user, the step counter should send the step count at 0:00 and the application should calculate the possibly most accurate number by a day (according to the detailed requirement for total system, and log files showing some users manually transferred data after 22:00)
- ✘ The following needs by users should be discussed for inclusion as requirements
  – Enabling to show more data than a week
    - By a graph?
    - By a number?

✘ Basically, ignore for minimum re-design

Agreed (130509)

4. Detailed requirement: Goal settings

- Goals should have default (recommended by general knowledge) values and can be set for individual manually (currently done in this way)

From the 5th user meeting,

- Users are satisfied with ”The way to change goals”
- However, few of users changed their goal

Followings should be discussed

- Necessity for the goal setting function to be at top level of menu and separately from each function

Technically possible
Partly already done in one version that Thomas has implemented

7. Design options

- Total system
- Each function
  – Goal setting
  – Food habit
  – Steps
  – BG measurement
  – Tips
  – Others

8. Validated UI design principles

- Basically, only corresponding detailed principles should be referred on each requirement
- After implementation, heuristic evaluation with a check list for design flaws should be conducted for double checking

9. Limitation and restriction by practical reasons

- Usage of windows mobile based mobile phone (HTC dual, SAMSUNG, others?)
  - Display size, aspect ratio, resolusion
  - Others?
- Others?

10. Profile as basic rules

- General profile applied through FTA
- Specific profile for each function (and screen)

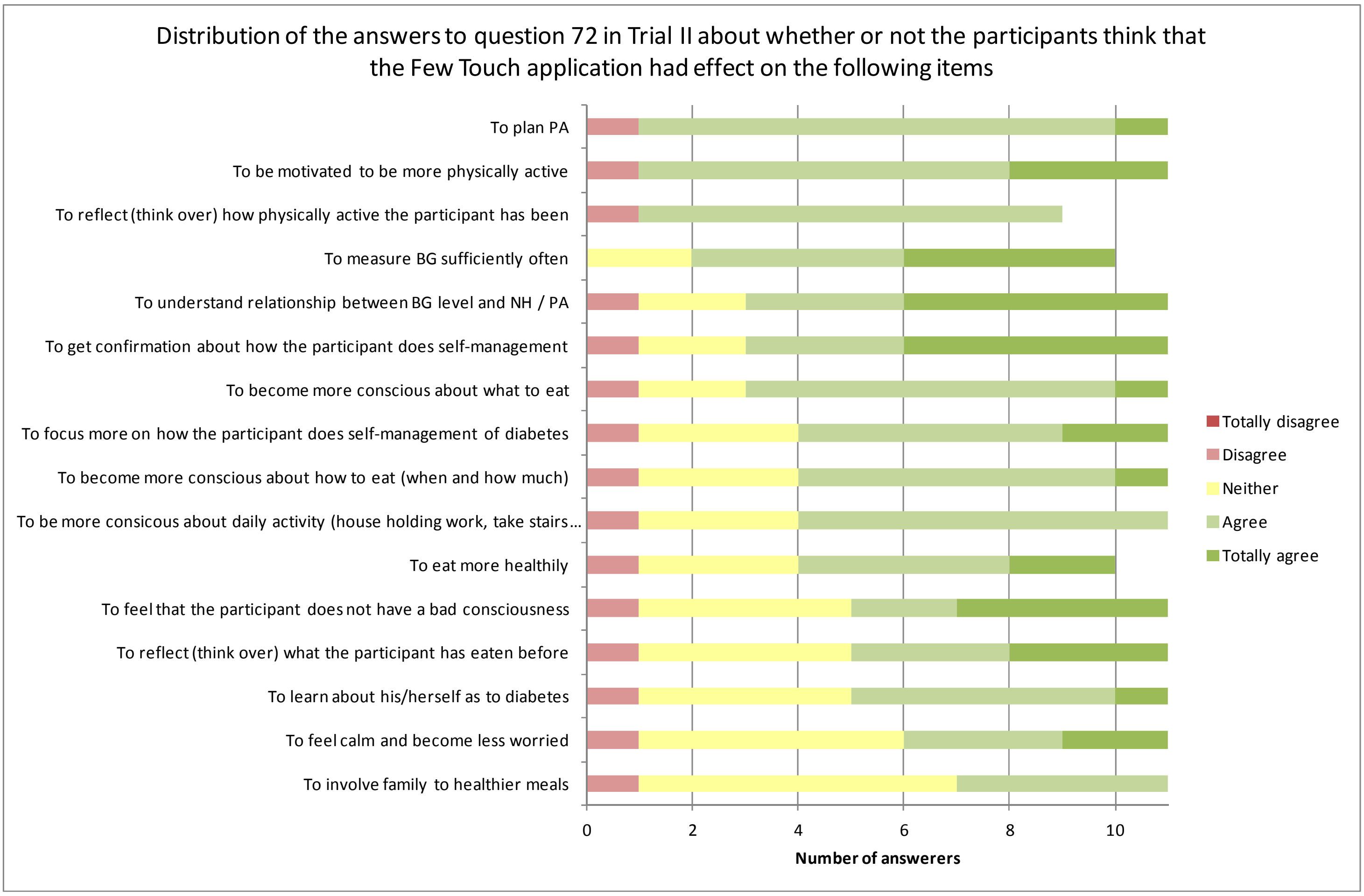
APPENDIX 10

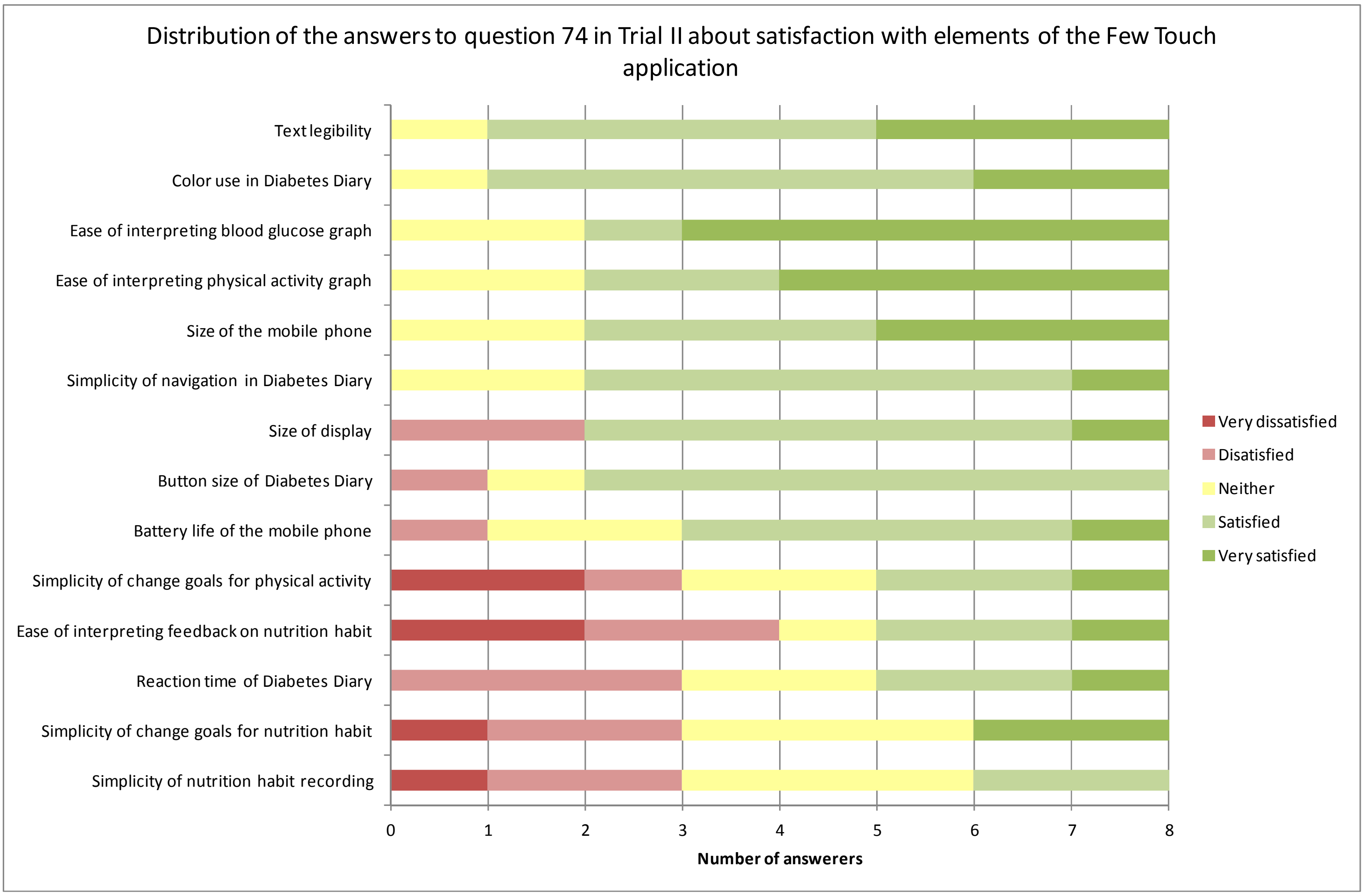
SUMMARY OF QUESTIONNAIRE RESULTS (PHASE 2)

Questionnaire results Part I

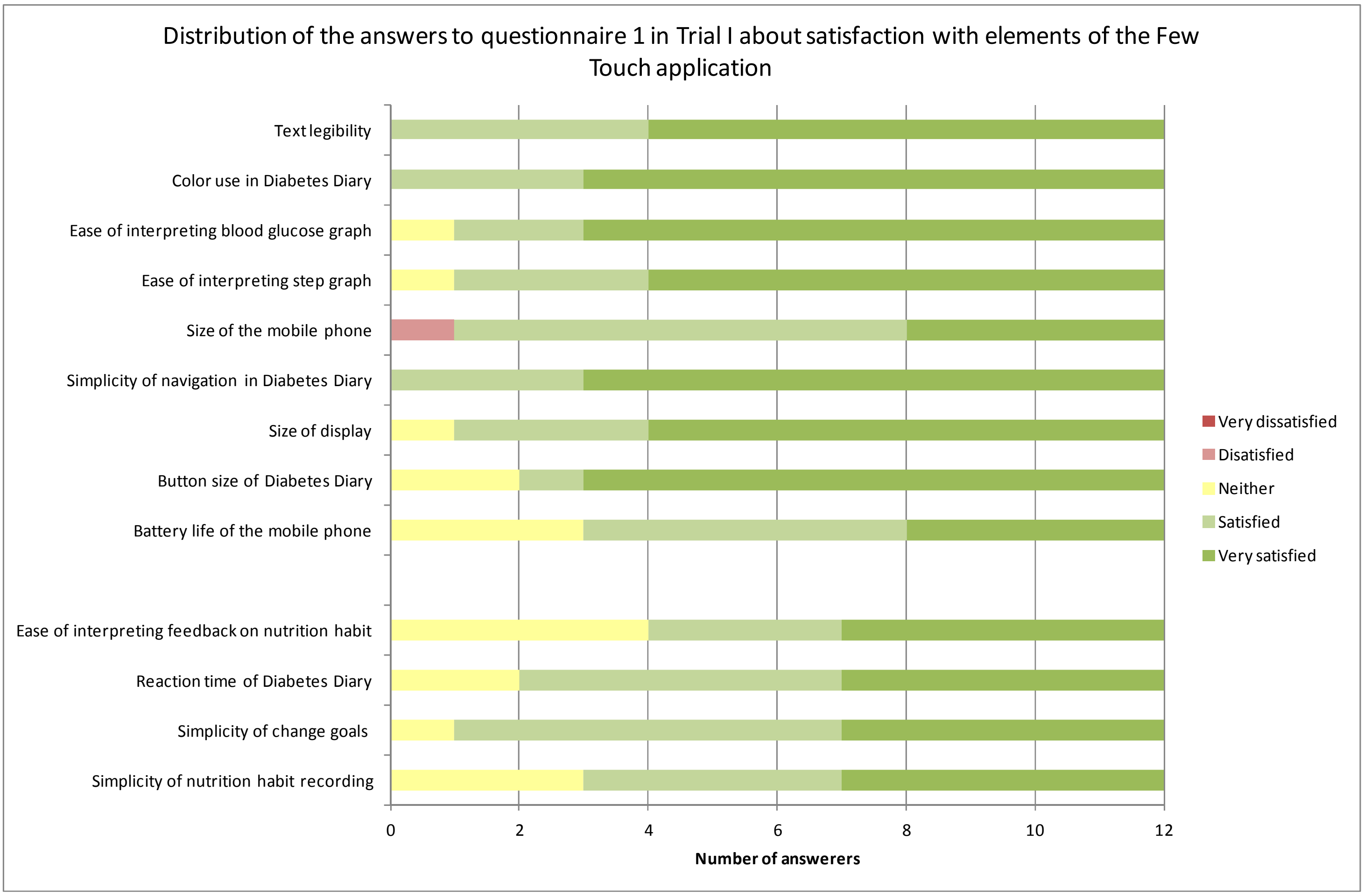
Results of questions regarding clinical status and recording of self-management activities (Question 4-7)

Question		Group A				Group B			Group C			
		HP02	HP04	HP09	HP10	HP03	HP07	HP11	HP01	HP05	HP06	HP08
4	The period of having diabetes (year)	20	13	4	20	14	N/A	3	2	-	5	12
5	Use of insulin for treatment	x		x	x							
6	Use of oral medication	x	x	x		x				x	x	x
7	How they recorded self-management activities											
	With a paper-based diary				x	x		x	x			
	Without any specialized tool			x								x
	With a computer-based tool									x (Accu check)		
	Have not recorded / others	x	x			x	N/A				x	

