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MHEALTH BASED ON NFC TECHNOLOGY – PRELIMINARY RESULTS FROM MEDIUM SCALE PROOF OF CONCEPT PROJECTS

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Abstract

mHealth enables patients suffering from chronic diseases to stay in contact with their care givers anywhere and anytime. The usage of mobile phones as patient terminal requires a barrier-free user interface design and plug'n play interplay with medical sensor devices. To meet these requirements for usability and security a patient terminal concept based on mobile phones and medical sensor devices enabled with NFC technology was developed. It was linked to a Web based telemonitoring system and used in proof of concept telemonitoring applications. Preliminary results after monitoring 279 patients suffering from Diabetes type I and type II as well as chronic heart failure and pulmonary arterial hypertension (92,378 cumulative monitoring days, 132,259 data transmissions, adherence rate > 81.9%) indicate that the intended patient terminal is ready for adoption into routine operation. It helps to deliver intuitive, secure and reliable telemonitoring solutions even to elderly and technically unskilled people.

Keywords – ***Telemedicine, mHealth, chronic disease management, Usability, Near Field Communication,***

1. Introduction

The development and evaluation of mHealth systems have expanded rapidly in the last decade. One example is the adoption of mobile phones as patient terminal in health- and telemonitoring applications to monitor and communicate with patients suffering from chronic diseases. With mHealth patients can be fully mobile and yet stay in contact with their care givers anywhere and anytime [1]. Via the mobile phone acting as patient terminal they are able to acquire all kinds of health related data. Data acquisition can be done manually using a keypad or touchscreen or can be realized automatically by means of a wireless personal area network (PAN) link between the mobile phone and sensor devices [2]. Acquired data are forwarded to a telemonitoring center via mobile Internet to be aggregated and presented to the care givers. Actual and accurate data are necessary for professionals to make informed treatment decisions and to return feedback information how to react in a given situation. These instructions, but also motivational feedback and reminder messages, have to be sent to and visualized on the patient's mobile phone [3]. Since chronic diseases are also affecting elderly people, telemonitoring systems and the patient terminal in particular require a barrier-free user interface design. Usability and plug'n Play interoperability are essential and determine whether the patient is able to accept the system and willing to use it in daily routine.

1. 1. Wireless technologies: usability vs. security

Bluetooth is the most popular wireless PAN technology since it is widely adopted in handsets and also sensor devices [4]. But handling the Bluetooth link between a mobile phone and medical sensor devices still remains an open usability issue. Devices need to be paired to provide security against eavesdropping and man-in-the-middle attacks. But this pairing procedure that requires several manual steps to search/select a device and to enter a pin code is often too complicated for elderly and technical unskilled people [5]. On the other hand, once a device is paired permanently all data measured with and stored in this device's memory are transmitted automatically even if those data did not originate from this patient.

Near Field Communication (NFC) is an upcoming wireless interface to be integrated in current and future mobile and smartphones. NFC is a short range (<10cm) wireless technology evolving from radio frequency identification (RFID) technology [6]. This short range enables the touch paradigm. When devices are placed within a certain range of each other communication is started automatically. A mobile phone with NFC interface is also able to read RFID tags and trigger specific actions depending on the stored content. Thus, NFC is a more feasible technology compared to Bluetooth since it provides security without the need to be configured and paired. *Table 1* shows the differences between both technologies. In the context of mHealth, NFC enables the user to express his/her intention to acquire data simply by touching sensor devices and objects with a mobile phone.

Table 1: Comparison of NFC and Bluetooth technology

properties	NFC	Bluetooth
frequency	13,56 MHz	2,4 GHz and 5 GHz (V 3.0 + HS)
data rate	424 kBit/s	24 MBit/s (V 3.0 + HS)
range	< 10 cm	100 m (class1)
set-up time	< 0,1 s	> 5 s
configuration/selectivity	Automatically	manually
topology	peer 2 peer (only 2 participants)	net (up to 255 participants)
compatible to RFID	ISO14443, ISO15693	no
usability	human centric, intuitive	data centric

1. 2. Objective

The objective of this work has been to present the
- design and development and
- utilization in medium scale proof of concept telemonitoring applications

of a telemonitoring system using an NFC based patient terminal concept.

2. System design and implementation

2. 1. Patient terminal equipment

A patient terminal concept based on mobile phones and NFC technology was designed and developed in order to meet the requirements of high usability and security. This patient terminal allowed for intuitive interaction and acquisition of health parameters simply by touching objects and sensor devices. It consisted of the following two main components:

a) Set of sensor devices with NFC interface

In order to enable medical sensor devices with NFC capabilities an embedded NFC transceiver module was developed. This NFC module provided a serial data interface to be linked to an existing interface of several medical sensors. For each device the firmware was adapted individually to receive and forward the proprietary data. The module was embedded either into the existing housing of a sensor device or in a separate enclosure to be connected to the sensor device via cable.

