

Pervasive Calm Medication Reminder System

Improving and assisting the anticoagulant treated patients medication compliance

B. Brorsen, M. B. Hansen, S. Kalmar, M. L. Madsen, C. F. Pedersen, S. Wagner

Aarhus School of Engineering, Aarhus University, *Finlandsgade 22 DK-8200 Aarhus N.*

{05781, 09626, 00340, 09228, cfp, sw}@iha.dk

Abstract—This paper describes a context aware pervasive calm medication reminder system. The system aims at improving the anticoagulant treated patient’s medication adherence based on context awareness. By using advanced sensor technology to register the user context, the system reminds the patient to take the medication timely. The system prototype was tested and evaluated by a patient, and was reported useful. The context aware reminders also enhanced the patient’s adherence to medication intake.

Keywords: *Calm medication reminder, medication adherence, medication compliance, pervasive computing, context awareness, anticoagulant treatment, ubiquitous computing, ASEF.*

I. INTRODUCTION

Patients who have had a mechanical heart valve operation, or suffer from different kinds of cardiac arrhythmias, are usually on some form of anticoagulation treatment. And as a result of this treatment, the patients are regularly measured for their blood’s coagulating ability (INR - International Normalized Ratio) – due to risks of thrombosis. The anticoagulation treatment comes with an extra threat of internal bleeding, which also has to be monitored [1]. It is estimated that 80.000 patients in Denmark, are on anticoagulation treatment, and 50.000 of those are on lifelong anticoagulation treatment [2]. Measuring INR in these patients can be conducted by either regular ambulatory check-up at the GP/hospital. Or it can be done during a self-tested and self-managed patient treatment course, where the patient measures his or her own INR on a regular basis, and change the medication doses accordingly.

Only patients with the required cognitive capacities and interest in self-monitoring are offered the self-tested and self-managed treatment course. Patients with a mechanical heart valve are usually elderly or sometimes suffer from cognitive problems after the operation, due to the heart lung machine used during surgery, and is therefore not offered the self-managed INR measurement. This is mainly because of the potentially fatal outcome a poorly managed self-monitoring course can have.

Studies show that anticoagulation treated patients, who follow the self-tested and self-managed treatment course, both have a lower risk of treatment related conditions such as internal bleeding, apoplexy, heart attack, but also seem to have a much higher 1, 5 and 10 year survival rate, compared to the ambulatory INR measurement at the hospital. A compliance study showed that 36% of patients on self-tested and self-managed anticoagulant treatment course, missed 20% of their bottle openings, and that for each 10% increase in missed bottle opening, there is a 14% increase in underanticoagulation ($P < 0,001$) [3].

Even though confounding factors may influence on these results, medical professionals still perceive the self-tested and self-managed treatment course as preferable, not only because of positive scientific studies [3], but also because of positive elements such a patient empowerment, patient self-efficacy, improved life quality and economic benefits for the health sector[4, 5].

A. State of the art

Various kinds of specialized equipment have been developed to help patients with medication compliance. Intelligent pill boxes used today, such as the Medication event monitoring system (MEMS), combines a pill box with an intelligent lid that records when it has been opened [6]. A device like Glowcaps, not only records the time and date, but also reminds the patient by glowing when it is time to take the medication [7]. If the patient does not see the glow, an automated telephone call to the patient reminds the patient that the time for medication compliance has been exceeded. Another system, Movipill, not only reminds, it also engages and motivates patients to increase their adherence. Movipill measures the level of adherence by involving the patient in a mobile phone-based game, awarding correct adherence with “stars” [8]. Patients then have the opportunity to join a network to compete against other patients, in remembering to take their pills every day at the correct time.

State of the art systems provide the patient with various ways of reminding to take medication or try to shift the behavior of the patient towards better compliance. In the systems mentioned, context awareness of the patient is not included. The systems reminds regardless of whether the patient is in or out of his home environment and in the same manner. The systems do not adapt the different reminders according to the patient context.

B. Main objective

The aim of the present study is to develop and evaluate a “proof of concept prototype” that can assist the anticoagulant treated patient in improving medication compliance. The study combines sensors and calm medication reminders to determine the patient location and remind accordingly. This results in a synergy which state of the art products lack.