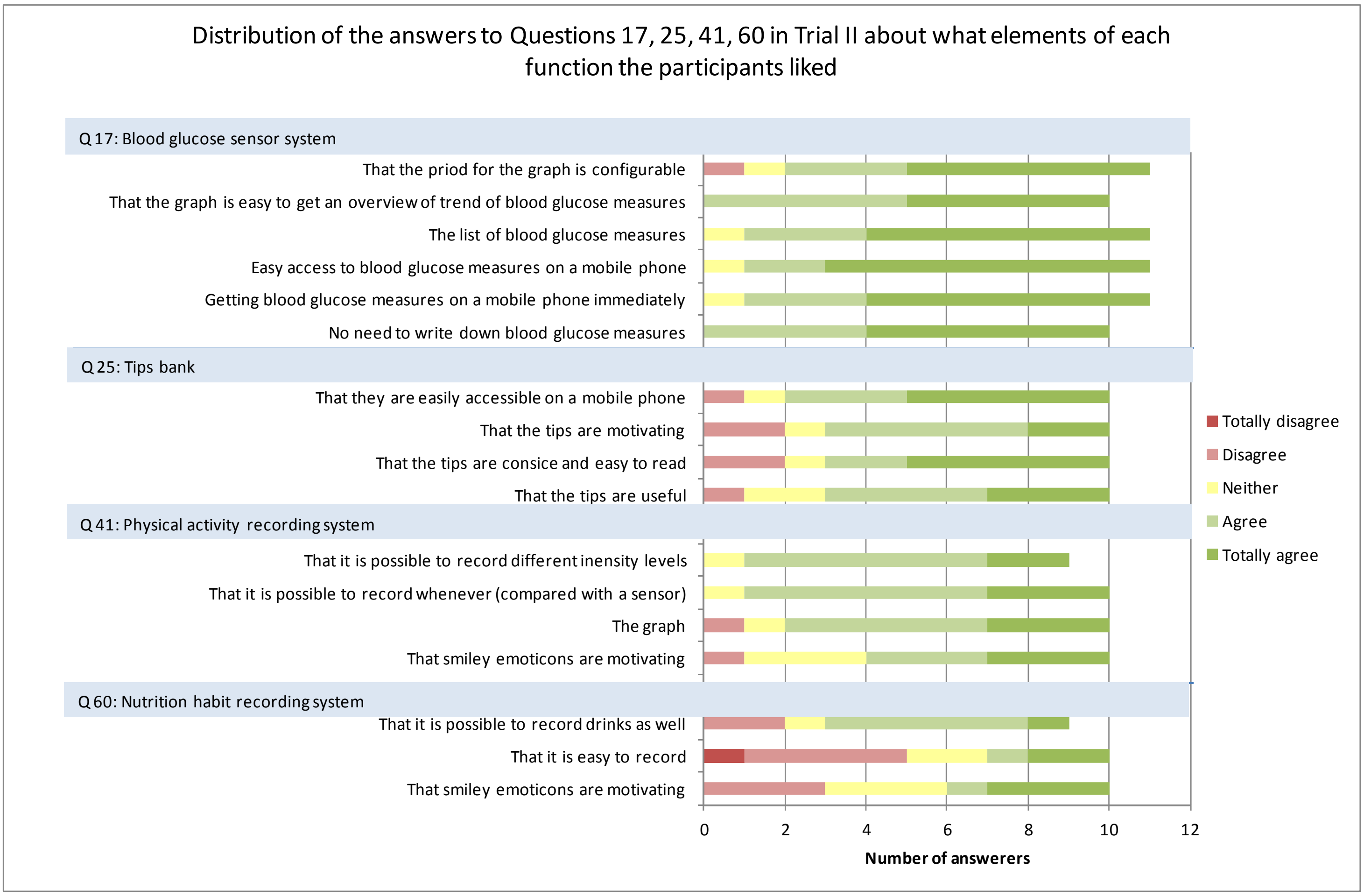


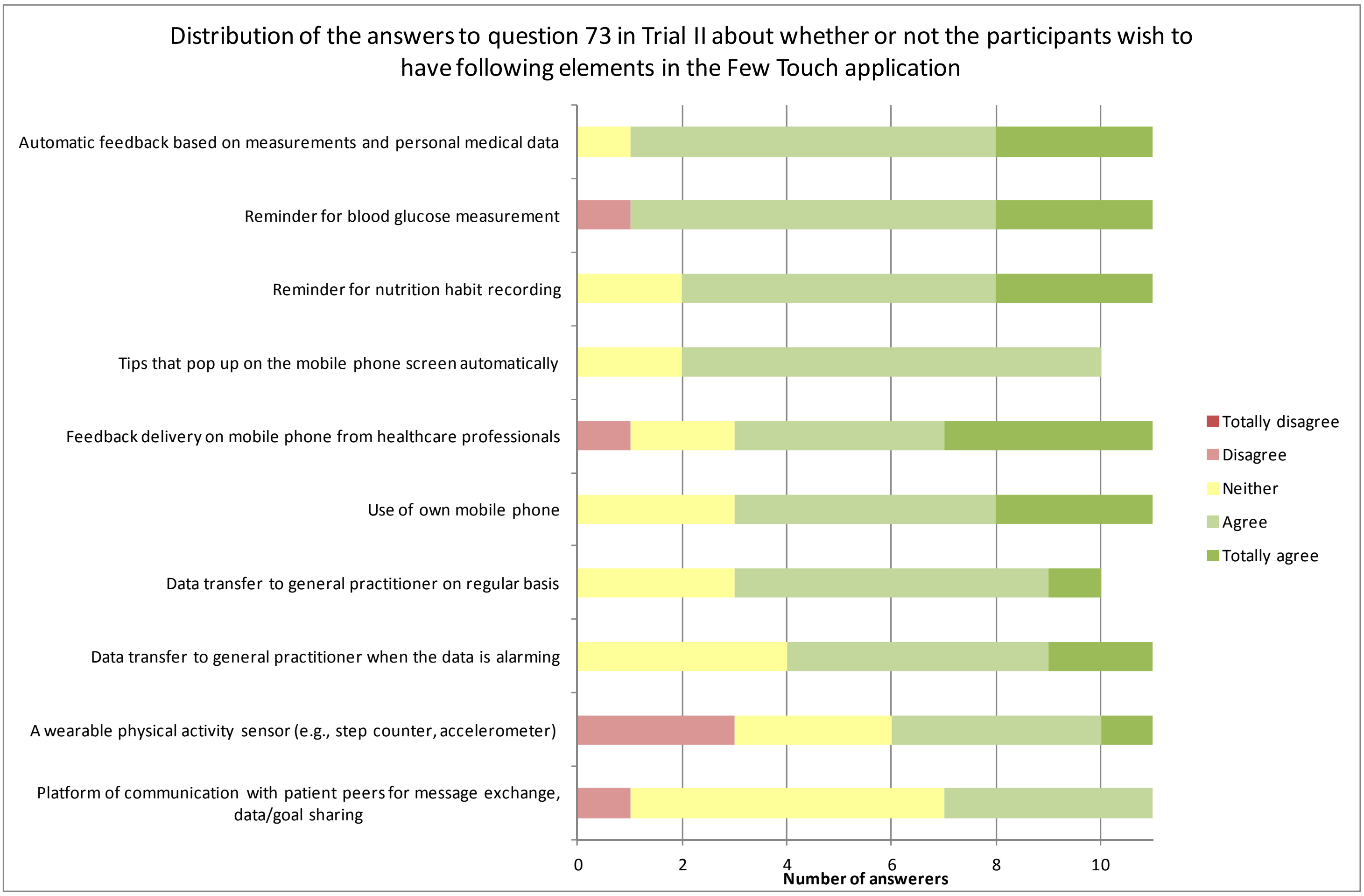


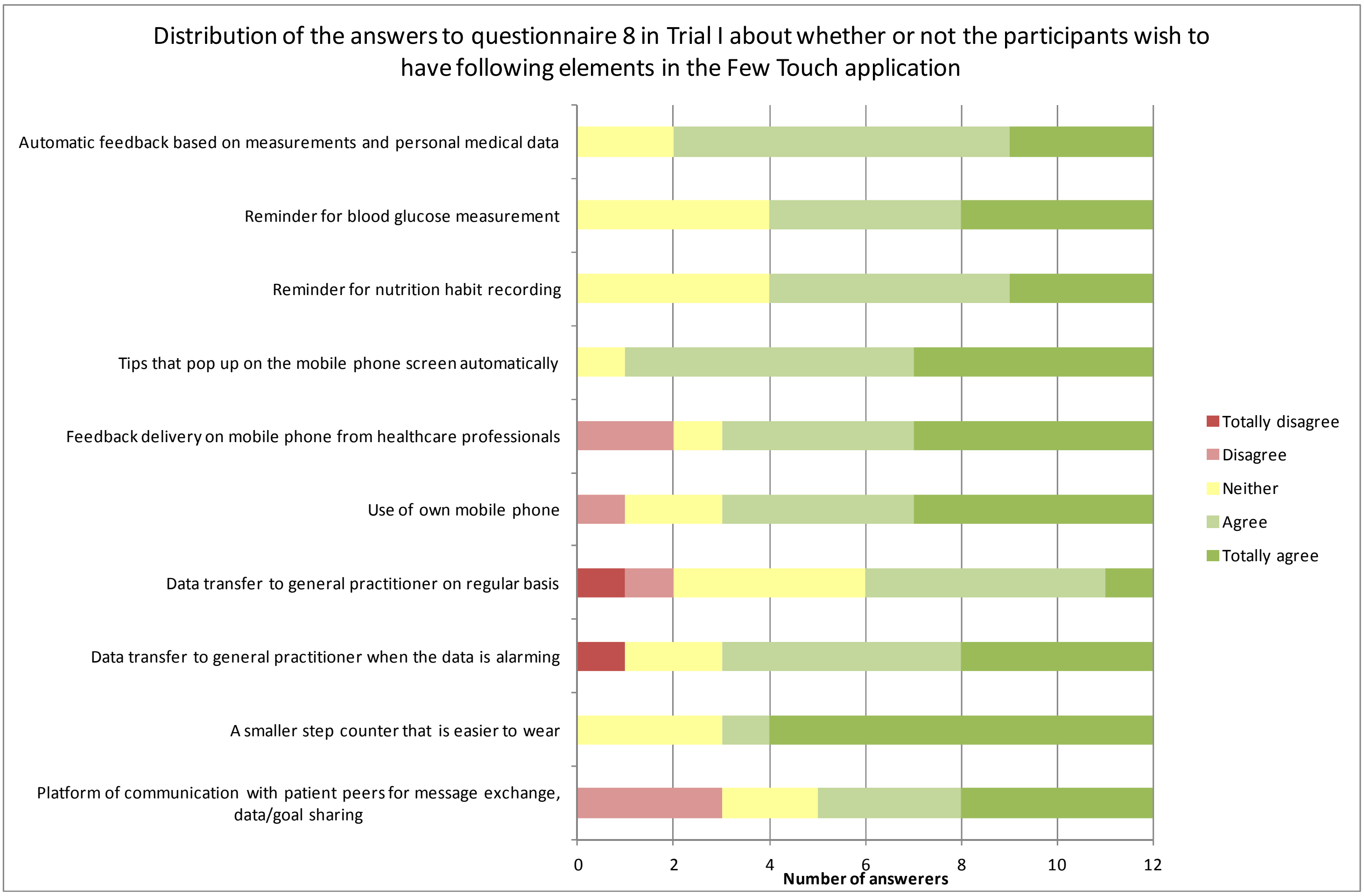
Distribution of the answers to question 74 in Trial II about satisfaction with elements of the Few Touch application
Text legibility
Color use in Diabetes Diary
Ease of interpreting blood glucose graph
Ease of interpreting physical activity graph
Size of the mobile phone
Simplicity of navigation in Diabetes Diary
Size of display
Button size of Diabetes Diary
Battery life of the mobile phone
Simplicity of change goals for physical activity
Ease of interpreting feedback on nutrition habit
Reaction time of Diabetes Diary
Simplicity of change goals for nutrition habit
Simplicity of nutrition habit recording
0
1
2
3
4
5
6
7
8
Number of answerers
Very dissatisfied
Disatisfied
Neither
Satisfied
Very satisfied



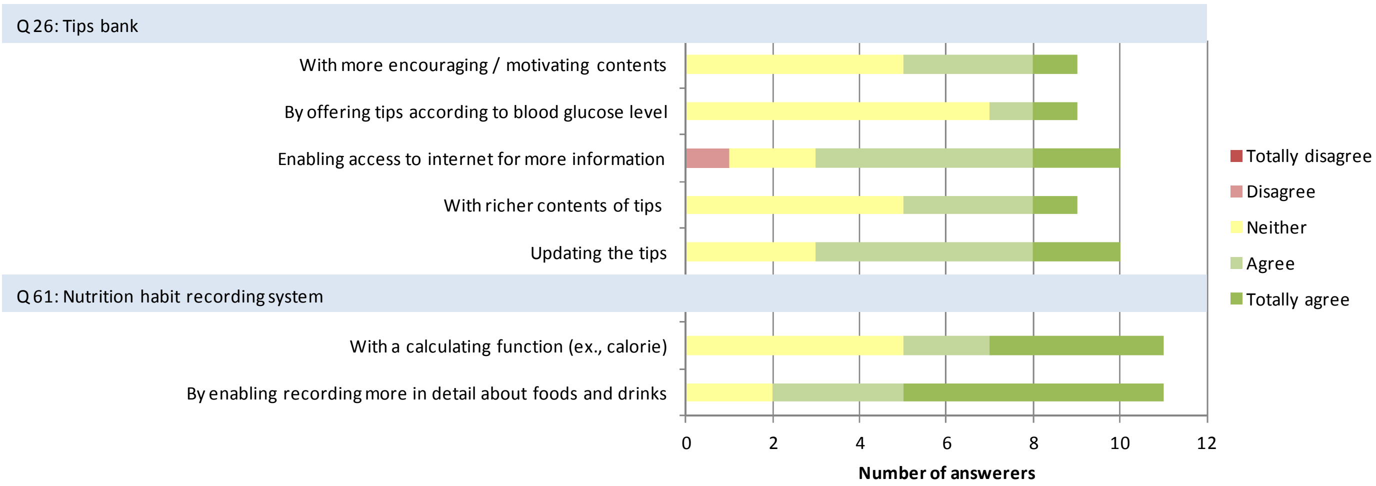
Distribution of the answers to questionnaire 1 in Trial I about satisfaction with elements of the Few Touch application
Text legibility
Color use in Diabetes Diary
Ease of interpreting blood glucose graph
Ease of interpreting step graph
Size of the mobile phone
Simplicity of navigation in Diabetes Diary
Size of display
Button size of Diabetes Diary
Battery life of the mobile phone
Ease of interpreting feedback on nutrition habit
Reaction time of Diabetes Diary
Simplicity of change goals
Simplicity of nutrition habit recording
0
2
4
6
8
10
12
Number of answerers
Very dissatisfied
Disatisfied
Neither
Satisfied
Very satisfied


Distribution of the answers to Questions 17, 25, 41, 60 in Trial II about what elements of each function the participants liked
Q 17: Blood glucose sensor system
That the priod for the graph is configurable
That the graph is easy to get an overview of trend of blood glucose measures
The list of blood glucose measures
Easy access to blood glucose measures on a mobile phone
Getting blood glucose measures on a mobile phone immediately
No need to write down blood glucose measures
Q 25: Tips bank
That they are easily accessible on a mobile phone
That the tips are motivating
That the tips are consice and easy to read
That the tips are useful
Q 41: Physical activity recording system
That it is possible to record different inensity levels
That it is possible to record whenever (compared with a sensor)
The graph
That smiley emoticons are motivating
Q 60: Nutrition habit recording system
That it is possible to record drinks as well
That it is easy to record
That smiley emoticons are motivating
0
2
4
6
8
10
12
Number of answerers
Totally disagree
Disagree
Neither
Agree
Totally agree


Distribution of the answers to question 73 in Trial II about whether or not the participants wish to have following elements in the Few Touch application
Automatic feedback based on measurements and personal medical data
Reminder for blood glucose measurement
Reminder for nutrition habit recording
Tips that pop up on the mobile phone screen automatically
Feedback delivery on mobile phone from healthcare professionals
Use of own mobile phone
Data transfer to general practitioner on regular basis
Data transfer to general practitioner when the data is alarming
A wearable physical activity sensor (e.g., step counter, accelerometer)
Platform of communication with patient peers for message exchange, data/goal sharing
0
2
4
6
8
10
Number of answerers
Totally disagree
Disagree
Neither
Agree
Totally agree


Distribution of the answers to questionnaire 8 in Trial I about whether or not the participants wish to have following elements in the Few Touch application
Automatic feedback based on measurements and personal medical data
Reminder for blood glucose measurement
Reminder for nutrition habit recording
Tips that pop up on the mobile phone screen automatically
Feedback delivery on mobile phone from healthcare professionals
Use of own mobile phone
Data transfer to general practitioner on regular basis
Data transfer to general practitioner when the data is alarming
A smaller step counter that is easier to wear
Platform of communication with patient peers for message exchange, data/goal sharing
0
2
4
6
8
10
12
Number of answerers
Totally disagree
Disagree
Neither
Agree
Totally agree

Distribution of the answers to Questions 26 and 61 in Trial II about possible solutions to improve each function



Suggestions for improvement (free-text comments)

Q18: Blood glucose sensor system
• Differenciating fasting blood glucose values and others.
• Enabling to set a default number to show values on a graph

Q 42: Physical activity recording system
• Enabling representation of all the three levels of intensity on a graph
• Enabling goals to be achieved by combining activities done at a higher intensity level
• Enabling editing records whenever after records were made
• Enabling recording specific types of physical activity;
• More accurate feedback regarding recorded intensity, because at a graph, intensity level is shown only by three types although it is possible to choose intensity level from an analog scale

Q61: Nutrition habit recording system
• Enabling more specified recording regarding types of foods and drinks
• Enabling data recordings for the passed dates

Questionnaire results Part II

Blood glucose sensor system

	Ques-tion	Self-management activities					Function		
		Frequency of blood glucose measurements					Blood glucose sensor system		
		11	12	14	13		15	16	9
Group	Partici-pant	Frequency	Degree of change	Satisfaction level	Reasons for change / no change		Agreement with motivatio-nal effects	Satisfaction level	Experience of Problem
A	HP02	21	1	2	A		2	1	X
A	HP04	7	2	1	B		1	1	
A	HP09	35 - 56	2	2	A		2	2	
A	HP10	18 - 20	2	2	A	B	1	1	
B	HP03	2 - 3	0	1	E		0	1	
B	HP07	14 - 21	2	1	other *		2	1	
B	HP11	15 - 20	0	1	E		0	1	X
C	HP01	14	1	1	B		1	2	X
C	HP05	21	0	0	other **		1	-1	X
C	HP06	3	1	0	A		1	1	
C	HP08	5 - 10	0	0	E		0	0	X

* "I don't have diabetes but am told by a doctor that I have a high risk of getting it."

** "I have used another program and still use it."

Physical activity sensor system

	Ques-tion	Self-management activities											Function		
		Frequency of physical activity					Length of physical activity						Physical activity recording system		
		29	30	32	31		33	34	36	35			27	39	40
Group	Partici-pant	Frequency	Degree of change	Satisfaction level	Reasons for change / no change		Length	Degree of change	Satisfaction level	Reasons for change / no change			Frequency of using the function	Agreement with motivatio-nal effects	Satisfaction level
A	HP02	4	1	1	B		4	1	1	A	B		5	1	1
A	HP04	4	1	1	A		3	1	1	A			5	2	2
A	HP09	3	2	0	A		3	1	0	A			2	2	0
A	HP10	4	2	1	A	B	3 †	1	1	A	B		5	2	2
B	HP03	4	0	2	E		4	0	2	E			4	0	0
B	HP07	3	2	-1	A	B	2, 3	1	0	A	B	other ‡	4	1	1
B	HP11	4	0	1	E		4	0	1	E			5	0	1
C	HP01	3	0	0	other *		2	0	-1	E			2	0	1
C	HP05	1	-1	-1	other **		††	-1	0	other **			0	0	0
C	HP06	3	0	0	E		3	0	0	E			4	1	1
C	HP08	3	0	0	E		4	0	1	E			4	0	1

* "Neither"

** "I was reported sick (to reduce workload) a week after the start. My motivation has therefore gone down, mentaly tired."

