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# Feasibility of mHealth and Near Field Communication Technology based Medication Adherence Monitoring

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*Abstract*— **Poor patients' adherence to intake of prescribed medication has been identified as a serious problem in the treatment of chronically ill patients. Technical solutions are needed to measure and – if necessary – to increase the patients' adherence. A telemonitoring solution was developed to record a patient's medication intake based on smart blisters and mobile phones with NFC functionality. The components allowed recording of drug type, timestamp, and dosage of pills taken. The system's usability and technical feasibility was evaluated in the course of an application study. Over a period of 13 months 59 patients suffering from diabetes were monitored. 1,760 blisters were handed out to these patients and 14,843 takeout events were recorded and transmitted via mobile phone. Results indicate the feasibility of this concept to monitor adherence. Although the system still needs to be optimized for routine use it shows the potential for targeting the problem of poor patient adherence by NFC enabled devices.**

## I. Introduction

Medications are the most potent actuators in healthcare and account for a large part of the healthcare expenses in the developed countries. In Austria, for example, drugs consume approximately 20 % of the budget from healthcare insurances [1]. It is also well known that there is a huge gap between what the doctor prescribes and what the patient takes. This is in particular the case for chronically ill patients who are typically the patient group to which most of the drugs are prescribed [2]. Often those patients are required to take many different drugs at many different times of the day, a situation designated polypharmacy, and a factor further complicating medication management.

Several key performance indicators have been defined to assess the degree (the percentage) to which patients follow the medication therapy schedule …

- as prescribed by the doctor = compliance,
- as agreed between the patient and the doctor = adherence,
- without temporarily or permanently discontinuing taking the drugs = persistence.

In the following the term adherence will be used, being defined as the degree to which patient behavior coincide with healthcare objectives and respective therapeutic regimen as jointly agreed between the healthcare provider and patient [3]. A number of studies have dealt with the consequences that arise from low degrees of adherence. In monetary terms, non-adherence has been estimated to cause direct costs exceeding 100 billion USD per year and further 50 billion USD for patients earning and productivity losses [4].

However, to date only limited information is available on the detailed causes of non-adherence and the effectiveness of adherence increasing methods and measures. In part, this seems to be the case due to the lack of pervasive adherence monitoring technology that is easy to use by patients and healthcare providers, that is ubiquitously available and that comes at a price that allows application in a wide variety of therapeutic settings.

"Mobile communication devices, in conjunction with Internet and social media, present opportunities to enhance disease prevention and management by extending health interventions beyond the reach of traditional care—an approach referred to as mHealth" [5] Technologically, "mHealth" draws on mobile and wireless communication technologies as well as concepts like "pervasive and ubiquitous computing" and "ambient intelligence".

Near Field Communication (NFC) is an upcoming wireless interface to be integrated in current and future mobile phones and smartphones. NFC is a short range (<10cm) wireless technology evolving from radio frequency identification (RFID) [6]. NFC is well positioned to support any activity of users that can be mapped to a "tap and go" paradigm, e.g. where users need to "touch" an item in their environment so as to initiate and perform a brief communication with this item, for example to read out sensor data. Therefore, NFC is one of the enablers of the "Internet of Things" [7] and hence, may be suitable for adherence monitoring in combination with smart blisters. This kind of NFC enabled electronic blisters has already been proposed to be part of and operate in mHealth based medication management solutions [8]. Up to now, however, a scientific evaluation of such solutions has not been published.

We previously had utilized NFC in a number of projects to empower mHealth-based systems in support of chronically ill patients [9, 10] and research [11]. The present work has been done to assess whether NFC enabled medication blisters are a practical solution to the challenges of medication management in chronically ill patients. Therefore, a prototypical system has been developed and its technical feasibility and usability has been evaluated in a field trial.

