Developing a Motivational System to Manage Physical Activity for Type 2 Diabetes

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Abstract. Type 2 diabetes (T2D), a chronic disease, can be effectively managed with the combination of diabetic medications and a healthy lifestyle. Regular physical activity helps manage T2D and prevents complications. However, barriers to physical activity prevent some diabetic patients from achieving lifestyle modifications. This paper describes the preliminary work towards the development of a framework to motivate patients with T2D to engage in regular physical activity. Basic information, current health conditions and behaviours of diabetic patients will also be included in the framework for the identification of specific barriers. Computer technologies, including artificial intelligence and persuasive technology, will be incorporated into the framework to achieve the target goals. The framework is based on a comprehensive understanding of a behaviour and behaviour changes of patients.

1 Introduction and Motivation

Diabetes is a complex and chronic disease requiring expensive, continuous medical care and patient self-management [3]. The recent statistics indicate a dramatic increase in the number of diabetic people around the world, reaching 422 million in 2014 compared with only 108 million in 1980 [16]. This number is expected to increase to 552 million by 2030 [21] and 592 million by 2035 [7,18]. Annually, diabetes is estimated to cost around $825 billion [18]. Diabetes and its complications cause more than two million deaths each year [16]. Type 2 Diabetes (T2D) is the most common type of diabetes; approximately 90-95% of all diabetes cases worldwide are T2D [3]. Other types of diabetes include type 1 diabetes and gestational diabetes mellitus [3]. T2D, also known as 'non-insulin-dependent diabetes' and occurs when the body cannot use its insulin effectively [3,21]. Diabetic medications, either multiple-dose insulin injections or low-dose tablets, and a healthy lifestyle can help to manage T2D [3]. A healthy lifestyle can include regular physical activity, nutrition planning, smoking cessation etc [3]. Conversely, unhealthy lifestyles lead to poor health management and increase the risk of developing T2D [3, 19]. Public health professionals have begun focusing increasingly on lifestyle changes to improve the management of T2D and diabetics' overall health. [3, 16, 17, 19]. The World Health Organisation (WHO) defines physical activity as any bodily movement produced by skeletal muscles that requires energy expenditure [16].

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Although regular physical activity supports a patient's self-management of diabetes [19], there are barriers and obstacles that prevent patient from achieving the target goals [20]. These barriers can be defined, in general, as obstacles that prevent a person from achieving a goal, either partly or totally. Physical activity barriers are usually environmental, personal or medical constraints [11, 20]. Most of these barriers are shared with the non-diabetic population, typically linked to lack of motivation [3,10]. In addition, there are specific psychological [6] and health barriers for patients with T2D such as hypoglycemia [11, 19].

The most recent report from WHO and American Diabetes Association (ADA) suggests that advanced computer technology can support and improve the self-management of diabetes [3,16]. The technology can improve individual's lifestyles and lead to behaviour changes that support the better management of T2D and prevent or delay T2D development [3]. Moreover, technology can also influence a patient with regard to better lifestyle modification [17]. This paper presents a preliminary framework to assist patients with T2D to manage the physical activity barriers and persuade to lifestyle modification. Computer technologies that advise or persuade a patient regarding lifestyle modifications are based on a comprehensive understanding of a patient's behaviour and behaviour change in achieving the target goal.

The rest of paper is organised as follows: Section 2, we look at the research questions. In section 3 reviews the literature review and problem definition. Section 4 discusses the methodology of the framework. Section 5 gives points of the expected challenges. Finally, a brief conclusion and discussion about future work are given in Section 6.

2 Research Questions

Different diabetic medications, either injections or tablets, are common and expensive ways for T2D patients to manage diabetes [3]. Healthy lifestyle, such as regular physical activity offer a healthy and economical way to monitor the T2D. A healthy lifestyle can also reduce the risk of complications in T2D patients and prevent or delay diabetes development. Patient's current health status, with side effects like hypoglycaemia, obstructs the achievement of a satisfactory lifestyle. Today, computer technology plays a vital role in enabling patient to overcome complex problems, provide proper consultation, and influence a user to realise positive behaviour modifications. In this proposed framework, we will mainly investigate the opportunity and probability of computer technology intervention (artificial intelligence and percussive technologies) in managing physical activity for T2D patients. Understanding patient behaviour will be taken into consideration to ensure a convincing investigation and reply to the main question. Identifying the barriers to physical actively based on features or signs are presented as central roles in addressing the issue. Therefore, judging and assessing computer technology's ability to capture accurate physical activity barriers will be reviewed as the first sub-question. An evaluation and estimation of the strength of computer technology to persuade and influence patient modification will be examined in the second sub-question. As will mentioned in Section 4, depending on physical activity barriers, the proposed system provides a suitable consultation at the end. Accordingly, computer technology's ability to suggest a correct consultation will be measured and tested in the third sub-question. Evaluating and studying these combined sub-questions can guide this research to explore the capability of computer technology to manage the barriers of physical activity for T2D.