A blood pressure meter (UA767Plus NFC, A&D, Tokyo, Japan) was developed in cooperation with an industrial partner (Figure 1 a). This device was fitted with the NFC module and certified as medical product. After performing a measurement the recent measured value could be read with an NFC enabled mobile phone by touching the cover plate.

The existing *body weight scale* (UC321PL, A&D, Tokyo, Japan) and *blood glucose meter* (One Touch Ultra II, Lifescan, Milpitas, CA) provided a serial data interface. They were extended by an external NFC interface device with integrated battery compartment for two or three AAA batteries (*Figure 1 b, c*). They were mounted on the wall in case of the weight scale or pouched into the bag of the glucose meter. LED lights indicated the operation state or when batteries got low. When touching the device connected to the weight scale the recent measured weight value was read. In case of the blood glucose meter the last 35 recent measurements were read.

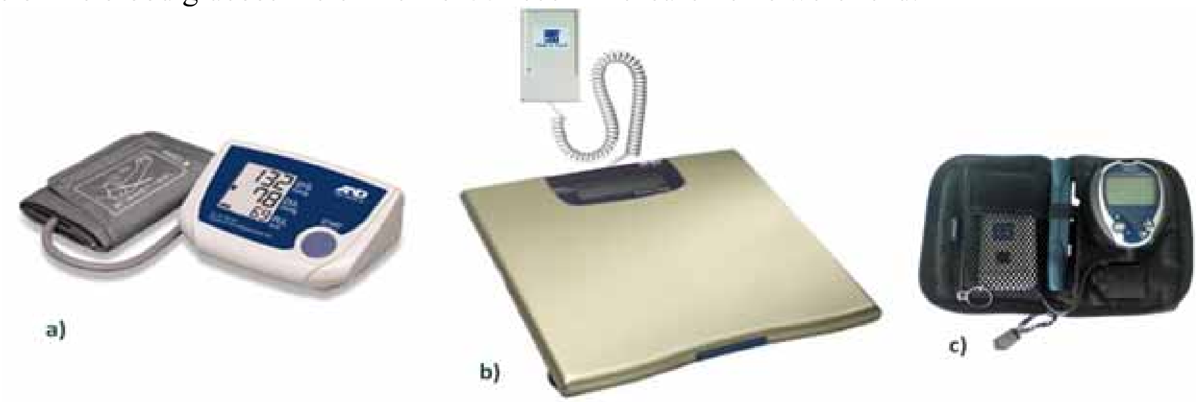

Figure 1: overview of NFC enabled sensor devices

b) NFC enabled mobile phone with RFID based user interface

A software application based on Java 2 Micro Edition (Oracle, Redwood City, CA) was developed to run on NFC enabled mobile phones. The application was developed in a generic design and was based on a configurable workflow engine to provide an individual data acquisition procedure. A graphical user interface guided the user through the data acquisition process. Data acquisition was started by touching a contactless smartcard acting as user token for identification and authentication (*Figure 2 a*). Entry of health parameters was done by touching NFC enabled sensor devices. In order to acquire subjective data or to run a questionnaire an icon table with RFID tags was used. For example to indicate the current well-being state or to answer a question the user only had to touch the appropriate icon (*Figure 2 b*). Finally data were aggregated, stored, and sent to a remote system via mobile Internet connection.

Figure 2: authetication via smartcard (a) and acquisition of subjective data by touchin iconized RFID tags (b)

2. 2. Telemonitoring platform

The mobile phone acting as data hub and gateway was linked to a remote telemonitoring platform. This Web based system was developed in three tier client-server architecture based on state-of-the-art Internet technology. Data received from the mobile phone were processed and stored in a central database. Feedback messages and reminders as well as configuration files were pushed to the mobile application. Additional services analyzed the stored data regarding individual thresholds, generated feedback messages and reminders for the patients and notifications to be sent to their health care professionals. Data were prepared by reporting-, statistics- and graphic services to be viewed by professionals in a browser based Web interface.

3. Adoption to clinical routine operation

After initial laboratory evaluations and field tests in clinical trials the system was adapted to be used in medium scale proof of concept telemonitoring applications.

a) Telemonitoring supported treatment of chronic heart failure

The complete telemonitoring system using the developed patient terminal setup was deployed to run a proof of concept at the general hospital of the Elisabethinen in Linz in Upper Austria. The system called ELICARD supported professionals from the outpatient clinic to treat patients suffering from chronic heart failure (CHF) and pulmonary arterial hypertension (PAH).

