Usability Evaluation of Blood Glucose Meters for Elderly Diabetic Patients

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Abstract. In the context of this study the usability of the first blood glucose meter that is connectable to a smartphone has been investigated by the use through diabetic patients of different ages and with different technical experiences. According to DIN ISO 2028-1 the participants had to solve usability-tasks with the think-aloud-method. Additionally the cognitive load has been measured for each task. As control variables we asked for age and gender as well as technical affinity and Health Literacy. A total of 12 participants (mean age = 60.17 years) took part in this study. The results show that elderly diabetic patients are willing and able to use modern blood glucose meters. A blood glucose meter for elderly should store data for about three months and should be able to export data easily to the physician by a file type like CSV. The blood glucose testing strip should have a mark which describes the orientation and way it should be inserted into the blood glucose meter. The testing strip should also be illuminated to improve blood glucose measurements during nighttime.

Keywords: Acceptance · Elderly people · Usability · Healthcare · Mental demand

1 Introduction

The quantity of diabetic patients in Germany is increasing exponentially. The International Diabetes Foundation states that 7.6 million people had diabetes in Germany [1]. More than half of those affected are older than 65 years, and the risk to come down with diabetes increases with age [2, 3]. In the context of a therapy, an autonomous control of the blood sugar level through the patient is often necessary. For this purpose so-called glucometers are used. In the course of the increasing digitalization, glucometers have been extended by many functions so that modern devices do not only measure the blood sugar level, but, in combination with a mobile terminal, also enable to process and analyze the recorded data and give feedback to the user. Various studies showed that those systems increase treatment adherence and patient satisfaction if they are accepted by the user [4, 5]. Hence the usability is especially important because a

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device that is not fit for this purpose may lead to an incorrect measurement and a decreasing therapy adherence [6].

This explorative study examined the usability of a glucometer connected to a smartphone with elderly patients. For this purpose, different key aspects of performance of a modern glucometer were considered. Additionally the usability has been explored by simulated blood sugar measurements. Thus, concrete design guidelines and recommendations for the design of modern glucometers could be derived.

2 Method

In the context of this study the first blood glucose meter which is connectable to a smartphone iBG-Star has been investigated according to DIN ISO 20282-1. For this investigation different usability tasks were defined which the participant had to process independently (Table 1).

Table 1. Usability tasks corresponding to the order of processing

No.	Task
1	Unpacking out of carton
2	Unpacking out of transport bag
3	Charging glucometer
4	Connecting the glucometer to tablet
5	Inserting blood glucose monitoring strips into glucometer
6	Simulated blood sugar measurement
7	Connecting glucometer to smartphone
8	Inserting blood glucose monitoring strips into glucometer
9	Simulated blood sugar measurement

During the processing, participants were observed using the think-aloud-method [7]. Subsequent to each task the subjective mental load was evaluated using the Rating Scale of Mental Effort [8]. This method is based on a visual and linguistically encoded scale of 150 Points (Fig. 1). Subjects rated their individual mental effort.

Since the glucometer is connectable to different types of mobile terminals the usability tasks were set twice. During the first run participants used the glucometer in combination with an iPad 2, and during the second one with an iPhone 4S. Therewith should be examined if the use of a smartphone or a tablet and related advantages and disadvantages do have an impact on usability. Compared to the presentation on a smartphone or the glucometer-display itself the larger display area of a tablet could be advantageous for elderly people, whereas the size of the mobile terminals could have a negative impact. A summarizing judgement of the usability in arithmetical form has been conducted employing the Post Study Usability Questionnaire [9].

Besides the usability tasks, a semi-structured interview was conducted which was supposed to examine factors of acceptance of a modern diabetes management system. We placed special focus on aspects of data processing and data release. Furthermore

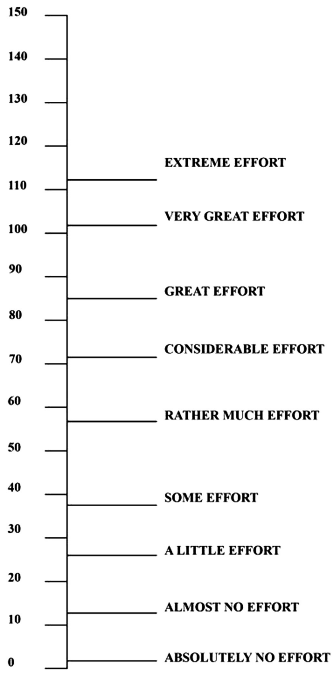

Fig. 1. Rating scale of mental effort according to Zijlstra [8]

participants were asked about their acceptance of functions that guide them and, beyond that, encourage them to lead a healthy life (Table 2).

