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Mobile Phone-Based Self-Management Tools for Type 2 Diabetes: The Few Touch Application

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Abstract

Background:

Mobile phones and other mobile information and communication technology applications and technologies hold great potential as a basis for powerful patient-operated self-management tools within diabetes. The work presented shows how such tools can be designed for supporting lifestyle changes among people with type 2 diabetes and how these were perceived by a group of 12 patients during a 6-month period.

Method:

The study used focus groups, interviews, feasibility testing, questionnaires, paper prototyping, and prototyping of both software and hardware components. The design process was iterative, addressing the various elements several times at an increasing level of detail. The final test of the application was done qualitatively in everyday settings in a cohort of 12 people with type 2 diabetes, aged 44–70 (four men and eight women).

Results:

A mobile phone-based system called the Few Touch application was developed. The system includes an off-the-shelf blood glucose (BG) meter, a tailor-made step counter, and software for recording food habits and providing feedback on how users perform in relation to their own personal goals. User feedback from the 6-month user intervention demonstrated good usability of the tested system, and several of the participants adjusted their medication, food habits, and/or physical activity. Of the five different functionalities, the cohort considered the BG sensor system the best.

Conclusions:

It was shown that it is possible and feasible to design an application where several sensors and feedback applications are integrated in an overall system. The presented Few Touch application challenges people with type 2 diabetes to think about how they can improve their health, providing them with a way to capture and analyze relevant personal information about their disease. The half-year user intervention demonstrated that the system had a motivational effect on the users.

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Abbreviations: (BG) blood glucose, (ICT) information and communication technologies, (RCT) randomized controlled trial, (SUS) System Usability Scale

Keywords: blood glucose, diabetes, mobile phone, nutrition, physical activity, self-management

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Introduction

Fueled by the epidemic proportions of lifestyle-related diseases, many players are seeking to design low-cost and tailored information and communication technology (ICT)-based systems for supporting lifestyle changes and disease management. The thorough review of computerized knowledge management in diabetes care by Balas and colleagues[1] showed the growing importance of electronic tools, with documented benefits in improving diabetes-related outcomes. The randomized controlled trial (RCT)(n = 866) by Williams and associates[2] also showed a significant positive effect of computer-assisted diabetes care on diabetes self-management. Until recently, tools for changing lifestyle behavior were based mainly on stationary terminals (personal computers and televisions). A study by Tatara and colleagues[3] from 2008 showed a rapid increase in publications addressing mobile self-help tools within diabetes from 2001 to 2008. The powerful handheld terminals emerging today provide a totally new foundation for "always available" tools, e.g., the Windows Mobile terminals[4] and the Apple's iPhone terminal.[5]

The biological revolution, with advances in genetics and biomedical engineering, has brought new diagnostic tests and sensors. Advances in ICT in general have provided us with hardware and software that offer great benefits for self-management systems. However, many of the patient-operated health tools on the market do not fully utilize the potential that technology provides for a truly user-friendly and useful end product. In Czaja and Lee's review[6] of designs of computer systems for older adults, they concluded that issues such as screen design, input devices, and interface style are largely unexplored. They also emphasized the importance of knowing why the technology may be difficult to use, how to design for easier and more effective use, and how to teach users to take advantage of the available technologies. There are still few systems where several sensors and feedback applications are integrated in an overall system, an attribute that is especially needed in systems for the compound challenges faced by people with diabetes. Thus, the main problem addressed in the presented work is how can a mobile system for monitoring of blood glucose, nutrition habits, and physical activity be designed in a way that will motivate patients to use them and benefit from them on a daily basis?

Many of the system designs presented in this article are inspired by research on human computer interaction, e.g., by Höök,[7] who stated: "A design process that fails to involve end-users in the design loop will fail to recognize the particular quirks and problems of how to design these artifacts." Much time and effort have therefore been spent on involving real users (people with type 2 diabetes) in design and testing—from early paper prototypes to near-finished prototypes right before the user interventions.

