Self management of chronic disease using mobile devices and Bluetooth monitors

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ABSTRACT

A prototype system has been developed, based on a mobile Smartphone linked via Bluetooth to a range of monitoring devices (pulse oximeter, blood pressure monitor, ECG monitor), with a facility to integrate to clinical information systems, to enable individuals to self manage their own healthcare. The system has been developed to be used in specific chronic disease applications. The research study described outlines three specific applications of chronic disease self management

- nutrition and exercise monitor for weight reduction;
- pulse oximeter and exercise monitor for pulmonary rehabilitation:
- blood pressure monitor for coronary heart disease patients.

The objectives of the work are to design the system around the clinical application, based on existing health service protocols. The key principles in design are to make the system accessible to and usable by both the medical professional and a lay user. The pulmonary rehabilitation application is explored in more detail, to demonstrate progress towards this end.

Categories and subject descriptors
J. Computer Applications, J3. Life and Medical Sciences.

General terms
Management, Measurement, Design, Human Factors.

Keywords
Self monitoring, telemedicine, Bluetooth, pulse oximeter, blood pressure, heart rate, pulmonary, wireless communications.

BODYNETS 2007, June 11-13, Florence, Italy

DOI 10.4108/bodynets.2007.96

1. INTRODUCTION

Throughout the developed world chronic disease is increasing in prevalence, due to longer life expectancy and occupational or lifestyle causes. [1] In the UK 15 million people live with a long term medical condition, defined as one which cannot be cured but can be controlled [2]. This places demands on health and social care delivery services, which historically have been designed around acute care. Models for management of long term conditions developed in the US and UK indicate that 70-80% of chronic disease patients are candidates for self management [3]. Not only does this reduce pressure on the healthcare system, but there is strong evidence that it also leads to better clinical outcomes for the patients [4]. The Chronic Care Model, developed in the United States is based on research that shows that the essential elements of high quality chronic disease care include self management support, delivery system design and clinical information systems [5]. A recent report by the Royal Society recommends accelerated development of information and communications technology based systems for healthcare [6].

Most work to date in telemonitoring or e-health has been on PC-based systems [7,8,9] , which are therefore restricted to individuals with appropriate access and aptitude. This research uses a mobile telephone based platform to monitor and systematically record key clinical indicators. The advantages are that the system is not only restricted to the home (it is mobile) and that it uses a technology to which the majority of the population have access [9].

2. APPROACH

Technology and products are readily available to provide telemedicine. The challenge is to develop applications of genuine clinical value by integrating available technology into current service provision. The methodology to develop the pilot applications described here has been to begin by understanding the clinical service delivery issues and to design the application around conventional structures. The physical system design then follows from this specification.

The goal is to develop an open architecture, based on configurable devices and conforming to available standards. This enables the

system to evolve as improved devices become available, or as the user requirements change.

A functional proof of concept system has been developed, in which a Smartphone is integrated with two different monitoring devices (blood pressure and pulse oximeter). The UA-767PC Blood Pressure Monitor (A&D, Japan) [10,11] was modified by adding the controlling processor MSP430 and Bluetooth Module Kingene MO-210 to enable wireless connection of the monitor to the BT-enabled cellular phone. Recently A&D Medical announced the release of the Bluetooth enabled Blood Pressure Monitor UA-767PBT. Unfortunately, it was unavailable at the time of our system development. The Avant 4100 pulse oximeter wrist-worn patient module (Nonin Medical, Inc.) with Bluetooth transmitter (version 1.1) was used. The client-software was developed and written on C++ for cellular phones running both Symbian Series 60 OS and Windows Mobile OS.

These devices were demonstrated to clinical partners, who identified specific applications within their service delivery. The detailed system was then designed, by working directly with the clinicians.

3. RESULTS

3.1. Nutrition and exercise monitor

Several patient groups (eg. diabetic, hypertensive, obese patients) are advised to control their diet and to take regular exercise. The use of nutrition diaries has already been piloted and found to have positive effects. Not only does it provide useful information to the clinician, but it is also found to be motivating to the patient. The mobile phone is always available to the patient and so is an ideal device on which to hold the information.