As control variables age, gender and technical affinity were recorded. The latter one was estimated by employing a questionnaire used in previous research [10]. Using another questionnaire, the previous therapy was evaluated. For this purpose participants

Table 2. Aspects that are evaluated by using the semi-structured interview

No.	Aspect
1	System gives instructions for a healthy life
2	System saves data automatically
3	Added value of an automatic data storage
4	Added value of a development display of stored data
5	Period for storing data
6	Automatic transfer of data to the treating physician
7	Diary function to collect more data such as eating habits and amounts of carbohydrates
8	Reminder for unrealized daily goals
9	Notification of compliant behavior to the health insurance
10	Desirable functions of a modern diabetes management system
11	Advantages and disadvantages of the considered system compared to the previously used system

were asked to state which health-related data they record in the context of their therapy and where they store it. In order to comprehensively document the participants' health-related knowledge we used the Health Literacy Questionnaire [11]. This questionnaire examines in how far the participant knows important facts about the disease, its therapy and compliant behavior.

After an approval of the ethics committee of the faculty of medicine of the RWTH University (EK028/15) participants were recruited via self-help groups and postings in the Aachen area.

2.1 Participants

Overall N = 12 participants (male = 4; female = 8) participated in this study (see Table 3). The average participant age is 60.17 (SD = 15.04). All participants stated that they are diabetics for more than ten years, whereby five participants suffer from type I diabetes, six from type II diabetes and one participant from type 3c diabetes. Three out of 12 participants stated that they suffer from physical constraint as a consequence of diabetes. On average the participants perform 3.58 blood sugar measurements a day, whereby the minimum in this sample is two measurements and the maximum seven measurements a day. With regard to the therapy compliance, the amount of daily blood sugar measurements of all participants corresponded with the specifications of the treating physician. Regarding the individual therapy, the semi-structured interview revealed that all participants hand over their therapy related health data to their doctor

Table 3. Characteristics of the analyzed participants

Variable	Level	Frequency/data
Sex	Male	4
	Female	8
Age (years)		60.17 (SD = 15.04)
Highest educational qualification	Finished secondary school	2
	Finished professional education	8
	Holding a university degree	2
Type of diabetes	Type I	5
	Type II	6
	Type 3c	1
Duration of therapy (years)	<2	1
	2–10	0
	>10	11
Health literacy	Access	3.25 (SD = 0.866)
	Understand	3.22 (SD = 0.519)
	Appraise	2.71 (SD = 0.964)
	Apply	2.83 (SD = 0.536)
	Disease prevention	3.17 (SD = 0.577)
	Health promotion	2.96 (SD = 0.698)
Technical affinity		2.672 (SD = 0.406)

personally. Seven out of ten documented their data paper-based. Only three participants stated that they enter their values in digital form and that they are stored in the glucometer itself.

2.2 Experimental Apparatus

The blood glucose meter "iBG-Star" produced by AgaMatrix Inc., 7C Raymond Avenue, Salem, NH 03079, USA which is distributed in Germany by Sanofi-Aventis Deutschland GmbH, Industriepark Hoechst, K703 Brüningstr. 50, 65926 Frankfurt am Main has been investigated in the context of this study. Besides that, an iPhone 4S (16 GB) and an iPad 2 (32 GB) by Apple Inc., 1 Infinite Loop, Cupertino, CA 95014 USA were used (Fig. 2).

Fig. 2. Blood glucose meter iBG-Star (Sanofi-Aventis Deutschland GmbH, 2015)

The products tested were provided by mySugr GmbH, Schottenfeldgasse 69/3.1, 1070 Wien, Austria. The necessary Blood Testing Strips were provided by Sanofi-Aventis Deutschland GmbH, Industriepark Höchst K703, 65926 Frankfurt, Germany.

3 Procedure

After the examiners welcomed the participants, an informal interview was conducted in order to collect information about their demographics and the individual diabetes therapy. After that, participants independently completed the questionnaires on technical affinity and Health Literacy. This was followed by the independent performance of usability tasks through the participants themselves. For this purpose, participants were introduced to the concept of the Rating Scale of Mental Effort by practicing the visual and linguistically encoded scale employing five everyday examples. Following this, participants were asked to unpack the product using the think-aloud-method.

Afterwards, a simulated blood sugar measurement was conducted using the glucometer in combination with an iPad. For direct comparison a second simulated measurement was conducted in which the glucometer was connected to an iPhone. Subsequent to these tasks, participants were asked to fill in the Post Study System Questionnaire (PSSUQ) with reference to both measurements. Thus a universal evaluation of the glucometer in full operational spectrum could be ensured. This was followed by an informal interview concerning the advantages and disadvantages of each measurement in relation to the glucometer used by the participants in everyday life. Each appointment was concluded with a semi-structured interview which examined acceptance factors of modern diabetes management systems. As compensation for their effort participants received 20 euros.

4 Results

The examination of technical affinity showed that participants were rather hostile to technology since the average value across all participants is 2.672 (SD = 0.406) on a 4-Likert-scale (1 = ‘I fully agree’ to 4 = ‘I completely disagree’). According to the Post Study System Usability Questionnaire the investigated glucometer was averagely evaluated with a value of 2.06 (SD = 1.02) on a 7-Likert-scale (1 = ‘I fully agree’ to 7 = ‘I completely disagree’) for usability. The inspection of the requested RSME-values confirms this usability evaluation (Fig. 3).