Methods

User Involvement

The study protocol was approved by the local regional ethical committee in 2006 (Regional komité for medisinsk forskningsetikk Nord, Ref. No. 13/2006). Fifteen people with type 2 diabetes were recruited through letters sent to all members of the local diabetes association aged 40–70. A few of these were also recruited at a members' meeting. Fifteen members of the cohort were involved in the design process from February 2007 to April 2007, when 1 withdrew for medical reasons. Thus, 14 members participated in the process until the start of the 6-month study in September 2008. Two of the participants could not take part in the study, as they were going to move to another part of the country. The result was that 12 persons participated in the test of the systems in their daily lives from September 2008 to March 2009. Four participants were men, and the 12 participants were aged between 44 and 70 at the start of the 6-month study, with an average age of 56.2 (a standard deviation of 9.6).

Design and Research Methods

Both design and research methods were used in this study. An iterative design process, described elsewhere,[8] where 12–15 participants were involved, generated the design requirements and answers to research questions. This entailed working toward getting the interfaces and interpretations as good as possible and then evaluating whether the aspects of the systems contributed to the goals. The specific methodologies used involved arranging focus groups, semistructured interviews and feasibility testing, tailor-made questionnaires, implementation of software and hardware components, automatic logging of all entered and automatically transferred user data, and manual logging of all contact with the participants. The paper prototyping method[9] and the System Usability Scale (SUS)[10] were used to obtain the cohort's subjective assessments of usability. Throughout the design period, 12–15 patients were involved in focus group meetings, from discussion of the problems to tests of the designs. The resulting Few Touch application is currently owned by the Norwegian Centre for Integrated Care and Telemedicine, and the plan is to use it in subsequent studies.

Results

Design of the Few Touch Application

On the basis of experience from previous studies,[11,12] the main design criterion was that functionality should be as automatic as possible, demanding little time and effort. The underlying premise is that self-help tools must be as automatic and easy to use as possible to avoid adding to the burdens of people with chronic diseases, as argued by Jensen and Larsen.[13] The chosen elements of the Few Touch application are based on the cornerstones of diabetes management: healthy diet, blood glucose (BG) management, and physical activity. The designed elements are integrated and interconnected in a mobile terminal-based application. The application is designed around the mobile phone HTC Touch Dual (HTC Corporation, Taiwan), but works on most phones with Windows Mobile operating systems.

Fully automatic data transfer was achieved for the BG sensor system and the physical activity sensor system using Bluetooth (Bluetooth SIG, Inc., Bellevue, WA), which is so far the only short-range communication standard widely implemented on mobile phones. The BG sensor system was initially made by our research group as described elsewhere,[11] but for this study a system involving the Food and Drug Administration-approved Polytel Bluetooth adapter (Polymap Wireless, LLC, Tucson, AZ) was made. This was connected to the OneTouch Ultra 2 blood glucose monitor (LifeScan Inc., Milpitas, CA). For recording physical activity, a tailor-made step counter was designed as described elsewhere,[14] enabling wireless communication with the mobile phone using Bluetooth. Where manual operation was inevitable, we applied "few-touch" principles to minimize users' effort and time. Thus, the nutrition habit registration system was based on data capture achieved by using the fingers to tap a few times on the touch-sensitive phone screen.[15] The same few-touch principle applies to retrospective access of BG and physical activity data, setting personal goals, accessing general information, and accessing ordinary phone functionalities from the main menu (see **Figure 1** for some examples of these user interfaces).

The three functionalities of the application—the BG sensor system, the nutrition habit registration system, and the personal goals functionality—were introduced to the cohort in September 2008. The general information functionality (daily tips) was introduced after 7 weeks, at the end of October. The physical activity sensor system was introduced in mid-January 2009 and was used for an average of 58 days (see **Table 1**).

Figure 1. Mobile phone displaying the main menu, step count feedback screen, goal setting, and general information as part of the Few Touch application; red disks in the main menu indicate choices made for the three subsequent user interfaces.