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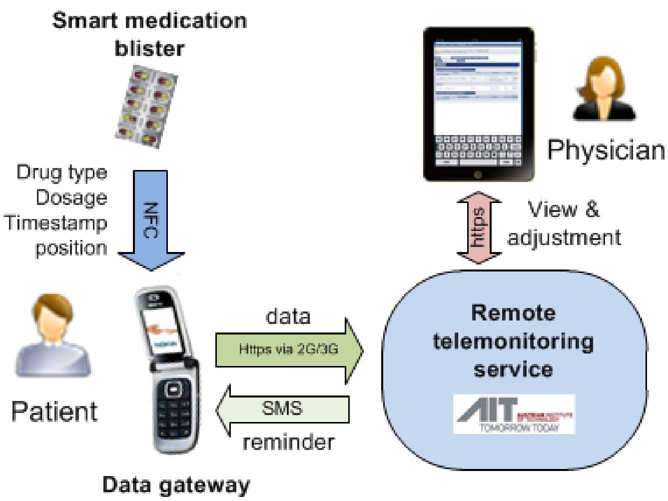
## II. Material and Methods

### A. System components and setup

A remote telemonitoring system was developed in order to record a patient's medication intake and to measure and – if necessary – to improve his/her adherence. This system was based on common information and communication technologies as well as printed electronics and embedded systems to track the timestamp and amount of pills taken. Figure 1 shows an overview of the developed system and components used.

Figure 1. Overview of the medication adherence monitoring system comprising of NFC enabled medication blisters, a mobile phone based data gateway and a remote telemonitoring service




#### a) NFC enabled smart medication blister

An electronic medication blister concept (OtCM$^{TM}$, DSM TCG B.V., Mauritslaan, The Netherlands) was used that was capable to track, when pills were taken out ("smart blister"). It was based on an ordinary medication blister with a self-adhesive printed circuitry label applied to the aluminum foil cover. Taking out a pill led to a broken conductive track underneath the respective position. A microcontroller (located on a separate printed circuit board packed on the blister's upper side) was linked to this label and was able to recognize this event. Position of the respective pill on the blister and timestamp were stored in the µC's internal memory to be interrogated by a proprietary protocol on top of an NFC based air interface.

#### b) Mobile phone based data gateway

Mobile phones were used to collect the data from the smart blisters. A Java 2 Micro Edition (J2ME) based software application was developed to run on NFC enabled mobile phones (Nokia 6131 NFC, Nokia, Espoo, Finland). The application was launched automatically after touching an RFID based user ID card which at the same time authenticated the patient and allowed to acquire data. In the following, a graphical user interface asked to touch smart blisters. The application utilized a third party closed source API collection provided by the smart blister manufacturer which included the proprietary data protocol to interrogate the blisters. Once the data from a single blister were read the process of synchronization with the remote system started immediately by means of a GPRS based mobile Internet connection. After indication of a successful transmission the application closed automatically. If data could not be synchronized, e.g. due to lack of network connection, they were stored on the mobile phone and sent later together with the subsequently interrogates data.

#### c) Remote telemonitoring service

A three tier architecture based Web system received the data from the mobile phone and analyzed timing and number of pills intake. Processed data were used to automatically remind the patients via SMS messages that –for privacy reasons – did not contain any private or medical content. Data were presented to the care giver numerically and graphically via browser based user interface.

### B. Monitoring workflow

The physicians were able to access the telemonitoring service after a secure login process. The browser based user interface allowed to register new patients and document anamnesis data. During this registration process the user ID card was assigned and handed out to the patient together with the mobile phone. Subsequently, the physician had to prescribe one or more medications and to set the timeframe and dosage of pills to be taken. This information was stored in the database to be accessed by the pharmacist.

After registration the patients visited the pharmacist to receive the prescribed medication. A special terminal device located at the pharmacy was used to connect to the database and to receive the prescription. This was triggered by putting the user ID card onto the NFC reader integrated into the terminal. As soon as the data were loaded the terminal asked the pharmacist to put one blister after another onto the NFC reader. During this process each blister was programmed and initialized.