C. Hypothesis

Improving medication compliance for patients in anticoagulant treatment can be fulfilled by combining three context awareness parameters and calm medication reminders.

The three context awareness parameters are:

- The user is out off/ in bed
- The user has taken the medication
- The user is out off /in the home environment

II. METHODS AND MATERIALS

A. Methods

To develop a proof of concept prototype, the objective was to include the concerned patient group, and have them participate in making the project user driven. The patients were involved in developing conceptual ideas of the product in an iterative process but also in evaluating and insuring correct usability of the software. In this process a heuristic evaluation was used [9]. The Adherence Strategy engineering Framework (ASEF) was deployed to deal with the adherence levels and challenges relating to the involved group of patients [10].

The product development was initiated with interviews of medical professionals, patients and interest groups related to the field of anticoagulant treatment, in order to discover how problems may arise in the everyday use of medication treatment [11].

In the finalizing state of prototyping, a pilot test was carried out, involving one patient. The patient carried out the test for two days, in her own home. During the pilot test, information regarding usability and concept sustainability was gathered, via think-a-loud test and semi-structured interview [12, 13].

B. Suggested solution

The suggested solution implements a sensor and reminder based system that works as a pervasive calm medication reminder, which tests for specific patient context scenarios and reminds accordingly, and only reminds when pill glass has not been lifted within the given time window (5 am to 11 am). The flowchart shown in Figure 1 explains how the prototype setup reacts depending on the user context.

The system works with three sensors, one for checking pill glass lifting (pill sensor), one for indicating whether the patient is in bed or not (the bed sensor) and one for indicating patient location (Smartphone/GPS). These sensors and their relationship are shown in Figure 2.

If the patient is lying in bed, the system will assume that the patient is sleeping, and therefore does not send out a reminder. If the patient is out of bed, and forgets to take his/her daily medication within the accepted time window of 1 hour, reminders will be send out.

The reminder concept builds on a principle of variation. As long as the medicine has not yet been taken, the reminders will vary with each occurrence, depending on the three context aware parameters described in the “hypothesis” section. As soon as the medicine is taken the reminders will stop. If the medicine has not been taken after three consecutive reminders, each with a 15 minute interval, the reminders will stop for the day.