Table 1.
Statistics for Use of the Physical Activity Sensor System; Average Steps Taken in the First Week of Use versus the Last Week of Use and Maximum Steps Taken in This Period for the 12 Members of the Type 2 Cohort[a]

User	Days of use	No. of readings	Average first week	Average last week	Maximum steps
User 1	48	220	10,222	9,489	19,063
User 2	63	59	5,574	6,208	10,843
User 3	54	54	1,760	2,515	5,144
User 4	56	58	7,163	11,284	15,193
User 5	89	103	7,094	10,000	16,860
User 6	60	226	3,839	3,038	7,170
User 7	32	51	3,717	5,588	6,581
User 8	50	93	4,118	5,988	11,028
User 9	60	89	4,813	5,317	16,363
User 10	40	62	2,927	2,763	4,376
User 11	55	134	9,508	10,301	20,222
User 12	91	98	3,522	5,013	7,796
Average	58	104	5,355	6,459	11,720

[a] First and last week averages are calculated on the basis of the nearest 7 days with valid recordings. This is because there are generally some days in a full week where data are not transferred.

Results of Testing the Blood Glucose Sensor System

The system functions without needing any more effort from the user than traditional BG measurements. After each measurement, the system automatically transfers the BG value using Bluetooth and lists the last seven BG values on the phone screen, with the current measurement at the top. With one touch on this pop-up list, users can also display a graph of the 50 last measurements (see **Figure 2**). In addition, these data and further information are available whenever users want to access the various data presentation screens for overviews and analysis. In the average test period of 167 days, the number of recorded BG measurements varied from 23 to 564 per user (see **Table 2**). The average for the 12 patients was 202 measurements. For the seven users who measured their BG values one or more times per day, the frequency was unchanged during the test period. The other five users measured their BG more often at the start of the period than in the middle and the end of the period.

Analyzing the users' databases, comparing BG values from the first 2 weeks with the last 2 weeks, we found a slight improvement for the group: 142 mg/dl versus 140 mg/dl. The average BG value improved (i.e., decreased) for six patients, remained unchanged for two patients, and increased for four patients. Visual presentations of BG graphs from two patients with 166 and 504 BG readings, respectively, are shown in **Figures 3** and **4**. **Figure 3** demonstrates the effects external factors can have on the patients' BG; this participant reported that the high BG values during February were caused by influenza. **Figure 4** illustrates BG values that vary considerably, but show an overall positive trend throughout the study.

From the focus group meetings after the study, the following quotations illustrate the variety of personal experience and perceptions of the BG sensor system:

"I can clearly see that the blood glucose graph is moving downward when I manage to hold the focus."

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

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

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

Figure 2. The BG element of the Few Touch application; red disks indicate choices made and arrows point to subsequent screen feedback.

Table 2.
Statistics for Use of the BG Sensor System: Number of Measurements, and Thus Uploads of BG Data, and Number of Days the System Was Used by the 12 members of the Type 2 Cohort

User	No. of measurements	Period of days in use
User 1	71	184
User 2	102	182
User 3	192	182
User 4	23	99
User 5	252	180
User 6	564	180
User 7	229	161
User 8	29	184
User 9	170	139
User 10	504	181
User 11	126	155
User 12	166	184
Average	202	167

Users were thus generally satisfied with the BG system, which is also confirmed by the relatively high usage of the system, i.e., 7 out of 12 used it one or more times per day.

Results of Testing the Nutrition Habit Registration System

The nutrition habit registration system was also tested during the whole 6-month intervention period. Unlike the two sensor systems (BG and physical activity), this registration system required manual data input, i.e., touching the touch-sensitive screen of the phone and choosing the corresponding food type. After each recording, the Few Touch application displays the user's progress in achieving his/her three food habit aims (see **Figure 5**).