The Nokia 5500 Sport was selected, as it contains a pedometer, which was used as a very basic exercise monitor. The user data input is via a series of menus, linked to a central database, which enables users to enter food items and time of consumption. The user feedback is via simple charts, indicating quality of diet and energy balance (see Figure 1). The patient will be given daily or weekly targets, based on the UK Food Standards Agency

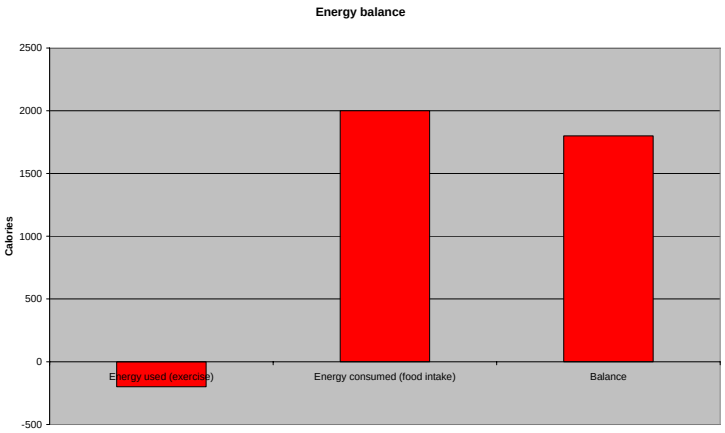

Figure 1: Example of feedback given to user of the nutrition and exercise monitor, showing energy balance

guidelines, against which they will be able to track progress. It is also possible for the user to programme alerts, so that they will be warned if they have eaten too much of a certain nutrient (such as fat) or if they have not eaten enough. This control software will be further developed to provide recommendations for both the patient and the dietitian.

The data held on each patient's mobile phone can be uploaded via the service provider or an ADSL link to a central server, which the dietitian can access to assess individual patient progress and review any trends.

3.2. Blood pressure monitoring

Patients with chronic heart disease are monitored by regular visits to a cardiac or general practice nurse to have their blood pressure monitored. Procedures for such monitoring are covered, for example, in the American Heart Association guidelines [13]. It is well known that this intervention itself often causes an elevation of blood pressure and is also disruptive to the patient's life. Enabling patients to monitor their own blood pressure, as part of a lifestyle improvement programme (including better diet and more exercise) is thought to be clinically beneficial. In this application patients are expected to measure their blood pressure once or twice a day and are sent an SMS alert at the agreed time. The patient must then put on the measuring cuff and press the Start button on the monitor controller. This automatically links to the Smartphone and transfers the data. The cardiac nurse, practice or community nurse, or cardiologist can review the data via the server.

3.3. Pulmonary rehabilitation

Patients suffering from chronic respiratory disease (such as chronic obstructive pulmonary disease, COPD) are given simple exercise routines, as part of their rehabilitation programme after an acute episode. Many fail to comply, as they tend to become

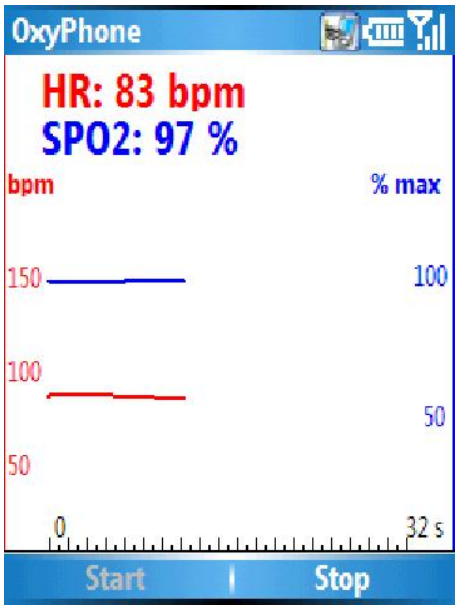

Figure 2: High level user interface for specialist users, which shows the output from a Nonin Bluetooth pulse oximeter, recording heart rate and blood oxygen saturation.

breathless very quickly when exercising and are concerned that this is harmful to them. In fact, repeated exercising through the breathlessness increases lung capacity and reduces disease symptoms. This application provides a 'personal physiotherapist' for patients and also an indicator that their oxygen levels are remaining safe. A Qtek 8300 Smartphone was linked to the Nonin 4100 Bluetooth patient module pulse oximeter [12], to record heart rate and blood oxygen levels.

The initial user interface developed is shown in a series of screen shots in Figure 2. This was designed for specialist use and hence has a smaller target user group. The specific application of pulmonary rehabilitation was developed in consultation with a physiotherapist and nurse, to provide support to patients undergoing the prescribed programme of exercises. Sample screen shots of the new interface are shown in Figures 3 and 4.