In the course of the registration the attending physician entered anamnesis data, selected and configured monitoring parameters, and prescribed the medication to be monitored by the system.

Devices were provided to the patient after discharge by an external HelpDesk. All components were configured and prepared (including a graphical user manual) to be sent to the patient's home via mail service. The equipment comprised a clamshell phone with NFC capabilities (Nokia 6131 NFC, Nokia, Espoo, Finland), NFC enabled blood pressure meter and body weight scales, as well as the ID card and the icon table. Patients suffering from CHF had to acquire and transmit their data on a daily basis in a strictly defined workflow. By touching the ID card the application launched automatically and asked for body weight or blood pressure. When touching the weight scale the mobile phone transmitted the value immediately (path 1). After touching the blood pressure meter the application visualized a questionnaire and asked for input regarding well-being and intake of the prescribed medications one after another (path 2). Patients answered these questions by touching the appropriate symbol on the icon table. Finally the application terminated automatically after data were synchronized with the backend system.

Data acquisition for PAH patients was slightly different. They were equipped with an additional pulse oximeter and had to answer three more questions during the questionnaire part. PAH patients had to perform the procedure only three times per week.

b) Therapy management of diabetes mellitus

The second proof of concept telemonitoring application was a medium scale telehealth project in cooperation with the Austrian insurance company for railway workers and miners (VAEB). When visiting the health resort insured persons who had a high risk for diabetes or who already suffered from diabetes were asked to participate in a health care program called "Gesundheitsdialog Diabetes". The remote telemonitoring system called DIABMEMORY was used as therapy management component in this project. Participants were able to choose a manually operated PC and browser based user interface or the mobile phone and NFC based patient terminal. Three different NFC mobile phone types ranging from feature phone to touchscreen-smartphone were used. In addition to blood pressure meter and body weight scale these patients received a blood glucose meter with NFC interface.

Components were handed out to the patients during the initial training session. Patients suffering from type I Diabetes (DM1) were asked to perform three blood sugar measurements per day. Type II Diabetes (DM2) patients only had to perform at least three blood sugar measurements per week. In both groups blood pressure and body weight (only for selected patients) had to be measured just once per week. The data acquisition workflow of this specific mobile software version was designed in a flexible way. Once started (after touching the ID card), the application asked to enter health data (blood sugar, blood pressure, body weight, well-being, activity and respective intensity). Patients could acquire only a single one or up to all parameters in one session by touching the devices and icons. The data acquisition procedure was finished and synchronization was triggered just by touching the ID card again.

4. Results

In the following the results from the two medium scale proof of concept projects are shown. Data are presented in medium ± SD.

a) ELICARD

The telemonitoring system started operation on March, 1st 2009. During a period of 35 months 40 patients were registered and equipped with the developed patient terminal. 23 CHF patients (6 females, median age 73.3 ± 11.4 years,) were consecutively admitted to the service right from the beginning. In August 2010 the system was extended to support the treatment of PAH patients. Thereafter, 17 patients suffering from PAH (11 females, median age 68.4 ± 8.3 years) were consecutively included to be monitored by their attending professionals. During this 35 month period in both groups a total of 89,245 data items were received in the course of 26,625 data transmission sessions. 13,154 out of those sessions transmitted only body weight values (path 1) while in 13,471 sessions blood pressure, well-being, and data about medication intake (path 2) were transmitted.

The cumulative monitoring period of the CHF patient group was 13,602 days (median 716.5 ± 411.9 per patient). In CHF group in 11,143 out of the 13,602 cumulative patient monitoring days at least one data transmission was performed which resulted in a patient adherence rate of 81.9%.

The PAH patient group was monitored over a cumulative period of 6,482 days (median 495.0 ± 174.9 per patient). A total of in 4,568 data transmission sessions (median 313.0 ± 136.1 transmissions per patient) were observed in this group. 2,240 sessions were used to transmit body weight values (path 1) and 2,328 to transmit the remaining data (path 2). Considering six requested transmissions per week this patient group showed an overall adherence rate of 82.2%.