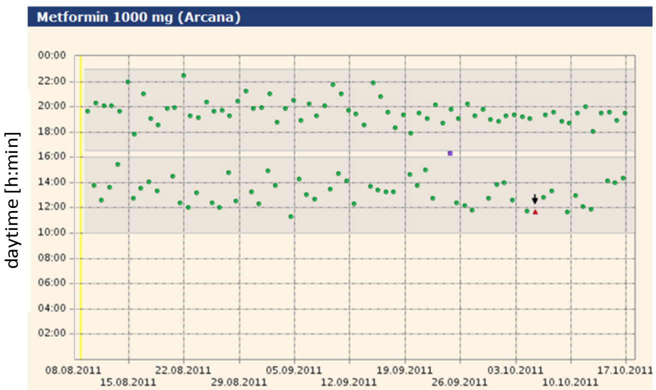
Figure 2. Action of reading data of pill takeout (time and amount) by touching the blister with the NFC enabled mobile phone.

Once handed out to the patient he/she had to take the pills according to the scheme as communicated by the physician. The patient launched the mobile application by touching the user ID card followed by an interrogation of the smart blister (figure 2). This procedure had to be repeated for each blister after taking out one or more pills.

In case of not receiving all of the expected data, an SMS was automatically sent on the following day to remind the patient to transmit the blister data. Data received at the backend were analyzed in real time to check whether the patient was adherent.

Physicians were able to view adherence data as represented in figure 3 and could contact the patient to give feedback (e.g. to ask for better adherence motivation).

Figure 3. Graphical representation of adherence to the intake of a single medication. Green dots: intake of a correct dosage at a correct time. Red triangles: intake of higher dosage than prescribed . Violet squares: wrong intake time. Gray bars: timeframe when pills should be taken.




Once all pills were consumed, the patient was requested to visit the pharmacist again. All blisters were put onto the NFC reader of the pharmacist's terminal to finally read all takeout events stored in the blisters' memory. These data were sent to the telemonitoring service again to be stored in the central database. New blisters were handed out as described above and the patient continued with medication adherence monitoring. Changes in dosage or time schedule were communicated by phone call or during a consultation with the physician.

## III. Results

The developed telemonitoring system supporting medication adherence monitoring was used at the diabetes outpatient clinic of an Austrian public health insurance company in Vienna, Austria. Technical feasibility and usability were evaluated based on the number of patients included in the study and on the number of blisters used by the patients. Additionally, the time in between medication takeout from the blister and data storage within the database was analyzed, since this time difference may indicate technical problems during data acquisition.

The study was running for 13 months to monitor the intake of the following four medications which were prescribed to participating patients suffering from diabetes:

- Metformin 1,000mg
- Simvastatin 40mg
- Crestor 20mg
- Ramipril 5mg

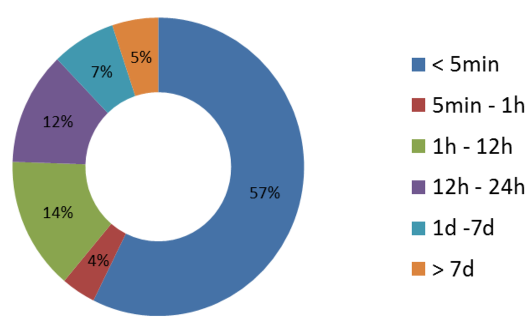
During the operation period of 13 months 59 patients (27 f, mean age 69.54 ± 4.63 years) were equipped with the telemonitoring system consisting of a mobile phone, the user ID card, and electronic blisters. A total of 1,760 blisters were handed out by the pharmacist. On average, patients received 28.9 ± 13.6 blisters. Metformin was the medication most often used with more than 1,012 blisters. Crestor, Simvastatin, and Ramipril were handed out less often, i.e. 200, 217, and 331 blisters, respectively. Table 1 shows the distribution of the four different medications and the mean number of blisters assigned to those 59 patients.