3 Literature Review and Problem Definition

Dramatic annual increases in the numbers of diabetic patients and difficulties with lifestyle modification, such as regular physical activity, have spurred the idea to use technology to influence a patient's lifestyle modification. Computer technology, includes artificial intelligence and persuasive technology, has been successfully utilised within the field of professional healthcare, developing the health services that are provided to patients [8,17]. Artificial intelligence has defined an intelligent behaviour in artifacts [14]; regarding Fogg, the persuasive technology is "learning to automate behaviour change" [5]. Expert systems, examples of artificial intelligence, are a successful employment in the field of medicine that supports self-management, consultations, decision-making and support [8].

In the diabetes field, various types of expert system and framework have been improved to support diabetes patients in managing the disease. Some of the diabetes researches are discussed below.

The authors in [15] demonstrates a diabetes management model to enable patients with T2D to alter their lifestyles. The goal of this model is to monitor and interpret patient's daily lifestyle changes in a form of decision support to achieve patient's health goals. Seven inputs are necessary to insert into the model: age, gender, weight, height, blood glucose (BG), exercise and diet. The system returns three outputs: glycatedhaemoglobin (A1c), exercise and diet level assessments.

The authors in [1] designed and implemented a rule-based expert system to manage one type of lifestyle, which is a healthy diet for patients with T2D. The system can provide the patient with a plan for a satisfactory amount of daily calories as well as a list of proposed foods.

The author and co-author in [9] developed a knowledge-based system that focuses on natural treatments, such as healthy nutrition, massage, acupuncture and gemstones, to treat diabetes and certain other diseases. For diabetics, the system produces an adequate consultation, providing a description and natural treatment solution. The system depends on the user's input of symptoms for distinguishing between diabetes and other diseases.

The authors in [12] improved a medical advising system to assist diabetics in rural communities. The system includes educational tools that educate diabetic patients, and even non-diabetics, regarding diabetic risks and management. The system produces a simple consultation instead of multiple solutions based on a patient's symptoms or signs. Some of the closed questions asked produce a final consultation.

The authors in [8] established a system to advise women with gestational diabetes regarding the adjustment of daily multiple-dose insulin and dietary habits. The system provides a consultation according to patient inputs, which include blood glucose level, time and nutrition modification. The system is evaluated in real scenarios and has proven to reduce the frequency of doctor visits.

The above researches in diabetes management are a success when it comes to achieving their goals, but are lacking when it comes to addressing patient behaviours that can significantly impact the management of their disease. In order to take these behaviours into consideration, the behaviour of user need to be understood [5, 13]. Once user behaviour can be appreciated, system developers are able to create a motivational system that has the ability to change user behaviour [5], rather than just provide a simple consultation. Conversely, a system that is designed without user behaviour in mind will yield a highly limited solution [5]. A patient or user may know, obviously, that eating healthier and more nutritional food leads to a healthier lifestyle, and vice versa, but the results are apparent in the future, not immediately. Imagine using a short video to show the direct cause-and-effect relationship between nutritional eating and a healthy or unhealthy lifestyle, and how this would affect the behaviour of the patient. This simulation lets the user explore and experiment with a real healthy or unhealthy consequence [4]. The simulation, which is based on motivation factors, simulates particular pleasure and pain elements and pushes a user to change the behaviour. [4, 5].

Physiological research studies have shown that opportunities for learning behaviour changing techniques, such as motivation and goals, influence a person's behaviour modification. Computer technology can play a motivational role in persuading patients to change their behaviour, despite a low health status [4,5,17]. Motivating a diabetic patient to change the lifestyle, like quitting smoking, is more efficient than just treatment alone [3]. According to the national standards for Diabetes Self-Management Education (DSME), diabetic patients must understand that a healthy lifestyle begins with high-quality self-management to improve overall health and prevent complications [3]. But how do we encourage, promote, and convince them to act on their beliefs? Consequently, a substantial problem is finding ways we can influence and persuade dietetic patients to follow a healthy lifestyle as directed through the medical advice. In order to effectively apply technology to influence a patient's behaviour change, the patient's behaviour must be taken into consideration [17].

Today, it has become possible to intervene persuasive technology into the system design to persuade users to change the behaviour [4,5]. The Fogg Behaviour Model (FBM) combines the physiological and technological sides, pushing a user towards behaviour modification; it is a suitable model to apply, in part, to this framework. [5]. FBM paves the way for the movement and application of the psychological theory on computer technology to influence user behaviour modifica-

