Insulin Management System for Diabetic Patients

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Abstract

The purpose of this study was to attempt a human centered design of a diabetes management system. Emphasis was put on the interface and the interaction between the user and the products, taking into account the varied social and psychological needs of the patient. The design focuses on simplifying tasks and improving communication with the doctor, for real time evaluation of the patient's needs. The aim of the paper is to promote an empathic and user centric approach to designing self-care medical systems, providing data security and rapid response systems for emergency situations, as well as, helping patients blend in to society rather than stand out.

Author Keywords

Healthcare; Interface Design; Diabetes; Body-worn devices; Product Design, User-Centered Design

ACM Classification Keywords

H.5.2 Graphical User Interface, Interaction Styles, User Centered Design
J.3 Medical Information Systems
Optional: C.0 Computer Systems Organization: General: Hardware/Software interfaces

Motivation

The scope for exploring human centric design in medical devices motivated me to take up healthcare as my area of study for this project. according to the International Diabetes Federation, there are 382 million people in the World suffering from diabetes, out of which 65.1million live in India. These numbers are expected to rise drastically over the next 20 years [1]. Estimating the impact of the problem, I was eager to attempt conceptualizing the future of diabetes management.

Introduction

Diabetes mellitus is a metabolic disorder that reduces or prevents the production of the enzyme Insulin, in the Pancreas. Insulin helps carry glucose through the blood to all parts of the body to release energy. Without Insulin, the concentration of glucose in the blood may lead to (possibly fatal) complications in various parts of the body. The research for this project involved understanding the disease, from the medical point of view (understanding the symptoms, causes, possible prevention methods, and existing solutions) and the psychosocial point of view (understanding the impact on the patient's and his/her family's lifestyle, the patient's image in society, and patient's interaction with the possible devices required). The main areas of concern indicated through this research were:

- Invasive and painful nature of the blood glucose monitoring and insulin administration techniques.
- The constant need for monitoring blood sugar levels, and taking appropriate measures (eating or insulin administration) to attain a normal blood sugar level.
- The scope for human error and the fear of subsequent catastrophic reactions.

The system that was conceptualized was a self-care diabetes management system composed of an actuator and a discrete access device. The next few sections will explain the system and its components, how they work, and their interaction with the user. The paper also opens up the scope for future work in this area, and possible areas of debate between the medical importance over the psychosocial importance of certain aspects of the system.

Insulin Management System (IMS)

The IMS is a diabetic patient's self-care kit for blood sugar testing, insulin administration, recording medication, medical appointments, alarms, and storing and sharing information with the doctor. The system primarily consists of two devices for the patient, an actuating unit for blood glucose testing and insulin administration, called the Insulin Administration Device (IAD), and a control unit for discrete access to the IAD, and storing and sharing data with the doctor. The control unit may be of two types; either a dedicated wearable device in the form of a watch or a pendant, or a smartphone application. These units and their roles in the system have been detailed out in the next few sections.

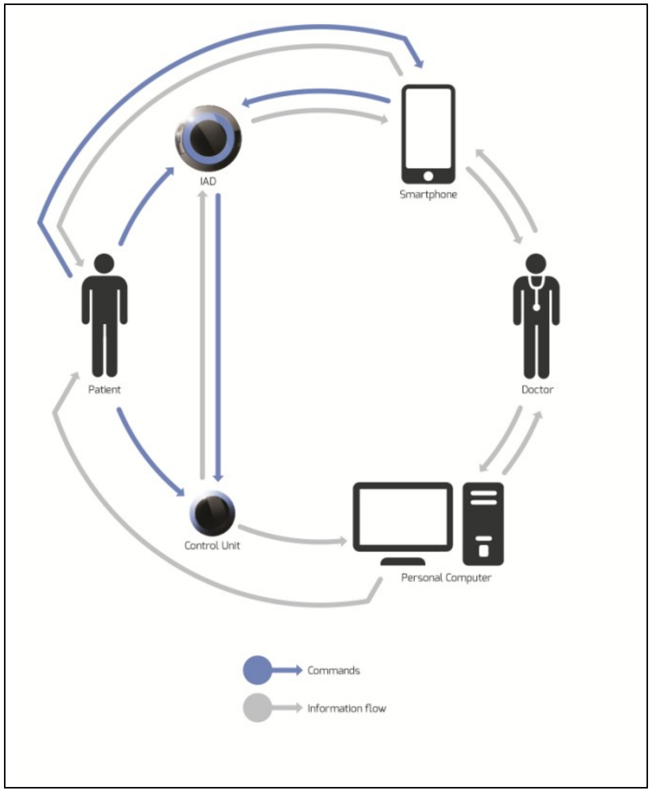

Figure 1. The information flow and command flow in the IMS [12, 13].

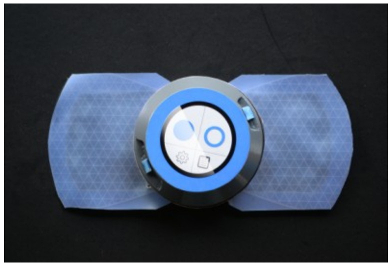

Figure 2. The IAD with the body attachment.