† "varies between intensity of PA, moderate and intensive (mostly moderate)"

†† "Depends on type"

‡ "Due to fibrositis, my health condition has changed. So the length followed this change"

Option								
2		more (more than double)	Very satisfied			Totally agree	Very satisfied	
1		More (less than double)	Satisfied			Agree	Satisfied	
0		No change	Neither			Neither	Neither	
-1		Less (not less than half)	Dissatisfied			Disagree	Dissatisfied	
-2		Much less (less than half)	Very dissatisfied			Totally disagree	Very dissatisfied	

Option														
5											Every time			
4	Almost everyday or more than 3 days/w					> 1 hour					Often (every 2-3 times)			
3	1-3 times/w					31 - 60 min					Sometimes (every 4-5 times)			
2	1-3 times/m	more (more than double)	Very satisfied			16 - 30 min	more (more than double)	Very satisfied			Seldom	Totally agree	Very satisfied	
1	Seldom	More (less than double)	Satisfied			< 15 min	More (less than double)	Satisfied			Used it before, but not anymore	Agree	Satisfied	
0	Never	No change	Neither			depends	No change	Neither			Have not used at all	Neither	Neither	
-1		Less (not less than half)	Dissatisfied				Less (not less than half)	Dissatisfied				Disagree	Dissatisfied	
-2		Much less (less than half)	Very dissatisfied				Much less (less than half)	Very dissatisfied				Totally disagree	Very dissatisfied	

Options for question 13, 31 and 35

A I have become more conscious

B The system was motivating

C I have learned myself so that I got to know that I don't have to do as much as before

D The system did not work for me to change self-management activities

E Self-management activities were good enough

Nutrition habit recording system

	Ques-tion	Self-management activity													Function			
		Amount of fruit / vegetable intake					Frequency of having main meal with little content of carbohydrate		Frequency of having main meal with high content of carbohydrate						Nutrition habit recording system			
		46	47	49	48		50	51	52	53	55	54			43	58	59	45
Group	Partici-pant	Amount	Degree of change	Satisfaction level	Reasons for change / no change		Frequency	Degree of change	Frequency	Degree of change	Satisfaction level	Reasons for change / no change			Frequency of using the function	Agreement with motivatio-nal effects	Satisfaction level	Better / worse overview
A	HP02	2	0	2	A	B	3	0	2	0	2	A	B		5	2	1	2
	HP04	1	1	1	D		5	1	1	0	1	E			1	0	-1	0
	HP09	1	-2	0	A		3	2	2	-2	1	A			4	2	1	1
	HP10	2	1	1	A	B	4	1	3	-1	1	A	B		6	1	1	2
B	HP03	1	0	1	E		2	0	1	0	0	other *			4	0	-1	0
	HP07	2	0	0	D		2	1	2	-1	0	B			4	2	1	1
	HP11	2	0	0	E		5	0	4	0	1	E			4	0	1	1
C	HP01	1	0	-1	D		3	1	4	1	-1	B			2	0	-2	0
	HP05	2	0	-1	E		3	0	4	0	-1	E			0	0	0	0
	HP06	1	0	1	D		2	0	2	0	-1	D			3	-1	0	0
	HP08	1	0	1	D		5	0	4	0	0	other **			2	0	0	0

* "I am a shift worker and so need to manage daily meal time depending on the shift on the day"

** "Note: I have changed my meal habit regarding amount of carbohydrates before this course started"

Option																
6													Every time after drinking/ eating			
5						> 3 times / day		> 3 times / day					Everyday, at the end of a day			
4						1 - 2 times / day		1 - 2 times / day					Often (every 2-3 times)			
3	> 600 g (= > 4 portions)					4 - 6 times / week		4 - 6 times / week					Sometimes (every 4-5 times)			
2	300 - 600 g (= 2-4 portions)	more (more than double)	Very satisfied			1 -3 times / week	more (more than double)	1 -3 times / week	more (more than double)	Very satisfied			Seldom	Totally agree	Very satisfied	Much better
1	0 - 300 g (= 0-2 portions)	More (less than double)	Satisfied			1 - 3 times / month	More (less than double)	1 - 3 times / month	More (less than double)	Satisfied			Used it before, but not anymore	Agree	Satisfied	Better
0	don't eat	No change	Neither			seldom or never	No change	seldom or never	No change	Neither			Have not used at all	Neither	Neither	Neither
-1		Less (not less than half)	Dissatisfied				Less (not less than half)		Less (not less than half)	Dissatisfied				Disagree	Dissatisfied	Worse
-2		Much less (less than half)	Very dissatisfied				Much less (less than half)		Much less (less than half)	Very dissatisfied				Totally disagree	Very dissatisfied	Much worse

Options for question 48 and 54

A I have become more conscious

B The system was motivating

C I have learned myself so that I got to know that I don't have to do as much as before

D The system did not work for me to change self-management activities

E Self-management activities were good enough

Tips bank under information function

Group	Question / Partici-pant	Function: Tips bank — 19 Frequency of using the function	22 Agreement with motivational effects	24 Satisfaction level	20 Agreement with useful-ness	23 Agreement with actual effects on improvement of total self-management
A	HP02	3	1	1	2	1
A	HP04	2	1	1	2	1
A	HP09	1	1	1	2	2
A	HP10	3	1	2	2	2
B	HP03	1	0	0	0	0
B	HP07	2	2	1	1	2
B	HP11	1	0	0	0	0
C	HP01	1, 0	0	0	1	0
C	HP05	2	1	0	1	1
C	HP06	2	1	1	1	1
C	HP08	2	0	1	1	0

The Few Touch application in total

Group	Question / Partici-pant	Self-management of diabetes in total: Satisfaction with current self-management — 63 Satisfaction level	64 Degree of change	65 Reasons for change / no change	Satisfaction with current knowledge about his/her own diabetes — 66 Satisfaction level	67 Degree of change	68 Reasons for change / no change		69 Improvement regarding diabetes		Total system: The Few Touch application — 71 Perception of usefulness of the FTA (7-Likert scale, 7: very useful, 1: very useless)
A	HP02	1	1	L	1	1	K		HbA1c	BG control	7
A	HP04	2	2	K	1	1	K		HbA1c	BG control	7
A	HP09	1	2	K	1	2	K		Medication	BG control	7
A	HP10	1	1	K	1	1	K		HbA1c	other ††	7
B	HP03	1	0	E	2	0	E		other ‡		3
B	HP07	N/A	N/A *	N/A	0	N/A			BG control	other ‡‡	5
B	HP11	1	0	E	1	0	E				4
C	HP01	1	1	K	1	1	L		BG control		2
C	HP05	-1	0	other **	-1	0	other		BG control		3
C	HP06	0	1	L	1	1	K	L	BG control		6
C	HP08	0	0	E	1	1	other †				4

* "I have not diabetes but now I think of what I eat more than before."

** "Alternative system / tool (Accu Check)."

† "Learned from diabetes nurse."

†† "Better health condition in total."

‡ "There has not been much change from how my blood glucose control was before."

‡‡ "Exercise more and thenk about what I eat more than before."

Option					
4	Daily - 2,3 / w				
3	Weekly - monthly				
2	Seldom	Totally agree	Very satisfied	Totally agree	Totally agree
1	Used it before, but not anymore	Agree	Satisfied	Agree	Agree
0	Have not used at all	Neither	Neither	Neither	Neither
-1		Disagree	Dissatisfied	Disagree	Disagree
-2		Totally disagree	Very dissatisfied	Totally disagree	Totally disagree

Option					
2	Very satisfied	Much more satisfied		Very satisfied	Much more satisfied
1	Satisfied	More satisfied		Satisfied	More satisfied
0	Neither	No change		Neither	No change
-1	Dissatisfied	Less satisfied		Dissatisfied	Less satisfied
-2	Very dissatisfied	Much less satisfied		Very dissatisfied	Much less satisfied

Options for question 65 and 68

K	By using the system I could get control over diabetes/ know more about my diabetes
L	By using the system I found that I did not have good enough control over/ know enough about my diabetes
D	The system was not good enough for me to have better control over / get more knowledge about my diabetes
E	I have been satisfied with how I control over / my knowledge about my diabetes from before

APPENDIX 11

RESULTS OF INQUIRY 1 AND 2 (PHASE 3)

Results of the questionnaire at Inquiry 1 in Phase 3

Color scale is used for the cells of Table 2 to make it easier to interpret the results: The more participants marked the corresponding option, the darker the color is.

Table 1 The results of Q1

When \ what type of information you want to get as "Tips"	**General information about:**				**Others**
	Food	Physical activity	Disease	Blood glucose	
At previously set time	1	1	0	0	0
When you press "Tips" button	10	10	10	10	2
In another way (describe concisely)	0	0	0	0	0
I don't know	0	1	1	1	2
I don't need it	0	0	1	0	0

Table 2 The results of Q2

When \ what type of information you want to look-up		**Information relevant to food**				
		General information about food	Picture of a food item in an amount that contains 10 gram of carbohydrates	Amount of carbohydrates in a normal portion of a food item	Glycaemic index (GI)	Nutrition contents of a food item
When you see:	Blood glucose measures	4	0	1	1	1
	Stepcount graph	1	0	0	0	0
	Nutrition habit status	2	3	6	3	3
When you record nutrition habits		1	3	3	2	3
When you do grocery shopping, cook, or are at a restaurant, etc.		3	2	2	4	3
Whenever (no special situation, time or place)		3	4	2	3	3
Other situations (describe consicely)		0	0	0	0	0
Neither / I don't know		0	2	1	1	1
I don't need it		0	0	1	1	0

When \ what type of information you want to look-up		**General info. about physical activity**	**General info. about disease**	**General info. about blood glucose**	**Info. to show the others**	**Reference book about diabetes**	**Others**
When you see:	Blood glucose measures	2	4	5	0	3	0
	Stepcount graph	6	0	1	1	1	0
	Nutrition habit status	1	0	3	0	1	0
When you record nutrition habits		2	1	1	1	1	0
When you do grocery shopping, cook, or are at a restaurant, etc.		0	0	1	0	0	0
Whenever (no special situation, time or place)		3	3	1	4	5	1
Other situations (describe consicely)		0	0	0	1	0	0
Neither / I don't know		0	1	2	4	3	1
I don't need it		0	1	0	2	0	1

Table 3 The results of Q3 and Q4

	A bookmark function	A link to a webpage
Yes, I want it.	11	6
I don't know.	0	3
No, I don't need it.	0	2

Results of the card sorting at Inquiry 2 in Phase 3

Color scale is used for the cells of Table 2 to make it easier to interpret the results: The more participants marked the corresponding option, the darker the color is.

Table 1 Cards that were used for the top level of a group and the number of participants who chose the card

Cards	The number of participants who chose the card for the top level
a. Food	10
b. Physical activity	9
c. Disease	5
d. Diabetes in general	5
e. Blood glucose	5
h. Glycaemic Index (GI)	2
i. Amount of carbohydrates in a normal portion of a food item	1
j. Nutrition contents of a food item	1
n. List of items in alphabetical order	1

Table 2 The cards used for the second and the third level in a group depending on the card used for the top level and number of participants who used the card

Cards at the top level	a. Food		b. Physical activity	
Cards at the second and third level	2nd	3rd	2nd	3rd
a. Food	N.A.	N.A.	0	0
b. Physical activity	0	0	N.A.	N.A.
c. Disease	0	0	1	0
d. Diabetes in general	0	0	0	0
e. Blood glucose	2	0	0	0
f. Information to show others (e.g. acute information, foods that are not recommended to eat)	3	6	0	0
g. Picture of a food item in an amount that contains 10 gram of carbohydrates	4	5	0	0
h. Glycaemic Index (GI)	4	2	2	0
i. Amount of carbohydrates in a normal portion of a food item	8	2	0	0

j. Nutrition contents of a food item	7	2	1	0
k. Reference book about diabetes	0	0	2	0
l. Quiz about diabetes	0	1	1	2
m. Bookmarks	0	1	1	1
n. List of items in alphabetical order	1	0	1	2
o. Search by word with manual typing/writing	1	0	5	3
p. Others – write your own category on a Post-it™	0	1 *	1 †	1 ‡

* Examples of food recipes for diabetics
† Combination of pulse and step counts (here this participant might have expressed the feedback screen of physical activity
‡ Training program

Table 2 (cont.)The cards used for the second and the third level in a group depending on the card used for the top level and number of participants who used the card

Cards at the top level	**c. Disease**		**d. Diabetes in general**		**e. Blood glucose**	
Cards at the second and third level	2nd	3rd	2nd	3rd	2nd	3rd
a. Food	0	0	0	0	0	0
b. Physical activity	0	0	0	0	0	1
c. Disease	N.A.	N.A.	0	1	2	0
d. Diabetes in general	3	0	N.A.	N.A.	2	0
e. Blood glucose	3	0	1	0	N.A.	N.A.
f. Information to show others (e.g. acute information, foods that are not recommended to eat)	1	0	0	0	1	0
g. Picture of a food item in an amount that contains 10 gram of carbohydrates	0	0	0	0	1	0
h. Glycaemic Index (GI)	0	0	0	0	1	0
i. Amount of carbohydrates in a normal portion of a food item	0	0	0	0	0	0
j. Nutrition contents of a food item	0	0	0	0	0	0
k. Reference book about diabetes	2	0	3	1	0	3
l. Quiz about diabetes	0	1	1	1	0	3
m. Bookmarks	1	2	2	0	0	2
n. List of items in alphabetical order	0	0	2	0	1	1
o. Search by word with manual typing/writing	0	0	0	0	0	1
p. Others – write your own category on a Post-it™	0	0	0	0	0	0

Table 3 The result of card sorting by P09

the top level	h. Glycaemic Index (GI)	i. Amount of carbohydrates in a normal portion of a food item	j. Nutrition contents of a food item	e. Blood glucose
the 2nd level	a. Food	g. Picture of a food item in an amount that contains 10 gram of carbohydrates	d. Diabetes in general	f. Information to show others (e.g. acute information, foods that are not recommended to eat)
the 3rd level	b. Physical activity	c. Disease m. Bookmarks	k. Reference book about diabetes l. Quiz about diabetes n. List of items in alphabetical order o. Search by word with manual typing/writing	

APPENDIX 12

TASK SETS OF THE USABILITY TESTING IN PHASE 3

Task sets of the usability testing in Phase 3

Table 1 Original task sets for search tasks used for the first five participants

Task id	Aim	Question	Food items	
			Item set A	Item set B
S1	1.1	How much carbohydrate does 100 g of the following item contain?	Papaya, 32nd item in the alphabetically sorted list of fruits and berry sub-category.	Rødbete (in English: beetroot), 33rd item in the alphabetically sorted list of raw vegetable sub-category.
S2	1.2	How much fiber does 100 g of the following item contain?	Brokkoli (in English: broccoli), 6th item in the alphabetically sorted list of raw vegetable sub-category.	Blåbær (in English: blueberry), 7th item in the alphabetically sorted list of fruits and berry sub-category.
S3	2	How much energy does 100 g of the following item have?	Smultringer (in English: doughnut)	Rabarbra (in English: rhubarb)
S4	2	How much energy does 100 g of the following item have?	Avocado	Wienerbrød (in English: danish pastry)
S5	3	How much carbohydrate does 100 g of the following items contain?	Appelsin juice og eplemost (in English: orange juice and apple juice)	Loff og grovbrød (in English: white bread and wholemeal flour bread)
S6	3	How much energy does 100 g of the following items have?	Ostekake med kjeks bunn og nøttesjokolade (in English: cheese cake	Fiskepinner og cashewnøtter (in English: fish fingers and

			with bisquit bottom and chocolate with nuts)	cashew nuts)

Table 2 Original task sets for comparison tasks used for the first five participants

Task id	Aim	Question	Food items	
			Item set A	**Item set B**
C1	4.2	Which of the following three items has the most fiber per 100 g?	Eple, kiwi og fersken (in English: apple, kiwi fruit, and peach)	Gulrot, isbergsalat, og nepe (in English: carrot, lettuce, and turnip)
C2	4.1	Which of the following four items has the most energy per 100 g	Nugatti, marsipan, og Seigmenn (in English: nut spread[1], marzipan, and fruit jellies[2])	Sorbet, potetchips, og pai (in English: sherbet, potato crisps, and pie)
C3	5	Which of the following three items has the least carbohydrate per 100 g?	Aprikos (tørket), eplenektar, og gulrotkake (in English: dry apricot, apple nectar, and carrot cake)	Grillpølse, fiskesuppe av pulver, og gresskar (in English: grill sausage, fish soup (powder base), and pumpkin)
C4	5	Which of the following three items has the least energy per 100 g?	Fiskeboller, brus, og Litago (sjokolademelk) (in English: fish ball, soda, milk beverage with chocolate flavor[3])	ALL-bran, sopp, og saftis (in English: breakfast cereal[4] type All-bran, mushroom, and water ice)

[1] Nugatti is a Norwegian brand of chocolate spread made from hazelnuts and nougat
[2] "Seigmenn" here means "Laban Seigmenn", which is a brand of sweets produced for the Norwegian market
[3] Litago is a Norwegian brand of milk bevarage
[4] All-Bran is a brand name of a breakfast cereal manufactured by Kellogg's®

C5	6	Which of the following three items has the most fiber? And how many items have less energy amount than that item?	Pumpernikkel, fruktmüsli, og lompe (in English: pumpernickel, muesli with fruit, and griddle cake made of potato)	Rødkål, molter, og mais (in English: red cabbage, cloud berry, and sweet corn)
C6	6	Which of the following three items has the least carbohydrate? And how many items have less energy amount than that item?	Baconcrisp, ris (hurtig, kokt), og banan (in English: Pork scratchings, rice (pre-boiled, boiled), and banana)	Brunost, kjøttkake, og karamellpudding (in English: Brown cheese, meatball, and caramel custard)

Table 3 Revised task sets for search tasks

Task id	Aim	Question	Food items	
			Item set A	**Item set B**
RS1	1.1	How much carbohydrate does 100 g of the following item contain?	Pære (in English: pear), 36th item in the alphabetically sorted list of fruits and berry sub-category.	Rødbete (in English: beetroot), 33rd item in the alphabetically sorted list of raw vegetable sub-category.
RS2	1.2	How much fiber does 100 g of the following item contain?	Brokkoli (in English: broccoli), 6th item in the alphabetically sorted list of raw vegetable sub-category.	Blåbær (in English: blueberry), 7th item in the alphabetically sorted list of fruits and berry sub-category.
RS3	2	How much energy does 100 g of the following item have?	Avocado, 4th item in the	Rabarbra (in English:

			alphabetically sorted list of fruits and berry sub-category	rhubarb), 37th item in the alphabetically sorted list of fruits and berry sub-category
RS6	3	How much energy does 100 g of the following items have?	Jordbær og Tomat (in English: strawberry and tomato) 18th and 42nd items in each sub-category.	Løk og Kiwi (in English: onion and kiwi), 19th and 21st items in each sub category.