HOME reminders

1. Reminder (light, no audio)
2. Reminder (light, incl. audio)
3. Reminder (SMS to next of kin)

OUT reminders

4. Reminder (SMS)
5. Reminder (SMS to next of kin)

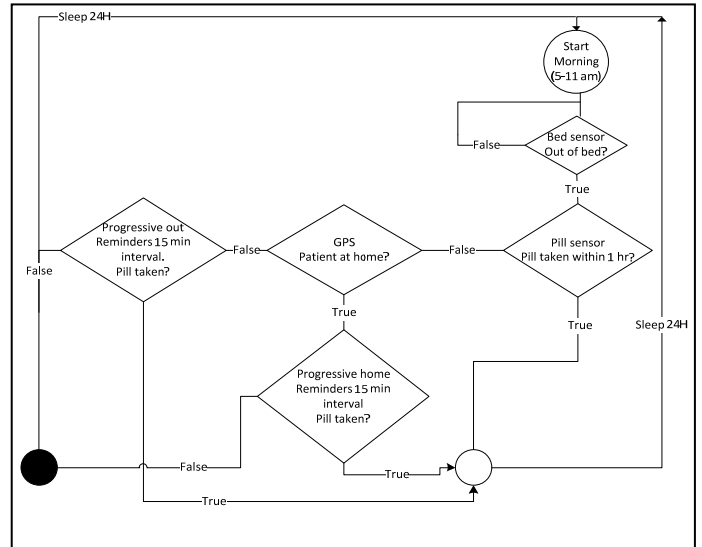


Figure 1. Flowchart

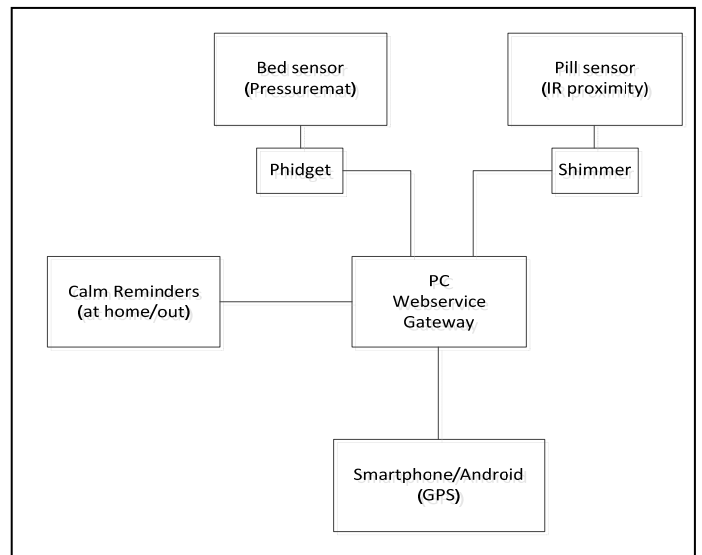


Figure 2. Block diagram

Specified reminder content

SMS: “You have not yet taken your medication”

SMS (next of kin): “The patient has not taken medication”

Light: Pleasant red soft light placed near by the pill box

Audio: Calm instrumental sound

C. Materials

To design the suggested solution hardware and software components listed in table I and table II were used.

TABLE I.

Hardware component list
1 PhidgetInterfaceKit 2/2/2, Phidgets Inc., Canada
1 PhidgetInterfaceKit 0/0/4, Phidgets Inc., Canada
1 Sharp Distance Sensor 2Y0A21F 9Y, Sharp Inc., Japan
1 Laptop, Toshiba.
1 Shimmer1 Wireless Sensor Unit/Platform
1 Pill glass holder

a. List of hardware components used for constructing suggested solution

TABLE II.

Software component list
ASP.NET
Android platform

b. List of software components used for constructing suggested solution

III. RESULTS

A. Prototype

The resulting prototype consists of the three context awareness parameters described in the hypothesis. The prototype also utilizes reminder elements such as light and sound control as well as mobile texting.



Figure 3. Prototype setup

B. Patient findings

The prototype was tested by an anticoagulant treated patient. The patient regarded the reminder functions as useful and relevant, though had concerns of practical nature regarding placing a sensor mat in the bed, and finding room for other space taking electronic equipment in the house. The patient expressed satisfaction in regards to the context aware reminders.

C. Heuristics

The user interface of the prototype was evaluated using heuristic evaluation [9]. Since the user interface is very simple, it presented very few potential usability conflicts.

D. Enhanced compliance

The patient regarded the prototype as a useful compliance enhancer, both due to its reminders and the reminding nature at the mere presence of the prototype hardware.

IV. DISCUSSION

The prototype testing involved only a single potential patient. A larger group of patients ranging different age groups, gender, technical knowhow and types of heart conditions could have been utilized to see whether skill level, cognitive capacity, preferences for technology or other factors would have influenced the patients' view on the prototype.

According to the ASEF model a full adherence model (FAM) is preferred when designing a compliance enhancer or compliance verifier [10]. The study's prototype does not live up to FAM requirements, and can only be regarded as a reduced adherence model (RAM). Implementing technology / sensors that could detect patient pill intake, and not just pill glass lifting, plus better "at home or out" detection, would improve the prototype's compliance verifying qualities. Though the typical patients for this type of medicine are not inclined to deliberately miss pill intake, due to the severity the action would have. There might be other types of patients (e.g. Antabus patients) who could benefit from a fully functional FAM based prototype for both compliance verification and compliance assisting purposes.

Certain healthcare professionals may argue that only patients with a personal interest in self-monitoring are relevant for the self-managed and self-tested patient course. But a compliance aiding and verifying product, such as the prototype of this study, could perhaps encourage patients with a fear of self-monitoring, due to the risks of forgetting to take medicine, to embark on the self-monitoring adventure.

The choice of sensors can also be discussed. Can we count on a patient to permanently carry a smart phone with GPS sensor around all the time? Or would a sensor "invisibly embedded" in patient jewelry, clothing or watch etc. be a better way to detect patient location?