Insulin Administration Device (IAD)

The IAD is a body worn device, that is used to perform insulin administration and blood sugar level checks. The current regimens of insulin therapy involve multiple daily injections for insulin administration and time to time glucose checks using finger pricks for blood tests. This heavy burden of compliance on the patients has prompted interest in developing alternative, less invasive routes of delivery [2]. Attempts have been made to exploit the nasal, oral, gastrointestinal and transdermal routes. One such painless and non-invasive route that I came across in a research paper, was ultrasound mediated transdermal insulin delivery and glucose monitoring [3]. Ultrasound can help make the skin permeable to insulin molecules, and, at a different frequency, can be used to measure blood glucose concentration. This not only eliminates the need for a dedicated glucometer, but also allows direct data generation (measurement of blood glucose levels) and actuation (delivery of appropriate amount of insulin), thus making the process faster and more efficient. The device has a touch based circular screen and two buttons used for actuating a blood glucose test or insulin administration. The blue scroll ring not only enables on screen navigation, but is also recognized as the universal symbol of diabetes. The insulin is stored and used in the form of skin patches with fixed amounts of insulin in them. Transdermal insulin delivery requires a medium of fat cells to synchronize the entry of glucose and insulin into the blood stream. This layer of fat is found on the reverse side of the thighs and arms, around the belly button, and on the buttocks. Due to the nature of this method of insulin delivery, it is advised to rotate the site of delivery, to prevent the pores from getting blocked by insulin. To facilitate the attachment of the device at various parts of the body, the device is attached to the skin using gel based pads, which can be washed and reused. The critical tasks of insulin administration and blood glucose checks are performed by pressing the two buttons in a combination for 3 seconds, to prevent unauthorized access and authentication of commands. In case of an emergency (an unconscious patient) The display will read out instructions to any third party that may

Figure 5. The Control Unit used as a smart watch.

Figure 6. Insulin Management Application

encounter the patient. The third party will then know what immediate actions must be taken before the patient is taken to the hospital. The device provides auditory assistance to the visually impaired, a list of profiles for insulin therapy based on the need of the patient, and a log of recent glucose checks, and insulin amounts delivered.

Figure 3. Usage scenario of the IAD

Control Unit

The Control Unit (as shown in **Figure 5**)is a small, discrete device that is the size of a watch dial and can be worn as an accessory (a pendant, a watch). It is required because most of the time, the IAD is present on the skin, under the clothes, and hence unreachable in a public environment. The device contains a single finger touch screen and a blue scroll ring for navigation. The screen conducts a finger print scan to unlock, and also to maintain the single identity of the user. It is easy to use, with only dedicated functions, and helps transfer data from the IAD to a personal computer from where data can be sent to the doctor concerned for real time monitoring of the patient's condition. The advantage of having a dedicated platform for such tasks is that it cannot be tampered with by mistake. Tasks like insulin delivery and glucose checks can be completed by setting the data on the Control Unit, and pressing the blue buttons on the IAD for the actuation to commence. Here I had consciously decided to keep the final actuation tasks to be completed by the blue buttons on the IAD, because the task of insulin delivery can be fatal if taken without needing insulin in the body. Hence while the entire process is touch based, it is important to get haptic feedback while conducting an insulin delivery.

Figure 4. Usage scenario of the Control Unit.

Insulin Management Application for Smartphones

The application (as shown in **Figure 6**) not only acts as a control unit, but also raises alarms when required, stores reminders, medical appointments, blood glucose records, and insulin delivery records. The app is a dedicated network for the patient and the doctor, allowing real time data sharing and monitoring of the patient's health. For the doctor, the application has profiles of each of his/her patients, which include their medication and insulin therapy logs. Thus, the doctor can keep a real time check on patients without needing an update in every meeting with a patient. The basic profile of the patient includes their name, age, gender, blood group, height, weight, and contact number. The profile of the doctor includes his identity, specialization, contact information, and most importantly, a 'sync data' command which allows the patient to synchronize various data logs with the doctor. As with the control unit, tasks like insulin delivery and blood glucose checks can be completed by setting the data on the application, and pressing the blue buttons on the IAD for the actuation to commence.

Key areas of debate and discussion

Some of the decisions I made for this concept are debatable and can help open up the field of study to peer reviews and further studies and experimentation. These decisions have been listed below.

- The validity of ultrasound mediated transdermal insulin delivery and blood glucose checks as a viable means of insulin therapy itself is questionable until research concludes with definitive findings.

- Since the IAD has well defined tasks and an interface to support these tasks, the need for a screen and a touch based interface is debatable. The screen makes the device operate independent of supporting devices, and thus reduces the dependency on a control unit. Yet, avoiding the touch screen can reduce the size and weight of the IAD, and since a control unit exists as a supporting interface, a screen in the IAD may not be required.

- The existence of the control unit and the smartphone application is also a debatable issue. In medical healthcare products, it is safer and more reliable to have a dedicated device for certain critical tasks, and not overload existing multi-tasking devices. Both the methods perform the same function of discretizing usage of the IAD, but one depends on an existing multitasking platform (the smartphone) while the other resorts to using a dedicated control unit. While the dedicated platform will be efficient and productive, maintaining security of the data collected, a smartphone has ample access to malicious and threatening programs, which may spread viruses and may tamper with delicate data. But since the actuating tasks lie with the IAD , it is possible to entertain the idea of an application as a control unit, over a dedicated device. An application is easier to handle, requires no learning curve in terms of interface, is easy to obtain and access, and has no maintenance costs, all of which are issues that one may deal with, when using a control unit.

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