Table 4 Revised task sets for comparison tasks

Task id	Aim	Question	Food items			
			Item set A		Item set B	
RC1	4.2	Which of the following three items has the most fiber per 100 g?	A: Aubergine	2.3 g	A: Paprika (rød) (in English: bell pepper (red))	1.9 g
			B: Paprika (gul) (in English: bell pepper (yellow)),	3 g	B: Løk (in English: onion)	2 g
			C: Tomat (uspesifisert, rå) (in English: tomato (unspecified, raw)	1.3 g	C: Stangselleri (in English: Celery stalk or root)	2.5 g

RC2	4.1	Which of the following four items has the most energy in 100 g	A: Jordbær (in English: strawberry)	34 kcal	A: Eple (in English: apple)	49 kcal
			B: Ananas	47 kcal	B: Kiwi	57 kcal
			C: Drue (grønn) (in English: grapes (green))	70 kcal	C: Banan (in English: banana)	83 kcal
RC3	6	1. Which has the most fiber per 100 gram?	A: Jordbær	Fiber: 2 g Carb.[a]: 6.6 g	A: Eple	Fiber: 2.1 g Carb.: 10.6 g
			B: Ananas	Fiber: 1.4 g Carb. 10.1 g	B: Kiwi	Fiber: 2.7 g Carb.: 10.6 g
			C: Drue (grønn)	Fiber: 1.1 g Carb.: 16 g	C: Banan	Fiber: 1.6 g Carb.: 18.1 g
			D: Bringebær (in English: raspberry)	Fiber: 4.3 g Carb.: 3.2 g	D: Molter (in English: cloud berry)	Fiber: 6 g Carb.: 4.4 g
			E: Kiwi	Fiber: 2.7 g Carb.: 10.6 g	E: Ananas	Fiber: 1.4 g Carb.: 10.1 g
		2. Approximately how many more times carbohydrates does it have compared with the one which	A: 0.2 B: 0.5 C: 1		A: 0.1 B: 0.4 C: 1	

		has the third most fiber?	D: 1.5		D: 1.5	
RC4	6	Choose the following items and compare them. 1. Which has the most fiber? 2. Which items have more fiber and less carbohydrate than paprika (rød)?	A: Paprika (gul)	Fiber: 3 g Carb.: 4.4 g	A: Paprika (rød)	Fiber: 1.9 g Carb.: 4.6 g
			B: Paprika (rød)	Fiber: 1.9 g Carb.: 4.6 g	B: Stang-selleri	Fiber: 2.5 g Carb.: 1.3 g
			C: Aubergine	Fiber: 2.3 g Carb.: 2.2 g	C: Tomat (uspesifisert)	Fiber: 1.3 g Carb: 1.7 g
			D: Tomat (uspesifisert)	Fiber: 1.3 g Carb.: 1.7 g	D: Aubergine	Fiber: 2.3 g Carb.: 2.2 g
			E: Agurk (in English: cucumber)	Fiber: 0.8 g Carb.: 1.2 g	E: Mais (in English: sweet corn)	Fiber: 3.2 g Carb: 12.6 g
			F: Squash (in English:	Fiber: 1 g Carb.: 2.2 g	F: Gulrot (in English: carrot)	Fiber: 2.7 g Carb.: 6.5 g

[a]: “Carb.” means Carbohydrates

APPENDIX 13

CHECKLIST FOR INSTRUCTION OF THE PROTOTYPES AT THE USABILITY TESTING (PHASE 3)

ListView

- How to move into category (= sub-category list of the chosen category)?
  - Click on the row of a category name
- How to move into sub-category (=list of food items in the chosen sub-category)?
  - Click on the row of a sub-category name
- How to access detailed information of a food item?
  - Click on the row of a food item
- How to close the pop-up window?
  - Click “cross” button
- How to go to another sub-category, or category?
  - Click “Opp” button on the top of the list
- How to compare different food items in terms of nutrition?
  - Check in a checkbox next to a food item
  - Continue until you have checked all the items to compare
  - Even though the items to choose are in different category/sub-category, selection remains
  - Click “Sammenligne” button
- How to change nutrients to show in the comparison table?
  - Click either nutrient-names (whichever is fine)
  - Choose nutrient name from a drop-down list in a pop-up window
  - Click “OK” button
- How to sort food items in ascending/descending order?
  - Click on the arrow above the name of nutrient or the name of food items
- When finishing comparison, or in order to do another comparison?
  - Click “Lukk” button, then you can go back to the list of food items
  - The selection made for the previous comparisons are cleared.

FoodMap

- How to start?
  - It has "navigation panel" and "Food Circle"
  - Click on an area of the Food Circle that you think a target item might be found
  - Then you can see pictures of food items in that area
- When it is unsure what pictures expresses?
  - Click "Zoom-in" button on the navigation panel
  - Then you can see names of food items on pictures
- How to see nutrition information of a food item?
  - Click on "information" button on the navigation panel
  - "Information" button is activated (with green OK mark)
  - Click on the picture of the food you want to see information about
- How to close the pop-up window?
  - Click "cross" button
- When the food item to search is not found?
  - Pan (Click and drag) the Food Circle
  - It might be better to deactivate "information" button
  - "Zoom-out" button on the navigation panel is also useful when a food item to search might be far away
- How to compare different food items in terms of nutrition?
  - Click "Selection" button on the navigation panel , and "Selection" button is activated
  - Click on the picture of a food item that you want to compare
  - Continue until you have checked all the items to compare
  - Click "OK" button on the navigation panel
- How to see the Scatter Plot?
  - Selected food items are positioned according to its values on nutrients that are used as X-/Y- axis
- How to access nutrition information of each food item in the scatter plot?
  - You can see nutrition information of each food item by clicking the picture
- Can I use pan/zoom in scatter plot as well?
  - Yes, you can.
- How to change nutrients to show in the comparison table
  - Click either nutrient-names (whichever is fine) above the scatter plot
  - Choose nutrient name from a drop-down list in a pop-up window
  - Click "OK" button
- When finishing comparison, or in order to do another comparison?
  - Click "cross" button, then you can go back to the Food Circle
  - The selection made for the previous comparisons are cleared.

APPENDIX 14

ATTRAKDIFF™ QUESTIONNAIRE (PRAGMATIC QUALITY) DISTRIBUTED AT USABILITY TESTING (PHASE 3)

AttrakDiff™ Questionnaire – Pragmatic Quality

With the help of the word-pairs please write "x" in a cell what you consider the most appropriate description for the user interface now you used.

Technical	☐	☐	☐	☐	☐	☐	☐	Human
Simple	☐	☐	☐	☐	☐	☐	☐	Complicated
Impractical	☐	☐	☐	☐	☐	☐	☐	Practical
Straightforward	☐	☐	☐	☐	☐	☐	☐	Cumbersome
Unpredictable	☐	☐	☐	☐	☐	☐	☐	Predictable
Clearly structured	☐	☐	☐	☐	☐	☐	☐	confusing
unruly	☐	☐	☐	☐	☐	☐	☐	manageable

APPENDIX 15

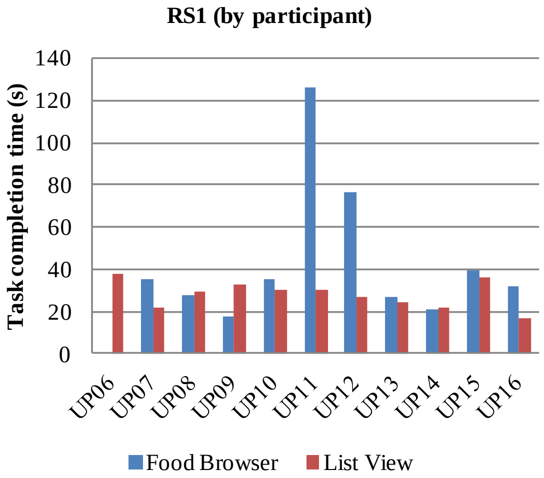
COMPLETE REPORT: RESULTS OF THE PILOT USABILITY TESTING IN PHASE 3 REGARDING EFFICIENCY OF PROTOTYPES FOR SEARCH AND COMPARISON TASKS BY THE LAST 11 PARTICIPANTS

Complete report: results of the pilot usability testing in Phase 3 regarding efficiency of prototypes for search and comparison tasks by the last 11 participants

Search tasks

RS1: To find out information of a food item whose category is obvious, and whose name starts with an alphabet that comes late in the alphabetical order

Figure 1 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 1 shows a statistic summary of task completion time. Mann-Whitney's U-test could not discard the null hypothesis as task completion time when using one prototype does not tend to be shorter or longer than when using the other.



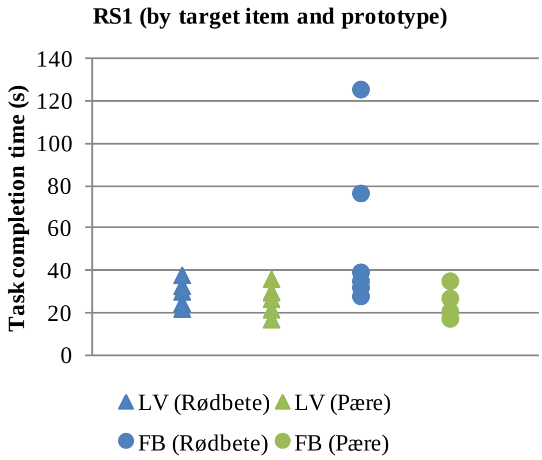


Figure 1 Task completion time for RS1

Table 1 Statistic summary of task completion time for RS1

	Food Browser	List View
Mean (SD) (unit: seconds)	43.79 (33.18)	28.10 (6.40)
Range (unit: seconds)	17.4 - 126	17.0 – 38.0
Mann-Whitney U-test: U, U' (P-value)	39, 71 (.260)	

Analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

- Food Browser prototype
    - Not utilizing direct zoom in by clicking on Food Map

        - UP07 and UP10 started the task with clicking on a magnifier icon to zoom while the other participants directly clicked on a pie of the circle corresponding to a correct sub-category.
    - Difficulty with recognition of images
        - UP07 zoomed in to the level 2 in which food names are displayed, and searched the name of a target item ("rødbete (in English: beetroot)") rather than finding it by outlook.
        - UP10 and UP16 obviously found a target item (tried click on it without activating selection), but before looking a detail view, they zoomed in with a magnifier icon to confirm the food name. For UP16, at the time of pressing magnifier icon at navigation, the target item, beetroot, was near bottom edge of the screen. Due to this relative position of the item, it went out of the screen by zooming in so that UP16 needed to pan to move to where the item was.
        - UP14 first clicked on guava to see a detail view, which looks quite similar to a target item, pear (Figure 2).

Figure 2 How pear and guava look like at the zoom level 1

    - Difficulty with use due to user interaction design
        - UP10 and UP12 had the same problem regarding navigation as UP05 had experienced (see the third bullet in 8.4.2).
        - UP11 simply could not find a target item, beetroot, for a long time. UP11 went around other categories after firstly going to the vegetable area and then to fruit area.
- List View prototype
    - Extra time consumed irrelevant to task itself
        - UP10 conducted the task in a right way, but it took about seven seconds since she was given an advice to write just alphabet for multiple choice rather than writing name of an item.

On the other hand, analyses of the video records also revealed that two participants, UP09 and UP14, completed tasks comparatively fast, in 17.4 seconds and 20.7 seconds, respectively (Table 2) when using Food Browser. They were at rank 1 and 2 among task completion time of RS1 with Food Browser, and at rank 2 and 3 among combined results by both prototypes. Both participants started the task by clicking on the fruit area (target item was pear for both), and afterwards, they neither panned (dragged the Food Map) nor used a magnifier to display names of food items before they clicked on the target item. The shortest task completion time for RS1 was 17.0 seconds, achieved by UP16 with List View and with a target item "pære". This indicates that the Food Browser can be competitive enough in terms of efficiency compared with List View, when it is used in the most efficient manner.

Table 2 Top five of task completion time for RS1

Participant	Prototype	Target item	Task completion time (seconds)
UP16	List View	Pære (in English: pear)	17.0
UP09	Food Browser	Pære	17.4
UP14	Food Browser	Pære	20.7
UP07	List View	Pære	21.7
UP14	List View	Rødbete (in English: beetroot)	22.1

RS2: To find out information of a food item whose category is obvious, and whose name starts with an alphabet that comes early in the alphabetical order

Figure 3 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 3 shows a statistic summary of task completion time. The data by UP15 seems as an obvious outlier. As described below, UP15 misunderstood the task and this caused such a long task completion time. Mann-Whitney's U-test returned U and U' as 29 and 81, respectively with P-value of 0.067. Therefore, for this test, I could conclude that there was a marginally meaningful tendency that task completion time when using List View tends to be shorter than when using Food Browser.

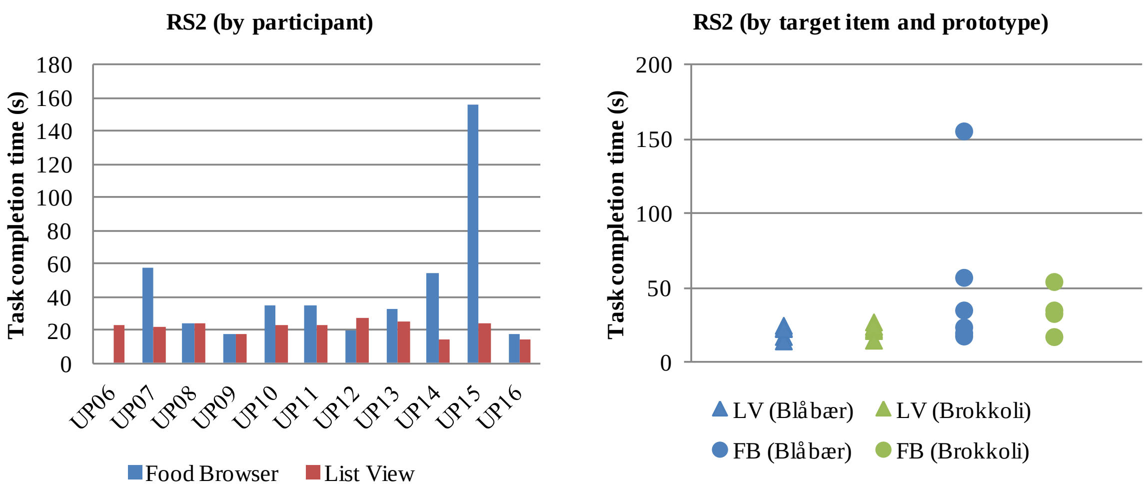


Figure 3 Task completion time for RS2

Table 3 Statistic summary of task completion time for RS2

	Food Browser	List View
Mean (SD) (unit: seconds)	45.14 (41.43)	21.75 (4.18)
Range (unit: seconds)	17.5 - 156	14.6 – 27.4
Mann-Whitney U-test: U, U' (P-value)	29, 81 (.067)	

Analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss when using Food Browser.

- Not utilizing direct zoom in by clicking on Food Map
  - UP07, UP11 and UP13 started the task with clicking on a magnifier icon to zoom while the other participants directly clicked on a pie of the circle corresponding to a correct sub-category.
- Difficulty with recognition of images
  - UP10 and UP14, whose target item was broccoli, first clicked on cauliflower and lettuce, respectively, both of which were found very near broccoli. Then they found what they thought broccoli was not broccoli and panned around. UP14 zoomed in to display names after a while, and finally found broccoli.
- Difficulty with use due to user interaction design
  - UP13 activated selection of food items for a detail view as the first navigation before clicking on the magnifier. This might be because in the RS1, UP13 first did not remember how to enable displaying a detail view after finding a target item, and clicked on the item icon several times. In this task (RS2) on the other hand, activation of selection first obviously hindered smooth panning because it caused pop-up of detail view of unintended items for many times in the course of panning.
- Extra time consumed irrelevant to task iteself
  - UP15 searched for a product "fiber" for the first 2 minutes 4 seconds (until UP15 used an un-magnifier icon to get back to the zoom level 0 at which the whole food circle is displayed). After UP15 noticed that it was blueberry to search, it took for her only 10 seconds to find it, but she used magnifier to confirm the name, and that took 23 seconds.

Comparing those whose task completion time was within top five (Table 4), participants who quickly found a target item with Food Browser could complete a task within competitive time compared with List View, although it is not so competitive as when a target item is found near bottom of the list. For RS2 with List View, both target items are shown in the list at click of the corresponding sub-category, and no need to scroll.

Table 4 Top five of task completion time for RS2

Participant	Prototype	Target item	Task completion time (seconds)
UP14	List View	Blåbær (in English: blueberry)	14.6

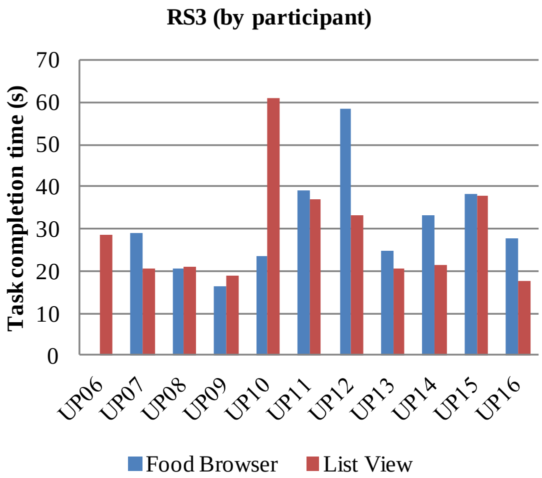
UP16	List View	Brokkoli (in English: broccoli)	15.1
UP09	Food Browser	Brokkoli	17.5
UP09	List View	Blåbær	17.6
UP16	Food Browser	Blåbær	17.9

Again, UP09 neither panned nor used a magnifier to display name of a target item before clicking on it for displaying a detail view. UP16 started clicking on the fruit area, but he used a magnifier icon to display food names, and panned. Actually, the sixth ranked was 20.1 seconds by UP12 searching blueberry using Food Browser. Similar to UP09, UP12 did not use either magnifier icon or panning after clicking on the fruits area. Considering the difference in task completion time among UP09, 12, and 16, efficiency of searching food item using Food Browser depends on how close the part of area a user first focused on is to a target item, and how quickly s/he notices it no matter if they try to find it by outlook of the item, name of it, or combination of both. This is also strengthened by the observation at UP10 and UP14 who chose a wrong item due to a similar outlook.

RS3: To find out information of a food item whose category is not very obvious

Target items, avocado and rhubarb are both categorized as fruits in The Norwegian Food Composition Table 2006 [200]. Therefore, if a participant chooses a sub-category "fruits and berries" at the first try when using List View prototype, it does not make almost any time loss. On the other hand, avocado and rhubarb are located in the fruit area close to vegetable area of Food Map of Food Browser. The positions are also close to center of the circle. Therefore, if a participant chooses either fruit or vegetable area to search for, the positions where these items are can also be within the IFrame at high probability. It is also highly probable that a participant can find it while panning from one to another sub category.

Figure 4 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 5 shows a statistic summary of task completion time. Mann-Whitney's U-test could not discard the null hypothesis as task completion time when using one prototype does not tend to be shorter or longer than when using the other.



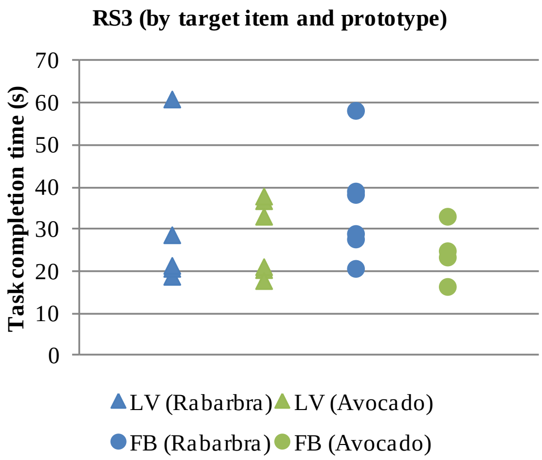


Figure 4 Task completion time for RS3

Table 5 Statistic summary of task completion time for RS3

	Food Browser	List View
Mean (SD) (unit: seconds)	31.09 (12.01)	28.88 (12.94)
Range (unit: seconds)	16.4 – 58.3	17.8 – 61.0
Mann-Whitney U-test: U, U’ (P-value)	44, 66 (.438)	

Analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

- Food Browser prototype
  - Not utilizing direct zoom in by clicking on Food Map
    - UP07, UP11 and UP13 again started the task with clicking on a magnifier icon to zoom while the other participants directly clicked on a pie of the circle corresponding to a correct sub-category.
  - Difficulty with recognition of images
    - UP15 obviously found a target item, rhubarb, (tried click on it without activating selection), but before looking a detail view, UP15 zoomed in with a magnifier icon to confirm the food name.
  - Difficulty with use due to user interaction design
    - UP12 again had the same problem regarding navigation as UP05 had experienced.
- List View prototype
  - Different mental model for categorization of food items from source of information
    - UP10, UP11, UP12 and UP15 first went into vegetables sub-category and found there was not a target item.