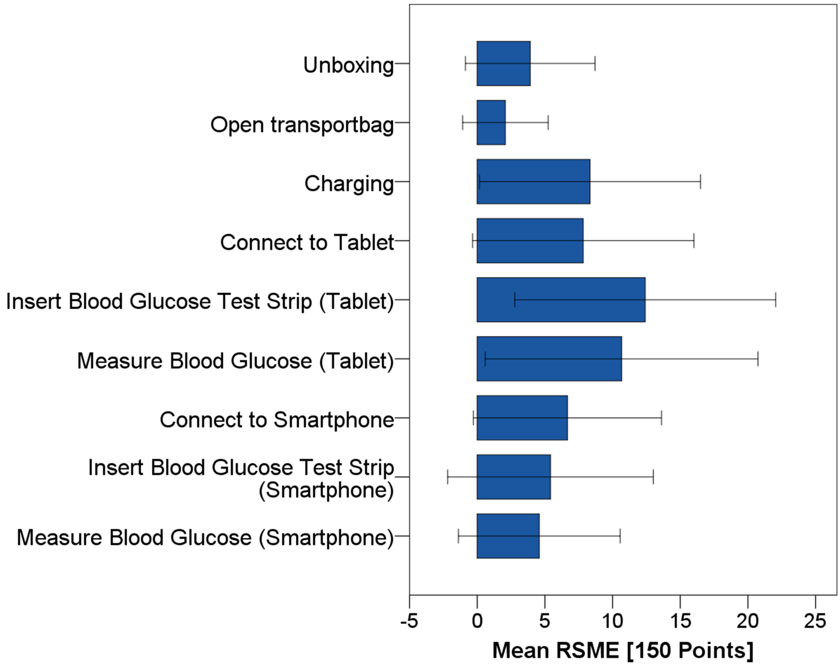

Fig. 3. Averages of the RSME values for each usability task

Furthermore participants stated that the glucometer can be used significantly better combined with the smartphone. Assumed advantages of the tablet as a result of the larger display were eliminated by disadvantages of the handling. Participants reported that the sheer size of the glucometer makes it more attractive due to the fact that it can be easily carried along in everyday life. Equally, half of the participants were convinced by the modern design of the glucometer as well as the evaluation possibilities with the aid of the app. On the other hand they considered the amount of product components that are necessary for a blood sugar measurement such as monitoring strips, lancet and charger as a disadvantage. Furthermore they criticized that the glucometer is solely compatible with apple products. They would like to have a universal port which allows applicability with mobile devices from different manufacturers.

5 Discussion

This paper presented a usability evaluation of the first blood glucose meter which is connectable to a smartphone. Elderly diabetic patients, who participated in this study, stated that they would recommend this modern glucometer. The space-saving and modern design of the evaluated glucometer was judged as beneficial and attractive.

According to the Post Study System Usability Questionnaire the blood glucose meter has a good usability as the value is around 2 points on the 7-Likert-scale. The inspection of the requested RSME-values confirms this usability evaluation. The requested values vary between 0 points and 50 points for individual participants on a 150-point scale (Fig. 1). The maximum value which was gathered of 50 points corresponds to a mental load between ‘little effort’ and ‘relatively large effort’. The highest average mental effort was measured when participants inserted blood glucose testing strips into the glucometer for the first-time in combination with a tablet. The participants stated that it was difficult to perceive in which orientation and at which position the testing strip has to be inserted. In addition it was exhausting to insert the small testing strip into the likewise small opening of the device.

Qualitative interviews showed that the used blood glucose meter lacked an illumination of the testing strip. This would facilitate the nightly measurement in the bedroom and thereby other persons present in the room would not be wakened by someone switching on the lights. Participants clearly criticized that the device cannot be used universally with every type of smartphone. However, the participants appreciated the automatic storing and the possibilities of long-term analysis of the tested blood sugar level. Furthermore participants named these functions as basic requirement for the use of such a modern blood glucose meter. These findings correspond to the results of Valdez who examined this question by using a fictional blood glucose meter [12]. Moreover, they stated that the corresponding app should visualize a period of at least three months in order to give a useful overview of the personal health state. In reply to the question with whom they would like to share their health-related data everyone stated that it should be available to their doctor immediately after the measurement. By contrast they do not want it to be sent to their health insurance or any other external group in health care. Besides the blood sugar value, further data, for example physical activity behavior or personal nutrition, should be recorded and stored.

The only restriction that was named in this regard is that there should be the possibility of correcting data because a glucometer is a device that often is not used by only one person. This leads to the risk that the values of another person could be assigned to the patients personal health file.

Asked about their actual diabetes therapy, participants reported that their physicians in charge do often not have the appropriate system available in order to transfer the data from their blood glucose meter digitally. Furthermore, they claimed that their glucometer is not designed to transfer data in an manner other than transcribed paper form. Participants agreed that this effort should be reduced through the use of a modern glucometer and that the automatic data backup would be a fundamental requirement if they would think about buying a modern glucometer connectable to a smartphone.

In conclusion, it can be noted that digitalization of a glucometer produces clear benefits for patients and doctors and that these advantages are also advocated for by elderly diabetic patients with low technical affinity. On the other hand, a lot of work is necessary to enhance interoperability among blood glucose meters and diabetic management systems as well as between patients' and physicians' systems.

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