The present study's prototype defined mornings as the time of the patient's daily pill intake. But not all patients take their daily medication at this time of day. Therefore a more flexible system that could handle pill intake at all times of day would be a far more practical system. However, this would require several other context awareness sensors/parameters to register a greater variety of different patient contexts – hence creating a system with several possible redundant sensors.

A. Future work

Combining a wider variety of sensors would more accurately report patient location, pill intake and patient context. This kind of elaborate sensor/system would require a home sensor infrastructure found in smart homes / intelligent houses. Building on an existing platform, such as a sensor

filled smart home, would also minimize the patient's feeling of an "overwhelming electronic take-over" when installing sensors in a non-smart home.

There are currently studies in Denmark on electronic medication dosing to anticoagulant treated patients [2]. Combining this type of electronic medication dosing with compliance verifiers and adherence aid would also be an interesting endeavor for the future.

ACKNOWLEDGMENT

Niels Holm Rasmussen, for his code producing assistance for the Shimmer sensor. Thanks for the user feedback.

REFERENCES

- [1] Aarhus Universitetshospital. "AK-Center (Center for Selvstyret Antikoagulationsbehandling)", Accessed:02/02/2012,<http://www.auh.dk/om+auh/afdelinger/ak-center>.
- [2] Patientforeningen AK-patient. "Maravan-rapporten -hvordan undgås blodpropper og blødninger", Accessed:02/02/2012,http://www.intramed.dk/data/archive/Marevan_report_CS0-anticoagulation.pdf.
- [3] S.E. Kimmel, Z. Chen, M. Price, C.S. Parker, J.P. Metlay, J.D. Christie, C.M. Brensing, C.W. Newcomb, F.F. Samaha and R. Gross, "The influence of patient adherence on anticoagulation control with warfarin: results from the International Normalized Ratio Adherence and Genetics (IN-RANGE) Study," Arch.Intern.Med., vol. 167, pp. 229-235, Feb 12. 2007.
- [4] H.E. Bloomfield, A. Krause, N. Greer, B.C. Taylor, R. MacDonald, I. Rutks, P. Reddy and T.J. Wilt, "Meta-analysis: effect of patient self-testing and self-management of long-term anticoagulation on major clinical outcomes," Ann.Intern.Med., vol. 154, pp. 472-482, Apr 5. 2011.
- [5] Sundhedsstyrelsen. "MTV - Selvmonitoreret blodfortyndende behandling", Accessed:02/02/2012,http://www.sst.dk/publ/Publ2009/MTV/blodfortyndende_medicin/Selvmonitoreret_bloedfortyndende_medicin_net_final.pdf.
- [6] Aardexgroup. "MEMS - Medication event monitoring system", Accessed:02/03/2012,<http://www.aardexgroup.com/>.
- [7] Vitality. "GlowCaps", Accessed:02/03/2012,<http://www.rxvitality.com/>.
- [8] R.d. Oliveira, M. Cherubini and N. Oliver, "MoviPill: Improving Medication Compliance for Elders Using a Mobile Persuasive Social Game," pp. 2011-http://www.nuriaoliver.com/papers/oliveira_ubicomp10.pdf, 2011.
- [9] J. Nielsen, "Enhancing the explanatory power of usability heuristics," in Proceedings of the SIGCHI conference on Human factors in computing systems: celebrating interdependence, pp. 152-158, 1994.
- [10] S. Wagner, O.W. Bertelsen and T.S. Toftegaard Eds., The Adherence Strategy Engineering Framework (ASEF), Aarhus University: 2012, *Internal report*.

- [11] P. Bate and G.B. Robert, Bringing user experience to healthcare improvement: the concepts, methods and practices of experience-based design, Oxford: Radcliffe, 2007, pp. xi, 207 s., ill.
- [12] B. Tognazzini, Tog on interface, Reading, Mass.: Addison-Wesley, 1992, pp. 331 s., ill.
- [13] S. Kvale, Interviews: an introduction to qualitative research interviewing, Thousand Oaks: Sage Publications, 1996, pp. xvii, 326 sider.