During the 35 month operation period four HI patients (1f) stopped using the system, because they didn't want to handle the devices every day. Three of them stopped within the first week and one person returned the devices after a period of one month. Four HI and five PAH patients died after a medium monitoring period of 343 ± 125.8 days and 133 ± 78.3 days respectively.

b) DIABMEMORY

The telemonitoring system designed to support diabetes management started operation in May 2010. At the end of January 2012 a total of 359 persons (57f) with a median age of 57.4 ± 10.2 years have agreed in participating to the "Gesundheitsdialog" health care program when attending the health resort of their insurance company. Out of these 359 participants 326 were suffering from type II diabetes. 26 were suffering from type I diabetes and seven participants had been classified with increased diabetes risk. 70.2% of all participants, 252 in total (52 f, median age 59 ± 10.2 years) chose the mobile phone based patient terminal to acquire their health data while the remaining 29.8%, 107 in total (5f, median age 54.1 ± 9.52 years) used the browser based interface. Ten participants (4f, median age 52.5 ± 10.2 years) of the mobile group (2.79% of total population) used the mobile phone without any NFC enabled sensor devices and entered the data manually. They only used the ID card to launch the application and login.

13 (4f) mobile users were classified as never beginners and four (2f) patients stopped participation within the first week. During the period of 21 month the remaining 239 mobile users had a cumulative monitoring period (duration between first and last transmission) of 72303 days (median 289 ± 184 days per patient). A total of 105634 data transmission sessions were performed. These sessions successfully carried a total of 189883 data items and 2614 manually written comments to be stored in the system's database. Blood glucose values constituted the main part of these data items (58.8%). The remaining items comprised data related to blood pressure, body weight, activity, and wellbeing with a proportion of 17.2%, 4.6%, 10.7%, and 8.7% respectively. A detailed comparison of the active patients with DM1 (18, 5f, median age 49.2 ± 17.12 years) and DM2 (211, 41f, median age 59.5 ± 8.59 years) showed an average of 28.76 vs. 17.81 transmitted data items per patient per week. In mean DM1 patients recorded 23.33 blood sugar values, 1.93 blood pressure values, 0.41 weight values, 1.14 well-being indications, 1.57 activity (incl. intensity) events, and 0.38 comments per week. Considering a target of three blood sugar measurements per day and one blood pressure measurement per week these patients reached and topped the target resulting in an overall adherence rate of 100%. DM2 patients on average transmitted blood sugar, blood pressure, and body weight values as well as well-being indications, activity events and comments with a proportion of 9.88, 3.25, 0.86, 1.6, 1.98, and 0.24 respectively per week. Thus this patient group showed a high adherence too by exceeding the four measurements (3 blood sugar and 1 blood pressure) per week.

5. Discussion

The preliminary results obtained from both proof of concept projects indicate that the intended concept of a patient terminal based on mobile phones and NFC technology is feasible for adoption into routine operation. Patients were willing to integrate the process of data acquisition into their daily lives and use the devices on a regular basis. In both projects the patients showed a high adherence of more than 80%. Results showed similarity over both groups of patients with different data acquisition schedule and also in both projects with completely different data acquisition workflows. ELICARD patients had to acquire all data within a single run while DIABMEMORY patients were able to decide on their own which data they want to acquire supplementary (in addition to blood sugar and blood pressure). Thus, the proportion of body weight and well-being transmissions in ELICARD was accordingly higher. The common ground for similar results in both projects may be found in the system's usability that comes hand in hand with technical benefits.

The physical act of touching objects and sensor devices to acquire data makes the process clear and graspable. Compared to Bluetooth or even other PAN interfaces like ANT+ or ZigBee the user is able to stay in control of the process and his/her data. A personal ID token is used to link measured values with patients. Thus, with the presented concept devices, that are normally used by more than one person in a household (i.e. blood pressure monitor and weight scale), can still be shared among several persons. With Bluetooth technology this scenario cannot be realized without further techniques. The interface devices for weight scale and glucose meter were fragile due to manufacturing in manual work. Thus, in both projects they had to be replaced occasionally. New devices were sent via mail service and patients could proceed to acquire data without any configuration.

Currently only a few types of mobile phone or smartphone are enabled with NFC technology. But this situation is about to change, since NFC enables the handsets to act as token for mobile ticketing and payment applications. The high potential for growth of mCommerce and other market segments will drive the manufacturers to provide handsets with integrated NFC technology. The health care industry is also starting to focus on this technology. The Continua Health Alliance, an industrial consortium to establish a system of interoperable personal health solutions, has joined with the NFC Forum to foster NFC in the field of telemonitoring and ambient assisted living [7]. Standards and guidelines are prepared to ease the development and interplay of future devices.

6. Conclusion

A patient terminal concept based on mobile phones and NFC technology was designed and implemented to establish a versatile and easy to use link between patients suffering from chronic diseases and their attending physicians. Results from medium-scale pilot projects indicate that NFC is an enabling technology and has the potential to reduce the complexity of telemonitoring applications to a minimum but keeps security on a high level. It helps to deliver intuitive, secure and reliable telemonitoring solutions to people with chronic diseases, even to elderly and technically unskilled ones.

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