Task completion times by UP10, UP11, UP12 and UP15 using List View were the four longest among the task completion time records by using List View (33.1, 36.8, 37.9, and 61.0 seconds, respectively). Considering this fact, the reason for non-normal distribution of sample can be due to bimodality which second peak represents the case in which a user first chooses a wrong sub-category.

Table 6 shows the top five of task completion time for RS3. Those by UP13 using List View and by UP08 using FB tied, so both are fifth ranked.

Table 6 Top five of task completion time for RS3

Participant	**Prototype**	**Target item**	**Task completion time (seconds)**
UP09	Food Browser	Avocado	16.4
UP16	List View	Avocado	17.8
UP09	List View	Rabarbra (in English: Rhubarb)	18.8
UP07	List View	Avocado	20.4
UP13	List View	Rabarbra	20.7
UP08	Food Browser	Rabarbra	20.7

The top ranked record was by UP09 using Food Browser. Even though UP09 first clicked on the vegetable area (Figure 5), avocado was also found at the edge of the screen. It was almost immediate that UP09 found avocado (on video records, it took approximately 4 seconds from the time UP09 clicked the Food Map to the time he displayed a detail view of avocado).

Figure 5 A screen displayed by the first click on the Food Map at RS3 by UP09

(a) At first click on the Food Map (UP08)

(b) At a click on the magnifier icon (UP08) An arrow indicates the direction UP08 panned.

(c) At first click on the Food Map (UP12)

(d) At a click on the magnifier icon (UP12) An arrow indicates the direction UP08 panned.

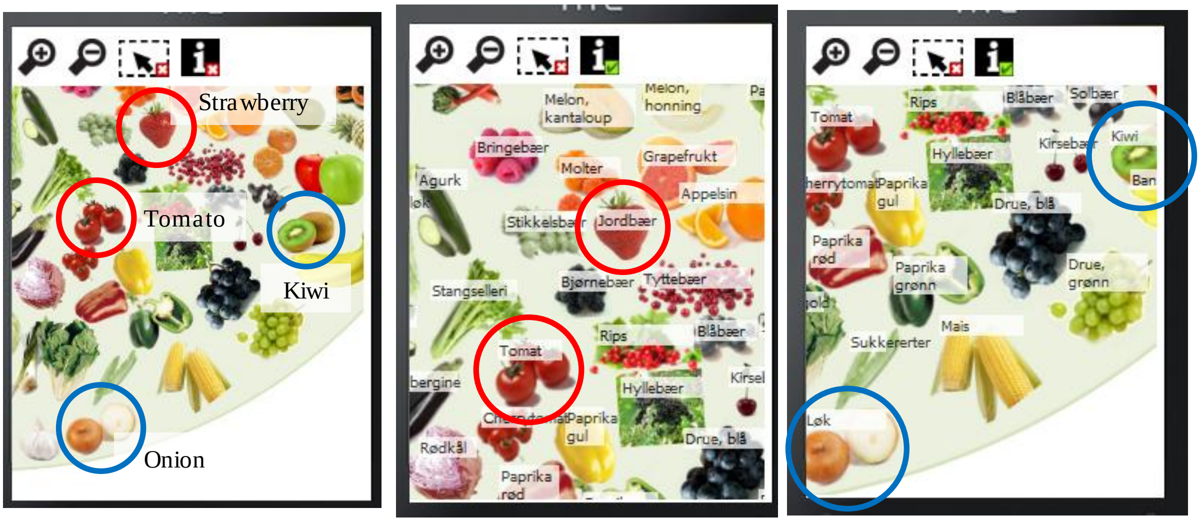
Figure 6 Screenshots of Food Map prototype at RS3 by UP08 and UP12

UP08 and UP12 also clicked on the area in which their target item, rhubarb for both, was found near edge of the IFrame (Figure 6, (a) and (c)). However, they immediately clicked on the magnifier icon to zoom in, by which rhubarb has gone to either totally or nearly outside of the IFrame. Interestingly, how they searched afterwards and their consequences were very contrasting. UP08 panned to vegetable area (shown as an arrow in Figure 6 (b)), but came back to fruit area, and found rhubarb there. The task completion time by UP08 was 20.7 seconds, which is second ranked among all the records by both prototypes. On the other hand, although UP12 started panning to area more fruit items are found (shown as an arrow in Figure 6 (d)), she could not find rhubarb there. She searched for around fruit area, went to vegetable area, and again came back to fruit area. During this process, rhubarb came into the IFrame several times, but UP12 did not notice it. As described above, UP12 had a problem with panning navigation as well, which caused her irritation and less attention to items displayed while having the problem. As a consequence, it took 58.3 seconds for UP12 to complete the task, which is the longest among records by Food Browser prototype and the second lowest ranked among all the records by both prototypes.

One of the concepts of Food Map which is tested by this task was that the Food Map would reduce potential time loss by choosing a wrong category or sub-category in a category-based data base structure like List View. The result shows that how quickly a user can find a target food item on Food Map simply depends on how close a target item is located to an area which a user believes s/he can find the item, regardless of the "(sub-) category area" that a user chooses to look at.

RS4: To find two food items whose sub-categories are different but next to each other

Tomato is found at the bottom of vegetable sub-category, but the other three target items are in the middle of the list of items in the List View. Figure 7 shows positions of the target items on Food Map of the Food Browser. Although two items in each item set belong to different sub-category, absolute distances between the two target items are rather short for both task sets, and they can be within a IFrame at the same time at zoom level 1 and 2.



(a) Positions of target items (red circles: item set A, blue circles: item set B) at zoom level 1

(b) Positions of target items for item set A at zoom level 2

(c) Positions of target items for item set B at zoom level 2

Figure 7 Positions of target items on Food Map of Food Browser for RS4

Figure 8 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 7 shows a statistic summary of task completion time. Mann-Whitney's U-test could not discard the null hypothesis as task completion time when using one prototype does not tend to be shorter or longer than when using the other. When seeing ranks of task completion times measured by using Food Browser, except one record with onion (in Norwegian: løk) and kiwi which is shorter than any other task completion time, all the other task completion time records with onion and kiwi were longer than those with strawberry (in Norwegian: Jordbær) and tomato (in Norwegian: Tomat). This is most probably reflecting the difference in absolute distances between target items, as shown in Figure 7.

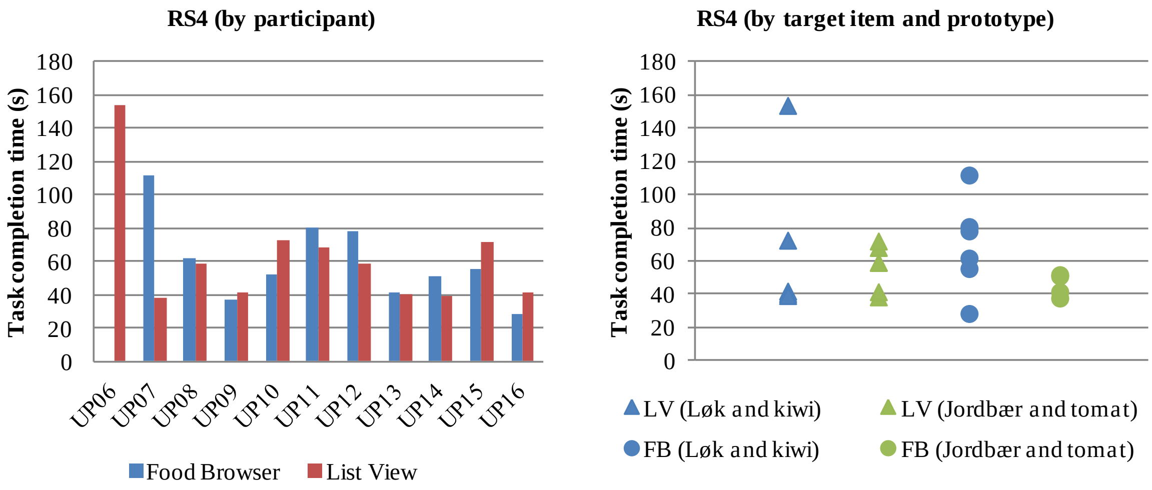


Figure 8 Task completion time for RS4

Table 7 Statistic summary of task completion time for RS4

	Food Browser	List View
Mean (SD) (unit: seconds)	59.96 (24.65)	62.52 (33.29)
Range (unit: seconds)	28.5 – 112	38.5 – 154
Mann-Whitney U-test: U, U' (P-value)	54.5, 55.5 (.972)	

Analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

- Food Browser prototype
  - Not utilizing direct zoom in by clicking on Food Map
    - UP07, UP11 and UP13 again started the task with clicking on a magnifier icon to zoom while the other participants directly clicked on a pie of the circle corresponding to a correct sub-category.
  - Difficulty with recognition of images
    - UP07 first pressed the magnifier icon twice to display food names and started looking in the vegetable area, but moved to another category up in the circle. After a while, UP07 could find onion. However, UP07 started looking for kiwi in the vegetable area and it took a while before going to fruits area. Even after getting in the fruits area, UP07 dragged the circle from left to right and vice versa for a long time before noticing that there are more fruits below.
    - UP10 first clicked on cloudberry, but found that it was not strawberry, then clicked magnifier to zoom into zoom level 2 to confirm food name.
    - UP15 obviously found target items (for both items. tried click on it without activating selection), but before looking a detail view, UP15 zoomed in to confirm the food name.
- List View prototype

- Difficulty with use due to user interaction design
  - UP06 first typed value for carbohydrates of onion in the answer form, and noticed it was wrong and retyped. After correctly answering to the first question, it took a while for her to close a detail view of onion, because she was wondering how to do it. After closing the detail view, she was lost because the screen does not show the arrow icon to be back to upper, and again it took a while for her to notice that she needed to scroll up the list to find the arrow.

The issues observed at the use of Food Browser were already seen previously, while part of the issue observed at the use of List View illustrates was not. Regarding closing a detail view, actually clicking on any place of a detail view closes it. Regarding positioning of the arrow to go up to the upper category while scrolling, we actually discussed in the development process. Keeping the arrow visible while scrolling was however technically difficult, and we did not prioritize this issue assuming that the scroll bar will indicates that the arrow should be found at the top. In addition, the longest list in the prototypes had only 42 items. Therefore, in the restricted time for development, we left this behind.

Table 8 shows the top five of task completion time for RS4. Unlike the first three tasks, the shortest task completion time achieved by using Food Browser was 10 seconds shorter than the shortest task completion time achieved by using List View. The second shortest task completion time was also by using Food Browser. This result indicates that Food Browser has a potential to be more efficient than List View for continuous search of food items that are in different but close categories. This however totally depends on firstly relative positions of target items on the Food Map, and secondly how close their positions to area that a user believes that they should be found.

Table 8 Top five of task completion time for RS4

Participant	**Prototype**	**Target item**	**Task completion time (seconds)**
UP16	Food Browser	Løk og kiwi	28.5
UP09	Food Browser	Jordbær og Tomat	37.8
UP07	List View	Jordbær og Tomat	38.5
UP14	List View	Løk og kiwi	39.3
UP13	List View	Løk og kiwi	40.5

Below, I will report results of each task. For each task, I made figures showing distribution of task completion time by participant and by combination of target item and prototype. For these figures, I used different types of indications to express error and incompletion of tasks. Incompletion of a task is expressed by a light color on the bar charts and by plots without color filling on the scatter plot diagrams. Errors are expressed as plots in cross shape on the scatter plot diagrams, while different types of markers are used on the bar charts. An upside-down triangle means an error due to the bugs of the List View prototype described above (2)

- d)). A cross mark means an error because of other reasons than the bugs. For figures regarding RC3 and RC4, blue color is used for answers given to the first question, while yellow filling with red outline are used for answers given to the second question.

Comparison tasks

Below, I will report results of each task. For each task, I made figures showing distribution of task completion time by participant and by combination of target item and prototype. For these figures, I used different types of indications to express error and incompletion of tasks. Incompletion of a task is expressed by a light color on the bar charts and by plots without color filling on the scatter plot diagrams. Errors are expressed as plots in cross shape on the scatter plot diagrams, while different types of markers are used on the bar charts. An upside-down triangle means an error due to the bugs of the List View prototype described above (2) - d)). A cross mark means an error because of other reasons than the bugs. For figures regarding RC3 and RC4, blue color is used for answers given to the first question, while yellow filling with red outline are used for answers given to the second question.

RC1: To compare 3 food items in a same sub-category in one parameter that is neither of parameters set by default (either energy or carbohydrates)

Figure 9 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 9 shows statistic summaries of task completion time. Calculations are based on records made by correctly completed tasks. Mann-Whitney's U-test could not discard the null hypothesis as task completion time when using one prototype does not tend to be shorter or longer than when using the other.

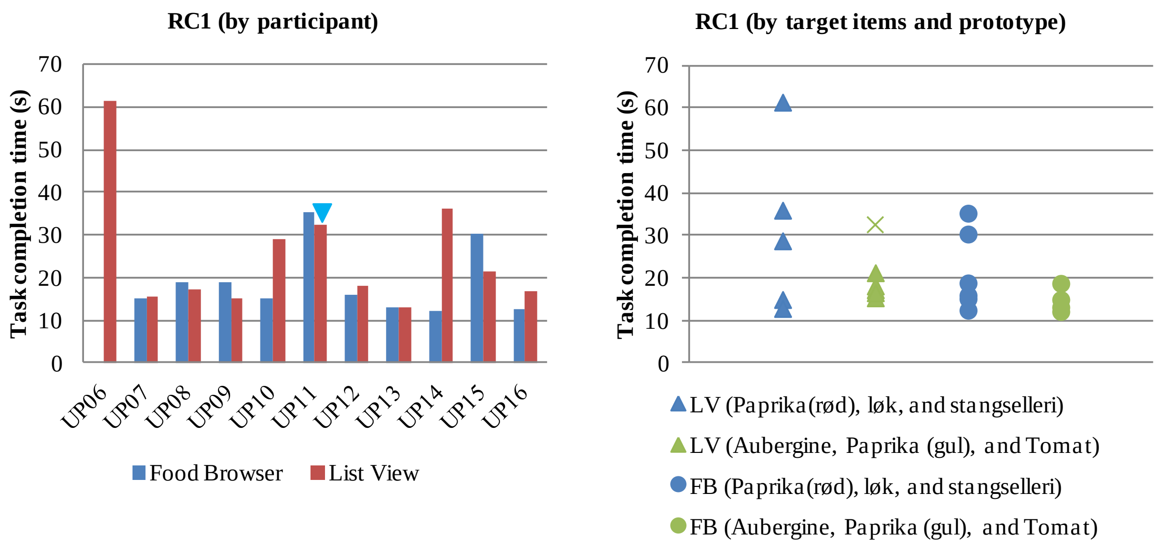


Figure 9 Task completion time for RC1

Table 9 Statistic summary of task completion time for RC1

	Food Browser	List View
Mean (SD) (unit: seconds)	18.75 (7.86)	24.29 (14.85)
Range (unit: seconds)	12.2 – 35.3	12.9 – 61.4

Mann-Whitney U-test: U, U' (P-value)	64.5, 35.5 (.273)

Analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

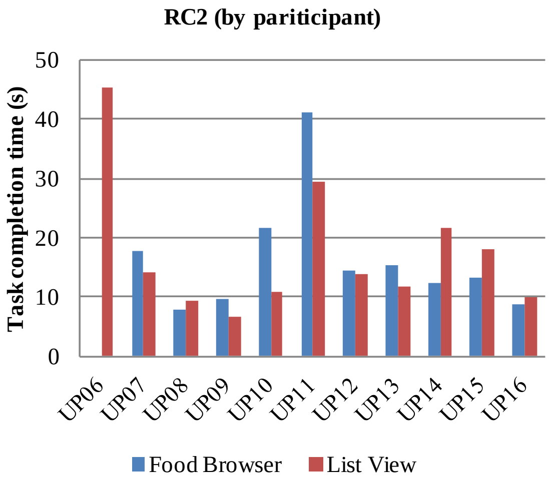
- List View prototype
    - Difficulty with use due to user interaction design
        - UP06 was wondering for a while how to change a parameter.
    - Extra time consumed irrelevant to task itself
        - UP16 typed the name of a food item instead of an option id in alphabet.
        - UP14 typed all the options (a, b, c) in the order of amount of fiber first, and then rewrote the correct answer.
        - UP10 was wondering how to answer and was advised that she can just type the option id in alphabet.

The error made by UP11 when using List View was due to a bug of List View, 2) - d) - i) "Misleading display of values", as shown in 8.4.4.3 (b). Although both item sets included one item whose value for fiber was shown without decimal fraction, from observation of captured video records, it did not seem any apparent reason of delay in answering for the other participants when using List View. This is in line with narrow range of task completion time by the participants except ones whose long task completion time was explained by other reasons as shown in Figure 9.

Except the case by UP06, parameter change was done almost without any problems for both prototypes. Sorting function in List View was used by four participants (UP08, UP10, UP11 and UP14). Except UP08, the three who used sorting function took comparatively long time to complete the task. Considering the small number of items, which was only three, it might not be so tedious to compare numerical numbers to find out the greatest value. The shortest task completion time was achieved by UP14 when using Food Browser (12.2 seconds) followed by UP16 when using Food Browser (12.5 seconds). The third ranked one was 12.9 seconds by UP13 when using List View. On the other hand, from video records, not any obvious reasons were identified for the comparatively long task completion time by UP11 and UP15 when using Food Browser. Therefore, for this type of comparison with very few items to compare and when there is clearly recognizable difference between plots on a scatter plot, neither user interaction design outperforms the other. This is consistent with the result of Mann-Whitney U-test.