Among all participants, the food habit recording application was used to register food and drinks 5.1 times daily on average. The most frequent user had a usage of 11.7 daily inputs, while the least frequent user used it once

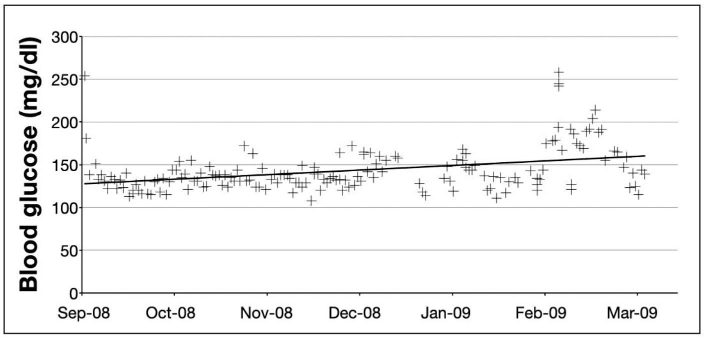

Figure 3. Blood glucose measurements for a patient in the half-year test period (trend line is indicated by the solid line).

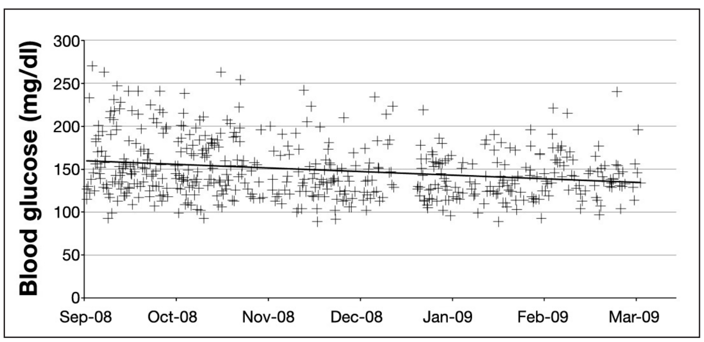

Figure 4. Blood glucose measurements for another patient in the half-year test period (trend line is indicated by the solid line).

Figure 5. Procedure for recording food habits; red disks indicate choices made, starting at the left user interface.

a week. At the focus group meetings in the spring of 2007, we learned that the three nutrition elements that most patients would like to improve were (A) eating more fruits and vegetables, (B) eating more meals a day, and (C) eating less carbohydrate-rich food.[15] Thus, the following three elements were implemented in the nutrition habit registration system, and usage was addressed in focus groups and questionnaires.

A. Seven of the users (58%) reported through questionnaires that they had increased their daily intake of fruits and vegetables, three of the users (25%) said that there was no change, and two (17%) reported a decrease. Analysis of the database reflecting use of the Few Touch application showed that for "Low carb. snack"—representing fruits and vegetables—seven of the participants had registered a considerable amount of fruit and vegetables, i.e., more than 100 units over the half-year period (see **Table 3** for details).

B. Four (33%) of the users reported that they had increased the number of daily meals, five (42%) of them reported no change, and three (25%) reported a decrease. When analyzing the database for recorded meal intakes for the total period, we found that patients registered data most frequently at the start of the study, but most of them kept up the food habit recordings fairly intensively throughout the half-year period (**Table 4**).

C. By analyzing the log file of the Few Touch application and comparing the first 2 weeks with the last 2 weeks, we found the following positive trend: participants generally had a reduced intake of carbohydrate-rich food types toward the end of the study compared with the beginning of the study. More specifically, nine participants had a reduction, two had an increase, and one (user 9) had too few recordings in total to be included.

The response from the users in the focus group meetings illustrates that the system was helpful to many of the patients, but that not all found this kind of nutrition habit registration system useful; there were several wishes for changes to the system:

"This is a tool that can help you to learn more about yourself, but sometimes I become tired of recording what I eat each day."

"I don't use the nutrition habit registration system, since I have a very balanced diet with few carbohydrates."

"The categorization of the food types is perhaps a bit rough."

"It is also feedback, or confirmation, that the things I eat on a daily basis are what I have found healthy."