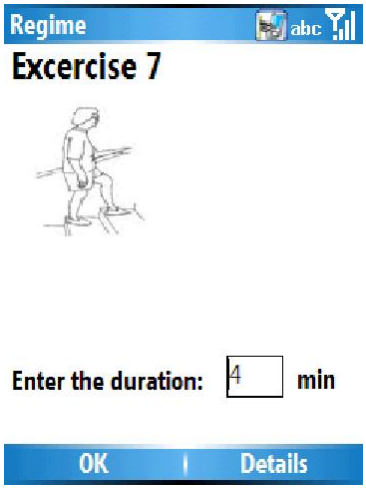

Figure 3: In the series of set up screens, the clinical professional sets up the exercise timings for the patient, based on the standard exercise protocol.

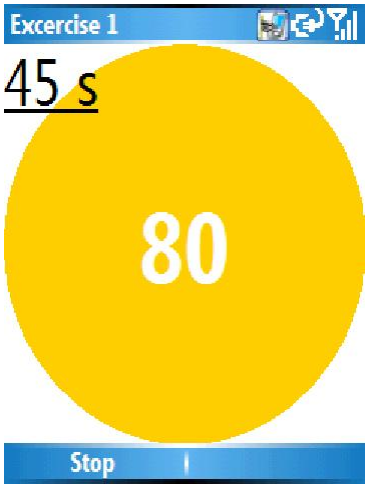

Figure 4: During the exercise routine, the patient is shown a numerical record of their heart rate and the time remaining for the current exercise, with colour coding (green, amber, red).

The interface consists of set up menus for individual exercise programmes (carried out in accordance with NHS guidelines and with the physiotherapist or nurse) and a monitoring screen during the exercise session. Monitoring information is provided to the user via audible or very simple visual alerts. For instance, the screen shown during the exercise itself (shown in Figure 4), indicates by colour coding green for safe (heart rate and blood oxygen saturation within safe limits), amber for becoming unsafe (within 10% of preset unsafe limits for that person) or red for dangerous. If the danger limits are exceeded, the phone also emits a warning signal and the user is advised to stop immediately.

The actual exercise programme carried out is recorded, with associated physiological data. Live data can be transferred to a remote server for review by clinical professionals, who would communicate back to the patients (see Figure 5). This includes the actual time spent on each of the exercises and the physiological data. It is thought that the physiological data itself may provide information of important clinical value, which could be used to refine and modify the rehabilitation programme, once larger scale trials have been completed.

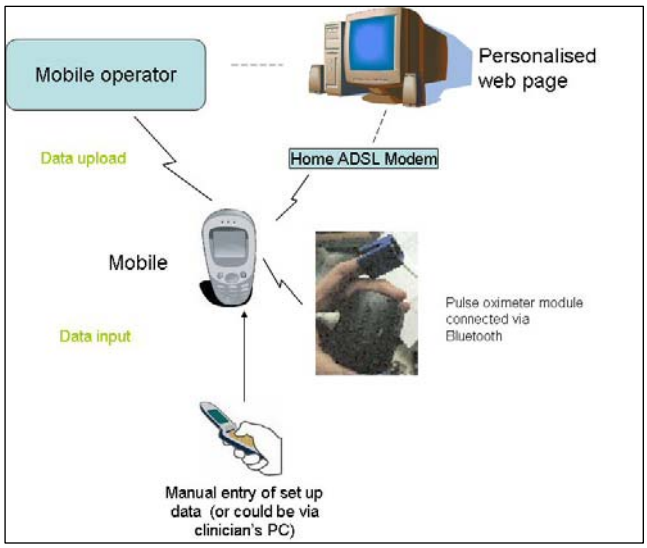

Figure 5: Schematic diagram showing the pulmonary rehabilitation system

4. TECHNOLOGY ROADMAP

The next technological challenge is to integrate wireless systems into the hospital information structure, for which a number of options are possible, including powerline communications. We aim to develop user applications in parallel with technological developments, so that evolving clinical requirements are met.

5. ACKNOWLEDGEMENTS

The authors acknowledge the support of the Royal Society, Rinicom Ltd, Russian Foundation for Basic Research (grant number 05-07-90181-8) and the New Dynamics of Ageing Programme (of EPSRC/ESRC/MRC/BBSRC/AHRC) for this

work. The authors would like to record their thanks to Alexey Antonov for programming work, and to Alison Coe and Lisa Chandler, Wakefield PCT for clinical advice and input to the design.

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