RC2: To compare 3 food items in a same sub-category in one parameter that is one of parameters set by default (either energy or carbohydrates)

Figure 10 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 10 shows statistic summaries of task completion time. Calculations are based on records made by correctly completed tasks. Mann-Whitney's U-test could not discard the null hypothesis as task completion time when using one prototype does not tend to be shorter or longer than when using the other.



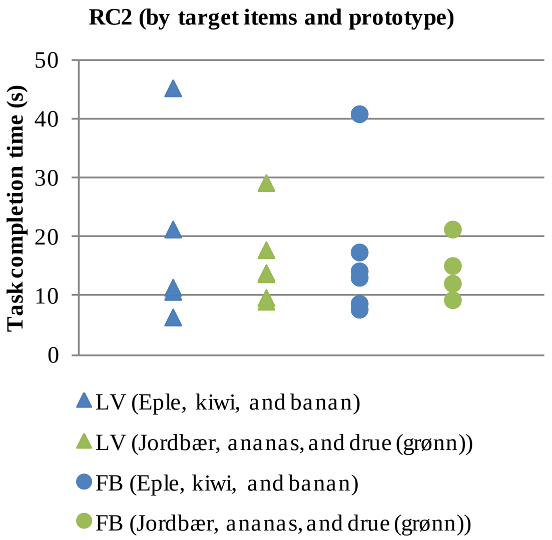


Figure 10 Task completion time for RC2

Table 10 Statistic summary of task completion time for RC2

	Food Browser	List View
Mean (SD) (unit: seconds)	16.17 (9.69)	17.32 (11.36)
Range (unit: seconds)	7.88 – 41.1	6.56 – 45.5
Mann-Whitney U-test: U, U' (P-value)		56.5, 53.5 (.916)

Analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

- Both prototypes
  - Unnecessary parameter change
    - Food Browser: UP07, UP10, UP11, UP12 and UP13
    - List View: UP14
- Food Browser
  - Difficulty with recognition of images
    - UP14 confirmed name of "drue (grønn)" by opening a detail view.

In this task, participants did not have to change any parameter. However, when using Food Browser, five participants (UP07, UP10, UP11, UP12 and UP13) changed Y-axis to "Kalorier (in English: energy)" though X-axis was already "Kalorier". UP10 changed X-axis from energy to fiber as well, although fiber did not appear in the question. These five participants' task completion time records were the five longest among ones taken by using Food Browser. Regarding List View, it was only UP14 who did unnecessary parameter change. UP14 changed a parameter shown on the right-hand side from energy to carbohydrates, and set it back to energy. Sorting function in List View was used by five participants (UP08, UP11, UP12, UP14 and UP16). Table 11 summarizes these operations together with the results about by which prototype a participant completed the task faster. From Table 11, regardless of parameter change when using List View, all the participants who did parameter change when using Food Browser took longer time to complete the task when using Food Browser than List

View. For three participants (UP08, UP14 and UP16) who did not any parameter change when using Food Browser but did sorting (plus parameter change for UP14) in List View, task completion time was shorter when using Food Browser. These facts indicate that sorting operation in List View causes some time loss but not as much as parameter change in Food Browser. This implies that the task design was not good enough to test two prototypes for the aim of this task.

Table 11 Summary of operations done at RC2 and a prototype by which the task was completed in a shorter time (within participant comparison)

Participant	**Shorter task completion time by:**	**Unnecessary parameter change**		**Sorting operation (List View)**
		Food Browser	List View	
UP07	List View	x		
UP08	Food Browser			x
UP09	List View			
UP10	List View	x		
UP11	List View	x		x
UP12	List View	x		x
UP13	List View	x		
UP14	Food Browser		x	x
UP15	Food Browser			
UP16	Food Browser			x

RC3: To find out food items that satisfy conditions with regard to two nutrients. (proportion)

Figure 11 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Due to very few cases in which tasks were completed, and due to observations described below regarding the participants who completed tasks, I concluded that statistical comparison is meaningless for RC3.

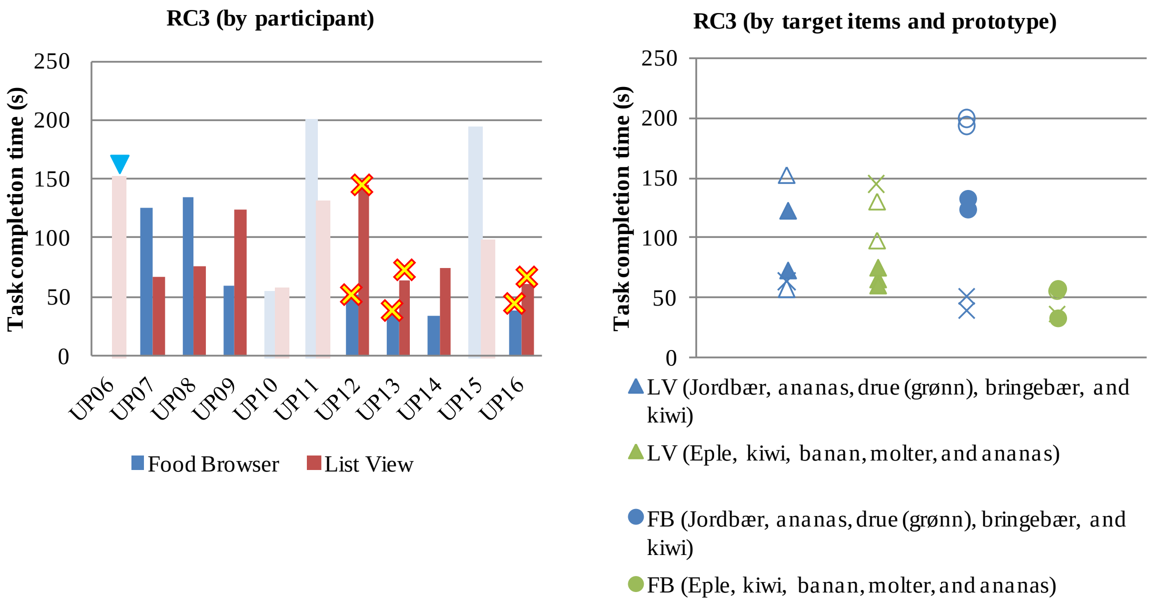


Figure 11 Task completion time for RC3

An error at RC3-1 by UP06 when using List View is due to a bug of List View that display values in misleading and error prone manner, explained as 2)-d)-i) previously.

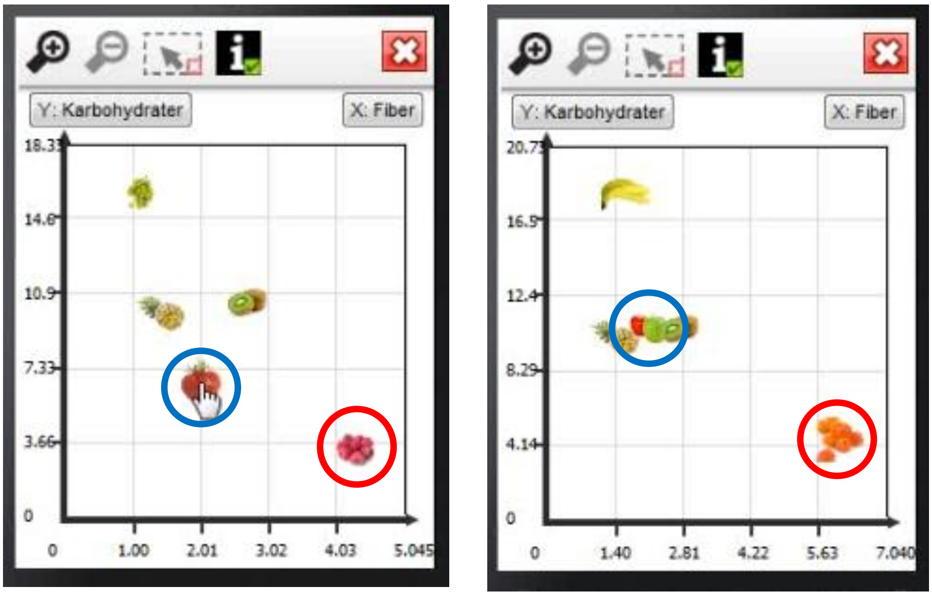
As described in Effectiveness section as 2)-a), low task completion rates and high error rates at the second question were mostly due to poor wordings of RC3-2, which was "Approximately how many more times carbohydrates does it (the item which has the most fiber) have compared with the one which has the third most fiber?". UP06, UP10, UP11, UP12, UP13, and UP15 did not understand meaning of the question, although during the test, one of us explained that the question asks them to compare in terms of proportion and it does not necessarily mean that the item with the most fiber has a greater amount of carbohydrates than the one with the third most fiber. This misconception led an incorrect answer by UP16 when using Food Browser, who calculated in the opposite way.

As also indicated at a reason 2)-b) described in Effectiveness section, "not setting two parameters that were asked about (fiber and carbohydrates)" was another reason for incompletion or error at RC3-2. At RC3-1, UP13 (by both prototypes) and UP16 (when using List View at RC3) changed one parameter to fiber from carbohydrates, which was set by default. Afterward, they did not change either parameter, fiber or energy, which were shown at that time. Therefore, they did not have any information to compare items with regard to carbohydrates. On the other hand, UP06 firstly changed one parameter on List View from carbohydrates to fiber, and she changed it back to carbohydrates instead of changing the other parameter. It seemed like that she tried memorizing two items to compare with regards to carbohydrates, but she gave up.

Regarding the task completion time records by the four participants who completed RC3 without error by using both prototypes (UP07, UP08, UP09 and UP14), analyses of captured video records revealed the following issues that caused a comparatively long task completion time or an obvious time loss.

- Food Browser
    - 1)-a), Difficulty in recognizing a difference in value between two food items which were too closely located on Scatter Plot (UP07 and UP08)
- List View
    - 2)-d)-i), Misleading display of values (UP09)
    - 2)-d)-ii), Direction and color of arrow above nutrition name not reflecting sorting of a list of selected items (UP14)

Figure 12 shows screenshots of Food Browser at RC3-2 for both item sets. Red and blue circles indicate items with the most fiber and the third most fiber, respectively. With item set B, pineapple, apple and kiwi are positioned very close to each other. Both UP07 and UP08 did not recognize that apple was the item with the third most fiber, and started to confirm values with a detail view of each item.



(a) Item set A (b) Item set B

Figure 12 Screenshot of Food Browser (Scatter Plot) for RC3. (X-axis: fiber, Y-axis: carbohydrates.)

When using List View, UP09 first misunderstood that the one with the most fiber was kiwi, and it took a while before he noticed that there was “molter” (in English: cloud berry) at the bottom of the list sorted in ascending order by fiber.

From Figure 11, it is apparent that these four participants took longer task completion time with a prototype by which they had a problem than with the other prototype. Considering the longer task completion time was nearly double length of the shorter task completion time for all the four participants, it is not reasonable to compare two prototype designs with regard to efficiency.

RC4: To find out food items that satisfy conditions with regard to two nutrients. (simple comparison in two nutrients)

Figure 13 shows task completion time by participant (on the left hand side) and by combination of target item and prototype (on the right hand side). Table 12 shows statistic summaries of task completion time. Calculations are based on records made by correctly completed tasks. Mann-Whitney's U-test could not discard the null hypothesis as task completion time when using one prototype does not tend to be shorter or longer than when using the other.

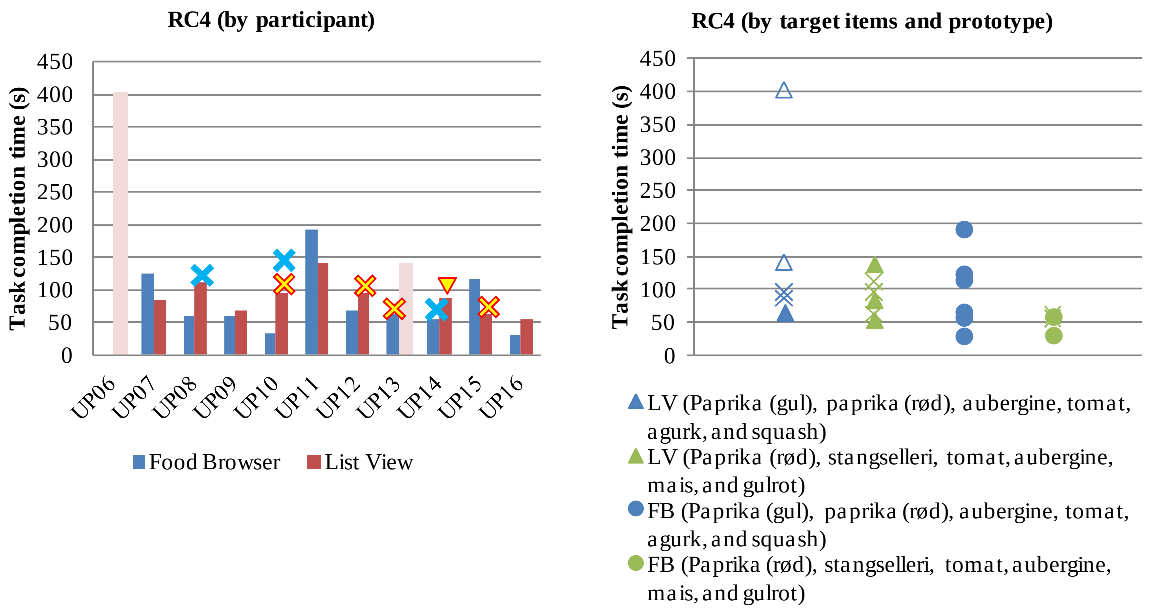
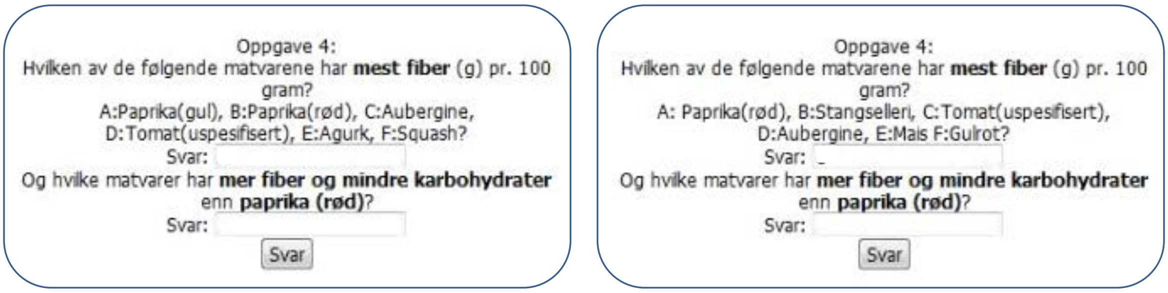


Figure 13 Task completion time for RC4

Table 12 Statistic summary of task completion time for RC4

	Food Browser	List View
Mean (SD) (unit: seconds)	85.30 (55.60)	86.73 (37.60)
Range (unit: seconds)	30.7 – 193	55.3 – 140
Mann-Whitney U-test: U, U' (P-value)	14, 18 (.808)	

Errors at RC4-1 by UP08, UP10 and UP14 are due to selecting a wrong option in spite of knowing a correct answer, explained as 2)-c) previously. UP08, UP14 (task set A), and UP10 (task set B) typed an option id (alphabet) which was next to the correct one. For UP08 and UP14, the correct answer was "A", but they typed "B", while for UP10 the correct answer was "E", but she typed "D". This implies the way of displaying options (Figure 14) was error-prone.



(a) Item set A (b) Item set B

Figure 14 How questions were shown at RC4

At RC4-2, reasons described under 1), "primarily due to user interaction/interface design of prototypes" in the Effectiveness section explain the following cases of incompletion and errors.

An error at RC4-2 by UP13 when using Food Browser can be explained by a reason 1)-a) "difficulty in recognizing a difference in value between two food items which were too closely located on Scatter Plot", as shown in **Error! Reference source not found.** (a).

Incompletion of RC4-2 by UP06 and UP13 when using List View can be explained by a reason 1)-b) "pure nature of text-, number- and list-based user-interface being difficult and error-prone to compare items in two parameters". UP06 and UP13 changed both parameters to correct ones (fiber and carbohydrates), repeated sorting the list by each parameter alternately, and ended up with giving up. This reason 1)-b) also caused an error at RC4-2. UP12 did not notice that "paprika (gull)" (in English: yellow bell pepper) is also a correct answer in addition to aubergine.

The other three errors are due to reasons 2)-b) (UP10 and UP15 when using List View) and 2)-d)-ii) (UP14 when using List View).

UP10 and UP15 changed a parameter from carbohydrates to fiber at RC4-1. Afterward, they changed neither axis. If the question at RC4-2 had asked about energy but not carbohydrates, the answer given by UP15 would have been correct, while this is not the case for UP10.

As obvious reasons for long task completion times or time loss, the followings were identified from analysis of captured video records.

- Food Browser
    - Extra time consumed irrelevant to task itself
        - UP07 first misunderstood the question to be "more fiber and more carbohydrates"
    - Difficulty with use due to user interaction design
        - UP11 did not notice that X-axis can be changed for a while.

- UP15 tried changing Y-axis to fiber, but it was not changed properly and UP15 did not notice that.

These three participants' task completion time was longer when using Food Browser than when using List View, although UP15 made an error at RC4-2. The other participants' task completion time was shorter when using Food Browser than when using List View.

When seeing the five most efficient cases, four out of the five are by using Food Browser (Table 13). The sixth fastest was by UP09 also when using Food Browser (60.0 seconds). The five participants whose task completion time when using Food Browser was within top five (UP08, UP09, UP10, UP14, and UP16) changed X-axis from energy to fiber at RC4-1, so that they did minimum number of operations through the task. On the other hand, the other participants changed Y-axis from carbohydrates to fiber at RC4-1 then changed X-axis from energy to carbohydrates when they started to work on RC4-2. Regarding tasks done with List View, difference in the number of operations such as parameter change and sorting did not obviously seem to have caused any delay or relatively fast completion, except the cases by UP10 and UP15 who did not do necessary parameter change and made an error at RC4-2.

Table 13 Top five of task completion time for RC4

Participant	**Prototype**	**Item set**	**Task completion time (seconds)**	**Error at RC4-1**
UP16	Food Browser	B	30.7	
UP10	Food Browser	A	31.8	
UP14	Food Browser	A	55.1	X
UP16	List View	A	55.3	
UP08	Food Browser	B	58.7	

Considering these issues described above as well as the result of Mann-Whitney U-test in spite of obvious reasons for long task completion times and time loss only observed in the cases when using Food Browser, to compare food items with regard to two parameters, such as "more than item A in parameter X but less than A in parameter Y", Food Browser's Scatter Plot user interaction/interface design can be competitive enough or even outperform List View interaction/interface design. However, this would also be depending on the number of items to compare and relative locations of icons on Scatter Plot.