Summarizing all feedback from the questionnaires and focus group meetings, we concluded that the food habit-recording component of the Few Touch application seems to be most useful as a tool for working with fruit and vegetable habits, i.e., element "A" described earlier.

Table 3.
Types and Amount of Food Intake Recorded Using the Few Touch Application for the 12 Members in the Type 2 Diabetes Cohort during the Half-Year Study[a]

User	High carb. snack	Low carb. snack	High carb. meal	Low carb. meal	High carb. drink	Low carb. drink	Total recordings
User 1	0	106	14	206	21	166	513
User 2	8	29	10	36	7	31	121
User 3	41	417	15	623	35	738	1,869
User 4	0	4	4	10	2	20	40
User 5	73	216	37	229	72	424	1,051
User 6	34	404	26	440	20	578	1,502
User 7	37	75	73	199	19	168	571
User 8	431	154	551	98	474	433	2,141
User 9	1	5	2	1	1	4	14
User 10	8	21	20	143	1	159	352
User 11	28	221	96	349	2	4	700
User 12	25	338	15	457	7	436	1,278

[a] The six categories starting with "High carb. snack" correspond to registration of food intake using the user interface and choices seen in **Figure 5** and denote food/drink intakes that the user categorizes as having either a high or a low content of carbohydrates.

Table 4.
Recorded Food Intake for the 12 Study Participants during the Half-Year Study Distributed by Users and Months[a]

User	Sep. 08	Oct. 08	Nov. 08	Dec. 08	Jan. 09	Feb. 09	Mar. 09	Total
User 1	70	163	127	40	67	13	33	513
User 2	20	7	54	12	12	6	10	121
User 3	133	288	232	322	452	308	134	1,869
User 4	24	15	0	1	0	0	0	40
User 5	96	170	164	151	178	175	117	1,051
User 6	128	282	293	206	219	219	155	1,502
User 7	—	108	109	110	166	21	57	571
User 8	164	339	339	291	413	337	258	2,141
User 9	—	—	7	3	0	2	2	14
User 10	102	54	65	71	30	48	36	352
User 11	—	174	165	119	102	88	52	700
User 12	135	302	219	202	232	95	93	1,278
Average	7.5	5.7	4.9	4.1	5	3.9	4.6	5.1

[a] Cells marked "—" represent either months where the user had not started the study (users 7 and 11) or data loss (user 9).

Results of Testing the Physical Activity Sensor System

This system was tested by 10 of the 12 patients for 2 months and by the last 2 patients for 3 months. The specially designed step counter automatically transfers and displays the number of steps to the user's mobile phone each evening at around 10 pm; see the second picture in **Figure 1**. In addition, users can transfer the number of steps to their mobile phone at any time of the day by pressing the only button of the step counter.

The average period of use was 58 days for the cohort. On average, users transferred data manually (pressed the button) 0.9 times a day, where the most eager user transferred data 3.6 times a day and the least eager none. The 12 participants reported in questionnaires that they checked the physical activity graph on the mobile phone once per day. Six of the 12 users experienced malfunctions with the step counter during the test period—usually a lack of battery capacity or an internal "hang-up" in the device that needed a hard restart. One of these had major problems, resulting in little use.

Regarding satisfaction with the step counter system, five answered "very satisfied," three answered "fairly satisfied," and four answered "neither satisfied nor dissatisfied." For the period of use, there was an increase in the number of steps from the first week they used the sensor system to the last week (see **Table 1**). As shown in **Table 1**, nine of the participants increased their number of steps, while three experienced a decrease in their number of steps. **Table 1** also shows how often the users manually transferred the number of steps to the Few Touch application, i.e., the "No. of readings" minus "Days of use," as one reading each day was automatically transferred to the application.

Some of the patients' comments on the system were:

"I think that the step counter is too big and it is a pity that I have to wear it attached to a belt."