TABLE I. Distribution of Medication Prescription

| *Medication type / combination* | *Patients* | *Blister/patient [m ± std]* |
|---|---|---|
| Crestor | 6 | 13.5 ± 5.2 |
| Ramipril | 5 | 18.2 ± 6.6 |
| Metformin | 18 | 26.8 ± 6.1 |
| Simvastatin | 7 | 14.6 ± 5.6 |
| Crestor / Ramipril | 3 | 31.0 ± 1.7 |
| Crestor / Metformin | 5 | 34.0 ± 10.0 |
| Ramipril / Metformin | 6 | 47.7 ± 10.2 |
| Ramipril / Simvastatin | 2 | 38.0 ± 9.9 |
| Metformin / Simvastatin | 4 | 39.3 ± 8.3 |
| Crestor / Ramipril / Metformin | 1 | 60.0 ± 0.0 |
| Ramipril / Metformin / Simvast. | 2 | 54.0 ± 8.5 |

The cumulative monitoring period was 7,265 days with a mean period of 123.1 ± 29.1 days per patient. Within this period a total of 14,843 takeout events were recorded. On average, 250.4 ± 124.4 pill takeout events were recorded and transmitted per patient. These events were transmitted by 10,790 transmission sessions. In 73.1% of these transmission sessions only a single event was transmitted while the remaining sessions contained data of least two events. Out of all 14,843 recorded events a total of 8,510 were transmitted directly (within 5 minutes) after the pills were taken out of the blister. Figure 4 shows the distribution of delay between the pill takeout event and the successful completion of the corresponding data transmission session. There was no participant without a recognized delay.

Figure 4. Proportion of data transmissions within a time period of 5 minutes, 1 hour, 12 hours, 24 hours, and 7 days after pill takeout.



## IV. Discussion

The results of the feasibility trial indicate that the use of NFC enabled medication blisters and mobile phones adherence monitoring is possible without any patient interaction other than touching a) an ID card and b) the medication blister with the mobile phone. This easy-to-use concept is suitable especially for elderly people who sometimes have problems with up-to-date data acquisition tools widely used for telemonitoring today – such as personal computers or mobile phones. On the other hand, those people are exactly the ones that have chronic diseases requiring the intake of several medications. Therefore, the concept described may be beneficial, since it addresses the patient group where adherence management is most important.

As can be seen in figure 4, about one third of the data recorded during the study were transmitted more than one hour after takeout. No detailed information about the reason for these delays is available. The delays may be caused a) by the patient (delayed transmission of the data from the blister to the mobile phone) or b) by technical problems (data transmission errors either from the blister to the mobile phone or from the mobile phone to the backend system). From our observations during the study, however, we have the notion that optimization of the blisters (more stable performance) will be necessary before they can be used in a routine scenario.

The NFC based medication telemonitoring system allowed to record the moment when pills were taken out from a medication blister. In several scenarios, this information is sufficient for quantifying patients' adherence to medication therapy. However, these points of time may differ from the moments, when patients finally take the medication, e.g. taking only a half pill or if medication dispensers are filled once a day / week. In the second case, other types of sensors would be necessary, monitoring the dispenser rather than the blisters. However, the concept could probably be applied to such scenarios as well.

Compared to other adherence management solutions based on stationary electronic medication dispenser with wireless interfaces such as Bluetooth and RFID [12] our approach using NFC enabled smart medication blister and mobile phones allows for mobility and closed loop feedback utilizing a single device. While other mobile solutions like electronic medication bottles with integrated GSM module [13] can only recognize the event of opening the bottle the evaluated solution is capable of tracking also the amount of pills taken and, therefore, to detect deviations from the prescribed dosage. However, further evaluations have to be performed how to deal with packaging (several smart blister in one blister pack) and handing them out to the patients in a real pharmacy environment.

## V. Conclusion

The obtained results indicate that medication adherence monitoring based on NFC enabled electronic medication blisters and mobile phones is feasible. Before large scale adoption, however, some improvements with respect to the electronic blister and the process of preparing, providing and recycling those devices is required. Patient and disease characteristics most suitable to be managed with such devices have to be established in further studies.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