APPENDIX 16

SUMMARY OF ADVICES OF A NUTRITIONIST AND WHAT I LEANED AT ANTIDIABETIC FOOD CENTER AT LUND UNIVERSITY

1. Summary of advices of a nutritionist

- Basics should be explained first
- Today's nutrition labels regarding amount of each type of carbohydrates and total amount of carbohydrates are sometimes confusing, for example, added sugar are included in the amount of mono- and disaccharide.
- Depending on type of carbohydrates, absorbing speed and level of blood-glucose increase differ. Therefore, amount of each type of carbohydrates should be shown.
- Fiber and potassium are important nutrients for patients with diabetes to pay attention to.
- Authorities don't favor using Glycemic Indices (GI) due to insufficient scientific knowledge regarding its benefit[1].
- The "dish model" ("tallerkenmodellen" in Norwegian) is recommended to implement.
- What types of nutrition information to focus on for each food item should shift depending on a type of the item. For example, amount of each type of fat should be shown for dairy products while amount of each type of carbohydrates should be shown for cereals.
- Focus on a few categories and products. Don't try to cover many food items.
- To make recommendations or suggestions of alternatives, follow conditions employed for "keyhole" symbols[2]
- Practical advices were given by a nutritionist about the appropriate food information and its organization to increase the benefit for patients with T2DM.
- Based on state-of-the art scientific knowledge, principles, strategies and tactics regarding food choice and preparation were summarized as a resource of information to provide.

2. Summary of what I learned at AFC - BASICS OF NUTRITIONAL SCIENCE WITH FOCUS ON BLOOD GLUCOSE INCREASE

PRINCIPLES

1. Keep the stable blood glucose level for the whole day (=avoid big excursions of blood glucose level)
2. Take 45-60% of necessary energy from carbohydrate (10-20% from protein, 35% from (unsaturated 20%, saturated <10%) fat)

STRATEGIES

1. Choose food items and food combinations that
    a. have as little and slow (moderate) impact as possible on the blood glucose level
    b. give as high and long-lasting satiety as possible
    c. have better influence on blood glucose level after the subsequent meal(s)
    d. (are digested slowly /make digestion slow: This applies the 3 items above)

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[1] http://www.matportalen.no/kosthold_og_helse/tema/kostrad/hvorfor_omtaler_ikke_helsemyndighetene_sporsmaalet_om_glykemisk_indeks_gi (Norwegian)

[2] http://www.nokkelhullsmerket.no/frontpage_en/article430.ece (English)

2. Eat often and little for each time (not exceeding total calorie intake for a day)
3. 750g (5 portions) of fruits and vegetables (according to Diabetesforbundet's brochure) e.g, 2 portions of fruits and 3 portions of vegetables
4. ¼-1/3 part of the meal plate for carbohydrate-rich food like potatoes, rice, cous-cous, pasta, and so on.

FACTORS/FEATURES OF FOODS FOR CONSIDERATION ON GLYCEMIC CONTROL

GLYCEMIC INDEX (GI)

GI is normally calculated from 120 minutes incremental postprandial blood glucose areas using 50g glucose as reference (D. J. Jenkins et al. 1981).

White Wheat Bread (WWB) that contains 50g carbohydrate can be used as a reference, and the value obtained from this method can be converted by using the ratio 70 (WWB): 100(Glucose)(Atkinson et al. 2008).

Low-GI foods are known to have the following effects:

- Playing a proactive role against certain cancers: ovarian (L. S. A. Augustin et al. 2003), breast (L. S. A. Augustin et al. 2001), and colorectal (Higginbotham et al. 2004; Franceschi et al. 2001)
- Reducing cardio vascular disease risk factors in Type 2 diabetes (Järvi et al. 1999)
- Improving glycemic control in Type 2 diabetes (Järvi et al. 1999)
- When eaten for breakfast,
  - improving insulin sensitivity at the time of the next meal (=one mechanism of the second meal effects) (T. M. S. Wolever et al. 1995)
  - postponing the "in-between-meal" fasting state (pasta breakfast) (H. G. Liljeberg & I. M. Björck 2000)

The following foods are known as low-GI foods on markets (Inger Björck et al. 2007; E. M. Östman et al. 2001):

- Bulgur
- Pumpernickel
- Barley
- Pasta (Y. Granfeldt & I. Björck 1991)
- Legumes (Tovar et al. 1992)
- Products based on whole cereal grains (Y. Granfeldt et al. 1994)

GI values should be used

1. As a hint when comparing/choosing food from similar/replaceable **carbohydrate rich products**.
2. Together with
   a. calorie intake by the portion considered
   b. carbohydrate amount in the portion considered
   c. satiety

GI values should **NOT (does not have to)** be used when the food contains

1. more than 30% of energy contribution by fat
2. less than 15 gram of carbohydrates

INSULINEMIC INDEX (II)

Insulinemic Index shows how much insulin is produced incrementally 2 hours after eating a target food containing 50g of carbohydrate, using 50g of glucose as a reference.

High and acute demands for insulin **induced by glucose**, which cause a short duration of hyperinsulinemia, may induce insulin resistance in healthy subjects (DeFronzo & Ferrannini 1991)

Insulin secretion is induced from different channel by glucose and protein. Glucose induced channel is more stressful to beta cells, while protein induced channel is less stressful to beta cell. Stress on beta cell wears function of beta cell, and it causes less effectiveness. Protein induced channel keep beta cell healthier.

DIETARY FIBER (DF)

SOLUBLE FIBER (IN CASE OF MIXTURE OF DIFFERENT LEVEL OF β-GLUCANS)

Effect: Lowering GI and II (E. Östman et al. 2006)
Mechanism: Soluble dietary fiber makes viscosity of the food in the intestine higher (= makes fluidity lower)

INSOLUBLE FIBER

Effect: High satiety, delaying appetite for the second meal, lowering glycemic response to meals consumed 75 minutes after the first meal for healthy men (Samra & Anderson 2007)
Mechanism: Unknown (probably hormone mechanism to transfer signals about the situation of colon to brain)

RESISTANT STARCH (RS)

RS is starch and starch degradation products that escape digestion in the small intestine of healthy individuals.
It is considered as the third type of dietary fiber, as it can deliver some of the benefits of insoluble fiber and some of the benefits of insoluble fiber.
There are 4 types of RS:

1. Physically inaccessible
2. Natural granular form (ex. Raw potato, green banana)
3. Cooked and cooled (chilled) down
4. Chemically modified.

Effect: Modulating glycemia at subsequent meals (in combination with low-GI food) (Inger Björck et al. 2007)
Mechanism: Promoting colonic fermentation

LACTIC ACID FOR BAKING (SOURDOUGH BAKING) – DURING STARCH GELATINIZATION

Effect: Lowering GI and II (H. G. Liljeberg et al. 1995)
Mechanism:

- Lactic acid creates macromolecular interactions between starch and cereal protein (=making barrier to amylolysis)
- Lactic acid promotes retrogradation of starch.

ACETIC ACID

Effect: Lowering GI and II, increasing satiety
Mechanism: Acetic acid reduces rate of gastric emptying

GELATINIZATION (UNDER 12%)

Effect: Lowering GI
Mechanism: Low enough level of gelatinization can keep high crystallinity. (=physically big size, which is difficult to digest)

Flaking of cereals under commercial conditions results in 24-40% of gelatinization level, which results in high GI (above 90)

"Easy-to-understand" examples of food products with low (under 12%) gelatinization: Minimum/Less processing (eat them as they are, e.g., muesli)

AMYLOSE RETROGRADATION

Effect: Lowering GI (Helena Liljeberg et al. 1996)
Mechanism: Amylose retrogradation favors a slower enzymatic digestion.
(heat retrograded food > just boiled, cooked)

Amylose retrogradation is specifically promoted by pumpernickel baking (low temperature (100 degree Celsius), long baking duration)

WHOLE GRAIN RYE PRODUCTS

Effect: Lowering II (not GI)
Mechanism: Unknown

BARLEY KERNELS FOR EVENING MEAL

Effect: Improving glycemic response (IAUC for blood glucose) after subsequent meals on the next day
Mechanism:

- Colonic fermentation of RS and DF, which makes short chain fatty acid (acetic acid, propionic acid (good for lowering cholesterol), butyric acid (good to prevent colonic cancer) that improve glucose tolerance, is promoted
- Plasma concentration of propionate, which influence on metabolic system of lever, is increased

MILK PRODUCTS (WHEY)

Effect: Lowering GI, improving glucose regulation, Stimulating insulin secretion
Mechanism: whey protein enhances insulin secretion (in better (less stressful manner) than glucose induced insulin secretion) and insulin sensitivity (not yet clear)

TACTICS

CHOOSE RATHER XX THAN YY

- Muesli (or bran, kernel type breakfast cereals) than corn flakes
- Young (not fully ripe) fruits than ripe fruits [More RS]
- Less processed food (coarse, with bran) than highly processed (fine, without bran) food

SUGGESTION FOR "HOW TO EAT" (WHEN, WITH WHAT, ETC.)

- Adding vinegar to high-GI food (ex., white wheat bread, boiled potato) [Lowering GI and II]

- Cool down and store boiled potato [Retrogradation]
- "Tallerkenmodellen" (1/2: vegetables and legumes, 1/4: rice, pasta, potato, bread, 1/4: fish, egg meat)
- 1-3 slices of bread for each bread meal
- 15-20 g of carbohydrate per serving does not critically influence on glycemic response
    - For sweet snacks (chocolate, etc.) or soft drinks, consider this value
        - Chocolate, ice cream (Low GI due to much fat) -> not suitable in the case of hypoglycemia
        - Soft drinks (> orange juice > apple juice): High GI -> suitable in the case of hypoglycemia
    - Still it needs to be considered as a part of calorie intake
    - Ex., one portion of potato crisp is 25 gram (approx. the size of a fist)
- Potato (baked potato(less gelatinization) >Boiled potato > potato salad > French fries, mashed potato)
    - GI and calorie perspective (it depends on patient's obesity status and activity level and so on)
    - Satiety
        - Low-GI food gives better appetite regulation (avoid hunger)

BREAKFAST

- Barley kernel breakfast [day-long glycemia]
- Low-GI food [second meal effect]
- Pasta (salad)[second-meal effect, postponing "in-between-meal" fasting state]
- Muesli (or bran, kernel type breakfast cereals) with yoghurt [low GI +low GI]
    - Milk product (whey) induces (or keeps) II by protein, which is good.

EVENING MEAL

- Barley kernel [overnight perspective]

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APPENDIX 17

USER MANUAL FOR A WEB APPLICATION OF A MODIFIED LIST VIEW WITH FOOD IMAGE ICONS NEXT TO ITS NAME IN THE LIST OF ITEMS

Bruksanvisning

1. Søk etter informasjon om matvarer
2. Sammenlikn matvarer i forhold til karbohydrater, sukker, kalorier, fiber og fett

Opplysningene i katalogen

Denne matvarekatalogen inneholder informasjon om 198 matvarer med hensyn til viktige næringsstoffer. Den gir deg også nyttige tips for å ha kontroll over diabetesen.

Matvarene i katalogen står både i brosjyren "Karbohydrater og insulin - Tilpass insulin til maten du spiser" og på Matvaretabellen 2006 (MVT-06). I tillegg vil du finne en rekke grønnsaker og frukt.

Opplysningene om næringsinnholdet er hentet fra Matvaretabellen 2006 (MVT-06).

Ved noen av matvarene er det også en Glykemisk Indeks (GI). GI verdiene er hentet fra "International Tables of Glycemic Index and Glycemic Load Values: 2008" (se detaljert informasjon under Referanser [5])
"GI note" under GI verdiene viser referansetabell og nummer til matvaren det henvises til.

Nummer i klamme: [ ] i tekstene er referansenummer. Detaljert informasjon om alle referansene kan finnes under Referanser.

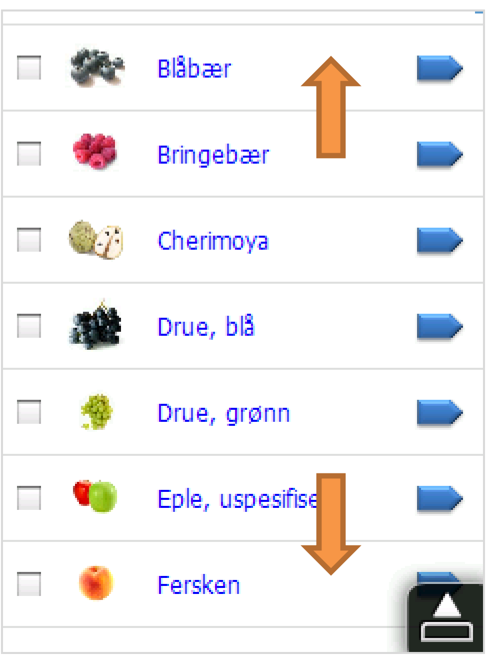
1. Søk etter informasjon om matvarer

Matvarene er delt inn i matvaregrupper og undergrupper.
Den første siden viser matvaregruppene.

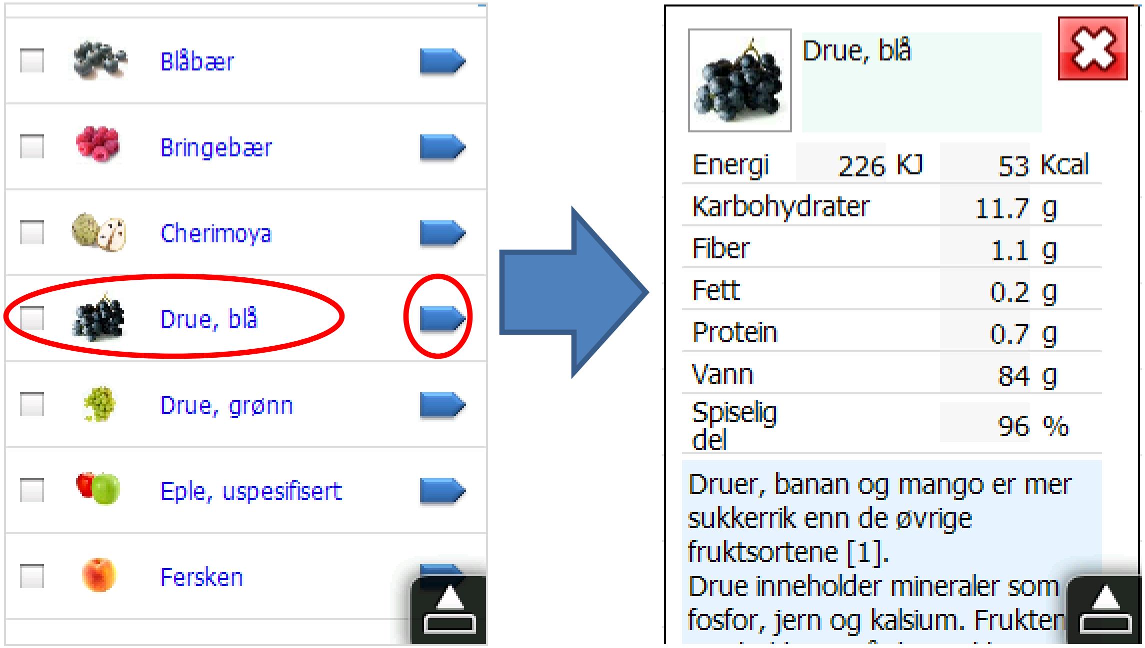
Ved å trykke på matvaregruppen eller den blå pilen vil man få opp en mer detaljert liste (undergrupper).

Ved å trykke på undergruppen eller den blå pilen får man opp listen over de enkelte matvarene.

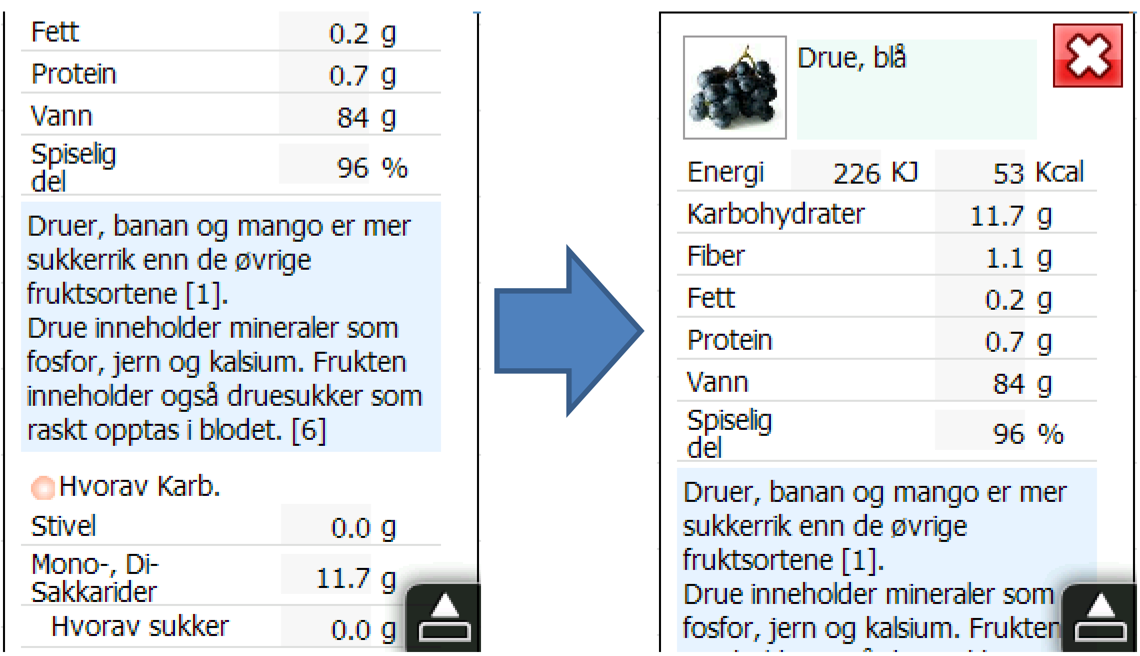
Er listen lang kan man rulle ned- og oppover med fingeren.