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

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

Most of the users expressed enthusiasm for the physical activity sensor system when they met in the last focus group meetings, despite a relatively high error rate for the step counter. In addition to the malfunctions, the large size (6 × 4 × 1.5 cm) and the fact that the sensor unit only recorded steps (not skiing, cycling, swimming, etc.) were mentioned as the biggest disadvantages. The concept of visually having an overview of the number of steps on their mobile phone was highly appreciated. Among all the 12 patients, there was an increase of 20% in the number of steps from the first week to the last week of use.

Results of Testing Personal Goals and General Information Functionalities

As **Figure 1** shows, patients were able to set, view, and change their personal goals related to food habits and physical activity. For both parameters, the users received immediate feedback after data capture from the system related to whether or not they had achieved their goals. Generally, many of the patients reported that they were motivated by the challenges of trying to reach the red line representing the aim for daily steps (see **Figure 6**) and trying to achieve a smiley face representing attaining their food habit goals (see **Figure 5**). Although they found it easy to change the goals, few of them changed the initial goals they had set for themselves.

Figure 6. The specially designed step counter attaches to the belt and transfers data each evening, whereupon the feedback screen is displayed on the mobile phone.

This general information functionality was introduced to the 12-patient cohort 2 months after the study start, thus it was tested for 4 months. The functionality is labeled "Tips" in the main menu and consists of 80 practical short tips related to type 2 diabetes (see the fourth picture in **Figure 1**). Users were especially satisfied with it in the beginning of the test, and many members of the cohort requested new texts with information at subsequent user meetings. Users reported at the end of the study that they used the functionality on average 1.7 times a week, and all 12 users appreciated the food-related texts as the most useful.

Discussion

There are several mobile patient-operated diabetes management systems available today, but few include all three cornerstones in diabetes management. Characteristics of the Few Touch application are its simplicity and ease of use, which distinguish it from similar systems, e.g., Logbook FX diabetic diary,[16] SiDiary,[17] t+ Medical,[18] and the OneTouch UltraSmart.[19] As part of a doctoral thesis,[20] an extensive literature search, patent search, and search for publicly available systems were performed, but no systems similar to the one presented were found. However, a comparison study between the Few Touch application and the more function-rich mobile applications remains to be done, as does an RCT of the former.

The idea of providing applications such as those presented is in line with the conclusion of Ballegaard and colleagues[21] that health care technology involves much more than informing clinicians; it is also about supporting the collaboration between patients and clinicians. As well as using the system as a mobile self-help aid, some members of the cohort showed the system to their medical doctor, suggesting the potential for a common benefit from its functionalities.

Due to the limited sample of patients who tested the Few Touch application, data provide an inadequate basis for general conclusions. Also, because the users were heavily involved in the design of the tested application, the results presented might be more positive than they would have been with an unbiased cohort. The current version of the Few Touch application is designed for motivated, healthy patients who want to improve their condition, but its various sensor elements may be useful for other cases as well. If the concept of enabling patients to record, view, and analyze their own health data becomes widespread, the result will be a kind of diabetes management that is quite different from what is available today.

Conclusions

The feedback from users does not indicate that use of the application created any additional burdens for them, other than when technical problems arose. Despite these problems, users emphasized the usefulness of the application, and the system scored high on usability assessed by the SUS questionnaire (84 out of 100). The cohort liked the BG sensor system the best of the five different functionalities and highly appreciated being able to see their glucose values as a historical trend graph on their mobile phone. Users liked the concept of accumulating the step count history on their phone, but added that the sensor size and form need further work. The nutrition habit registration system was fully used by a little less than half of the cohort, and individuals in the cohort expressed a wish to do more detailed recording of food data, which ideally should be an option.

Most of the existing self-help tools for chronically ill patients aim to provide help by interacting with health care workers. Even though this is usually the kind of help that patients want most and is also the most effective,[22–24] it is resource-intensive. Therefore, the presented and similar concepts that support the patients themselves in disease management are important in preparing support for meeting the expected increase in people with diabetes.

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