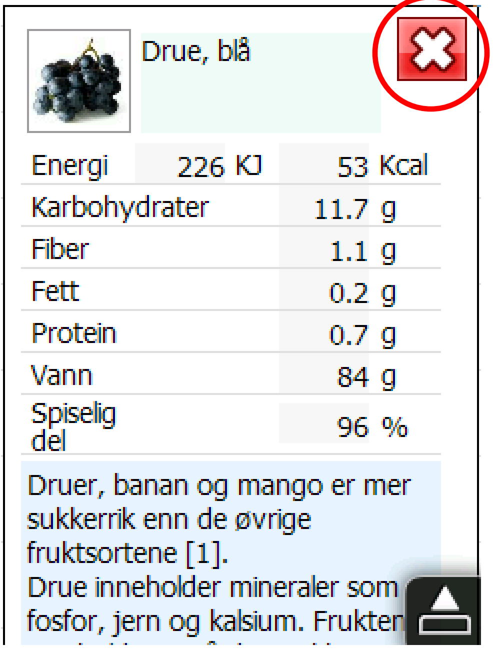
Trykker man på produktet eller den blå pilen , vil man få opp en oversikt over næringsinnholdet, og kunne lese annen relevant informasjon.
Rull nedover med fingeren om vinduet er for lite.



Om et vindu kommer opp midt på siden kan man rulle seg opp til toppen.



For å lukke vinduet, trykk  knappen øverst i høyre hjørne.



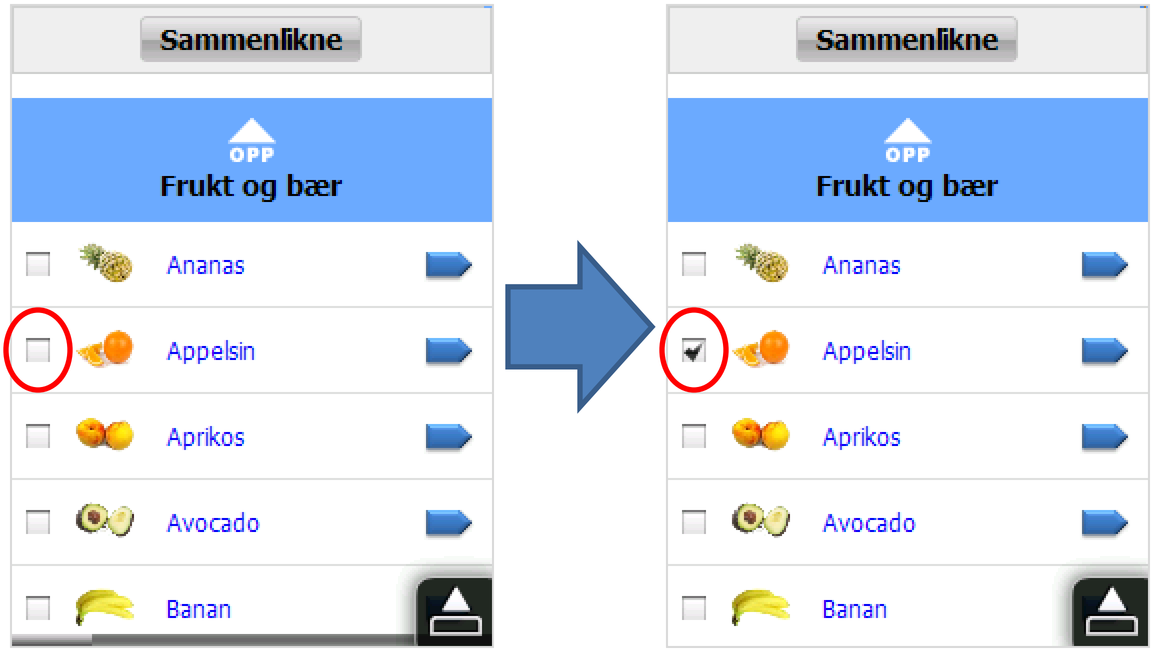
Ved å trykke  kommer man tilbake til listen over undergrupper.

På samme måte kommer man tilbake til listen over matvaregrupper.

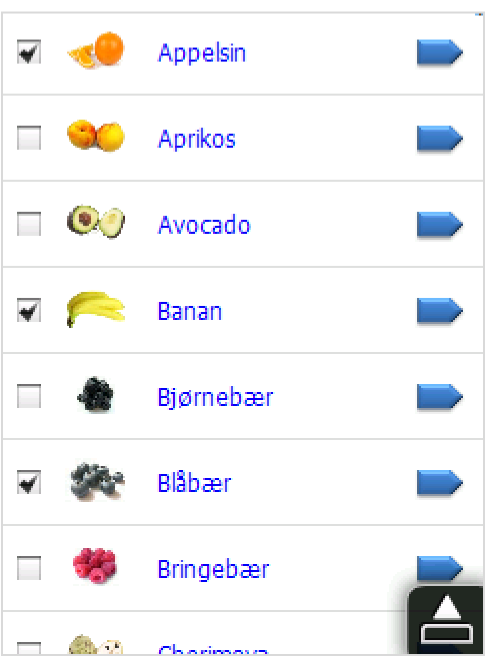
2. Sammenlikn matvarer i forhold til karbohydrater, sukker, kalorier, fiber og fett

Man kan sammenlikne flere næringsstoffer i matvarer (karbohydrater, fett, fiber, kalorier og sukker).

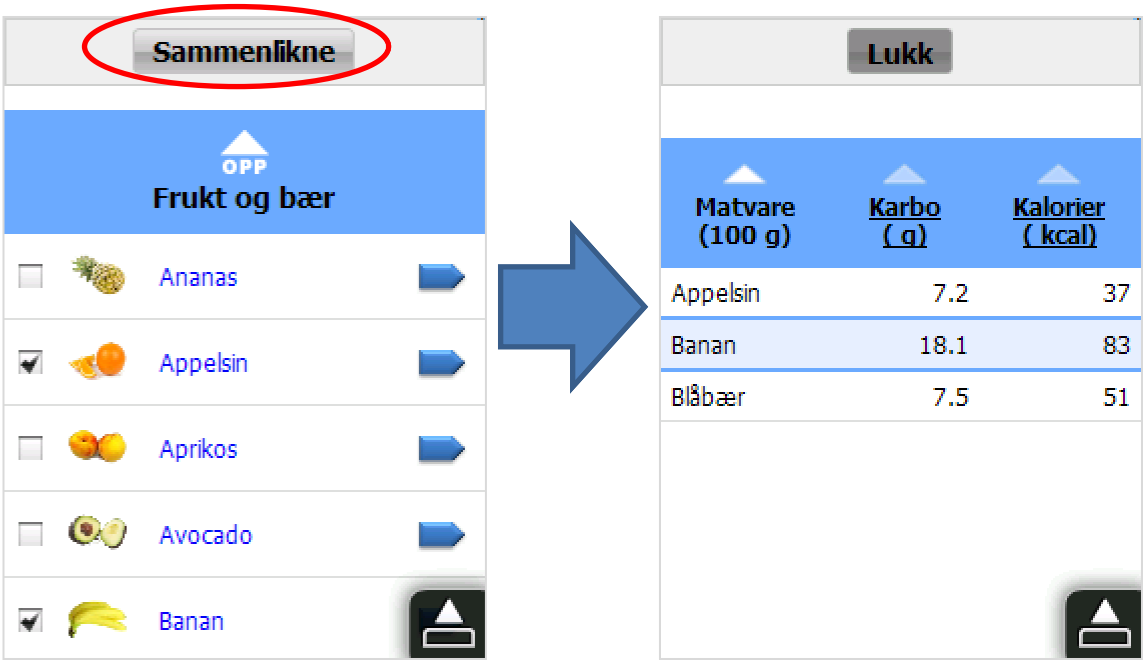
For å gjøre en sammenlikning, trykk på firkanten til venstre for matvaren. Det vil komme opp en hake i firkanten.



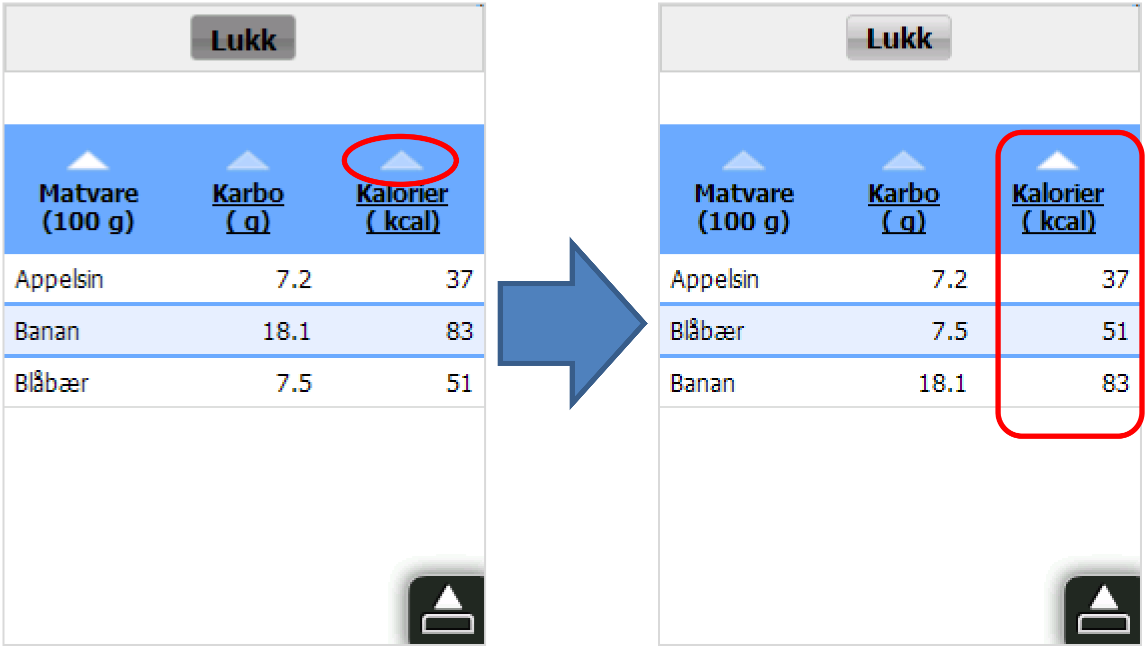
Hak av alle matvarene du ønsker å sammenlikne



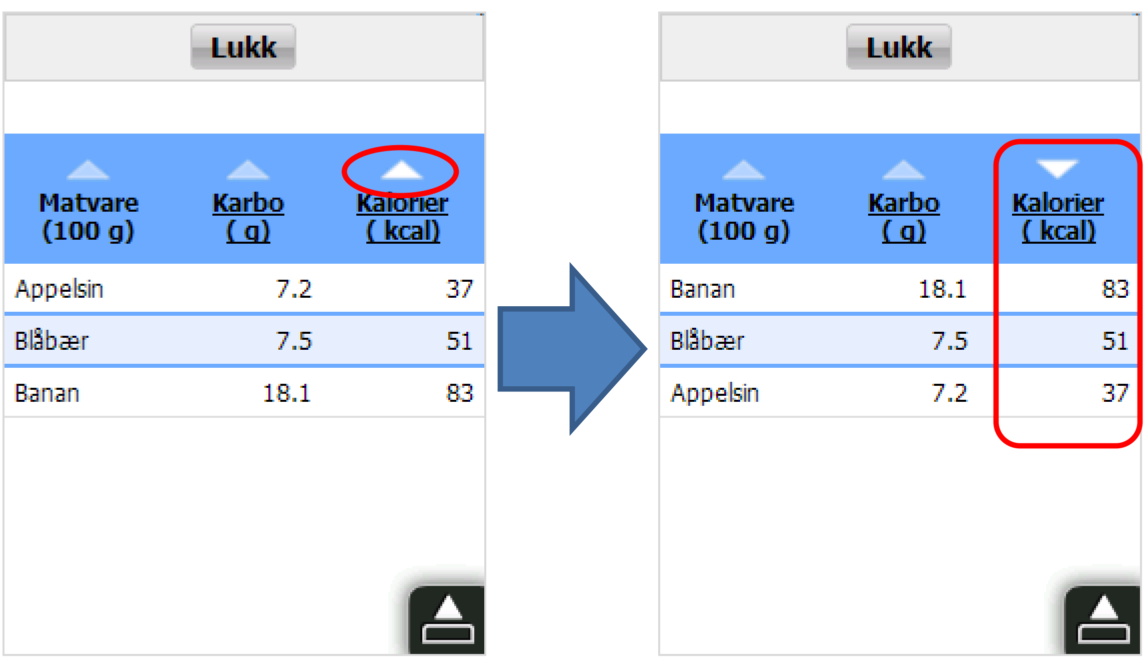
Trykk **Sammenlikne** og det vil komme opp en alfabetisk liste over de valgte produktene med verdier for to forskjellige næringsstoffer.



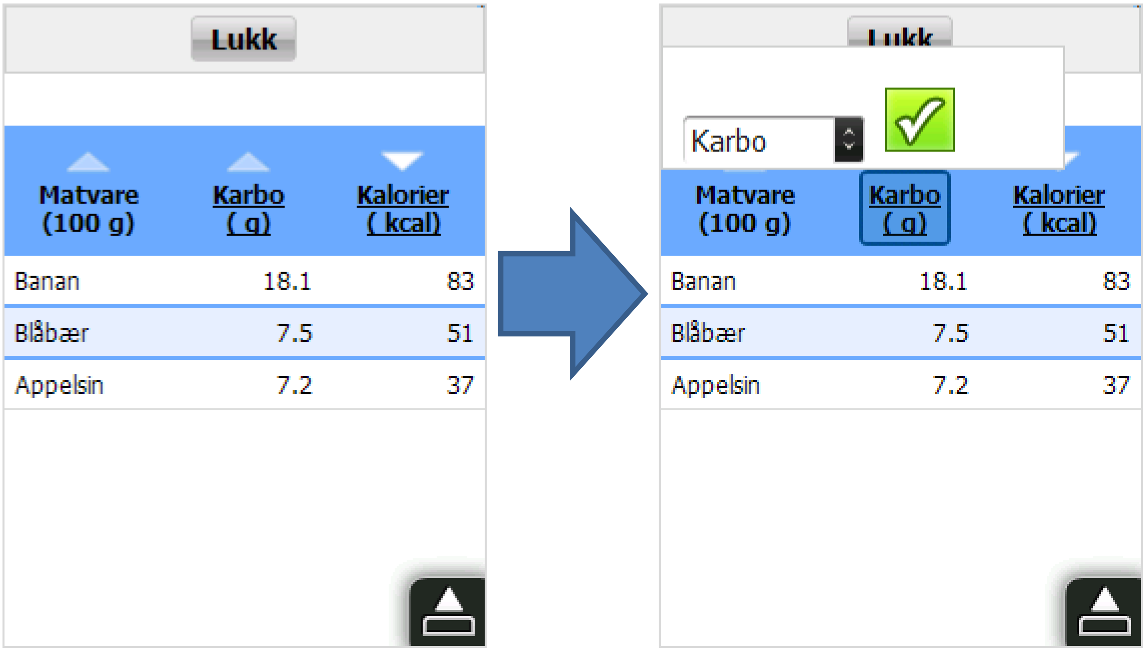
For å sortere matvarene etter næringsverdi, trykk på trekanten over næringsstoffet du vil se på. Det vil bli sortert fra lavest til høyest.



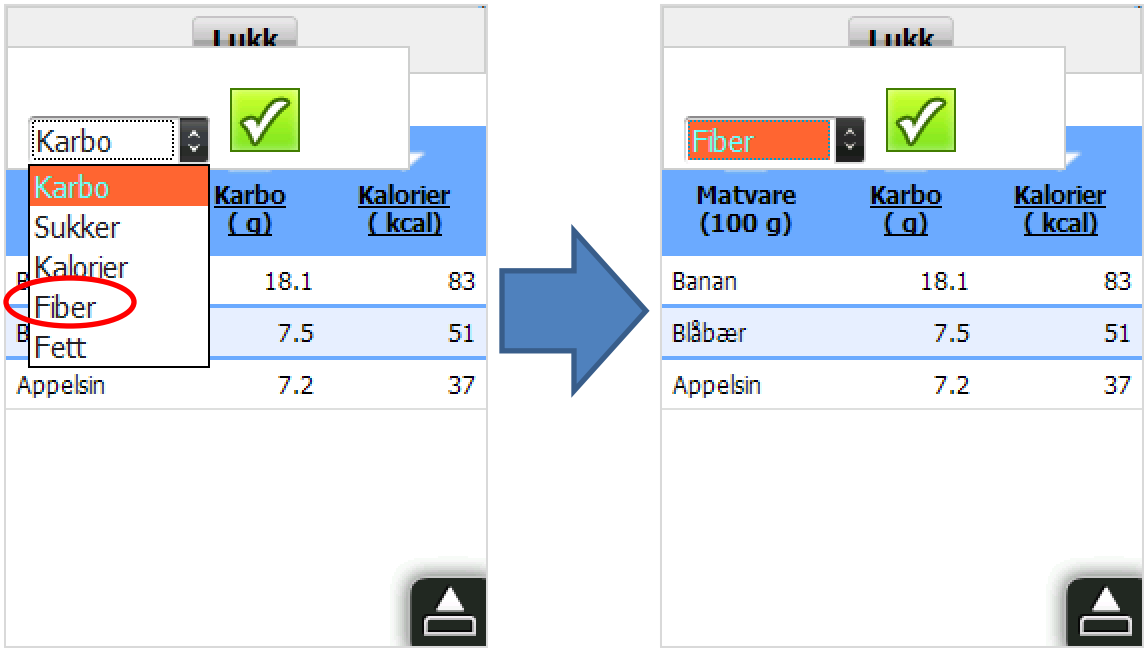
Ved å trykke på trekanten igjen, sorteres matvarene omvendt, fra høyest til lavest verdi.



For å se flere næringsstoffer, trykk på ett av de som vises (vilkårlig. Her er det ”Karbo” på venstre) . Det vil komme opp et hvitt felt med navnet til næringsstoffet, og en grønn knapp.



Feltet kan åpnes ved et trykk. Marker næringsstoffet du ønsker å få opp og trykk den grønne knappen.
Matvarene vil bli sortert i forhold til verdien til det valgte næringsstoffet. (lavest til høyest)



For å komme tilbake til listen over matvarer, trykk **Lukk**