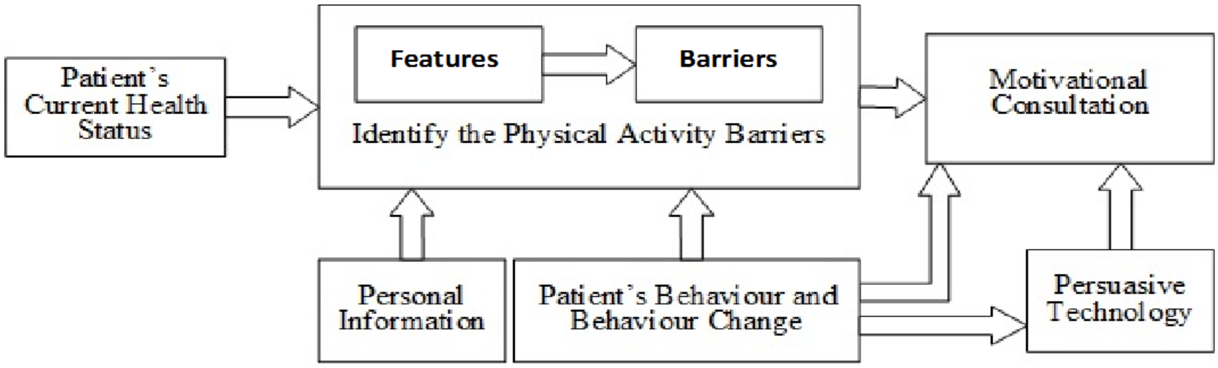

Figure 1. Preliminary Framework to Mange the Physical Activity for T2D

tion [4, 5]. FBM is a general model which can be used in the healthcare field to modify patient behaviour. FBM asserts that there are three combined factors (sufficient motivation, ability and trigger), which have to come together at the same time for a target behaviour to happen; otherwise, the behaviour will not occur. These factors have provided a platform for designers and researchers to understand users' behaviour and performance [5].

4 Methodology

4.1 Preliminary Framework for Managing Physical Activity

This research presents a preliminary framework for managing physical activity in individuals with T2D (Figure 1). The framework is based primarily on a comprehensive understanding of a patient's behaviour and behaviour change, to capture the actual barriers, provide a final exhortation, and design the persuasive technology. The personal information phase has enabled the system to obtain the necessary information from a patient such as age, gender, city, job (part-time or full-time) and other information. This phase assists in identifying basic features of barriers, such as lack of time, in the early stages. For example, according to a patient's daily diary, the time constraint barriers can appear, in part, in this phase. The phases of understanding a patient's behaviour and behaviour change are based on the psychological theory to complete this phase successfully. Emotions, social influences, motivations and goals (and other aspects) should be determined in this phase, as well as a patient's beliefs about their capabilities and consequences. These key determinates identify not only the initial features of psychological barriers, but also help to understand a patient's behaviour change [13]. The patient's current health status must be examined to identify any barriers related to their current health condition, such as the blood glucose level. Identification of patient's physical ability, in this stage, also helps to produce a suitable intensity, type and duration of physical activity by the end of the consultation. The design of the persuasive technology is based on the FBM, which includes behaviour modification, as well as a psychological understanding of a patient's behaviour and behaviour change. The phase of identifying the physical activity barriers is responsible for recognising the actual physical activity barriers based on the features of these barriers, from either the other phases or their own features (Subsection 4.2). Finally, a motivational consolation phase can produce a stimulated consultation depending on all of the above phases.

The preliminary model presents how these related stages (the personal information, patient's current health status, identify the physical activity barriers, patient's behaviour and behaviour change, and persuasive technology phases) can produce a motivational consultation for diabetic patients depending on an understanding of the behaviour (Figure 1).

4.2 Proposed Method to Identify the Actual Physical Activity Barriers

In the preliminary framework on (Figure 1), we suggest dealing with each barrier as an independent problem. Consequently, each barrier will be identified according to its own features or signs. Ignoring these features may lead to an incomplete consultation, or worse, an incorrect consultation. Identifying the actual barriers guides advisors to a successful and suitable consultation in the end. For example, bad weather is presented as a barrier for diabetic patients, as well as the general population [10]. Classifying either the weather condition is a barrier or not is dependent upon certain related states of the atmosphere and phenomena such as heat, cold, storms, and rain. The evaluation or assessment of each factor acts as a guide for accurate decision-making and a recommendation with more details, whether on the barriers side or the consultation side. In contrast, ignoring one or more these signs or features, even though they are forecasted in some cases, lead to inexactly identified barriers, and, consequently, inaccurate conclusions. The below if-then formula clarifies how to identify if the weather is a barrier or not based on a few weather signs.

IF it is winter OR the temperature is < 0 degrees
OR the weather is stormy
THEN The weather is a barrier because it is cold
We advise you to do indoor physical activity.

On the side of health barriers, hypoglycaemia, or low blood glucose, is classified as an obstacle to maintain physical activity for the patient with T2D [11,19]. Symptoms such as feeling hunger and nausea, blurred (impaired vision) and headache will be present with hypoglycaemia [2]. The blood glucose level, an indicator of the patient's current health status, is also indicative of hypoglycaemia [19]. The below if-then rules explain how to identify whether hypoglycaemia is a barrier to physical activity or not based on a few symptoms (features) and blood glucose levels. The following if-then rules explain how to determine whether hypoglycaemia is a barrier to physical activity or not, based on a few symptoms or signs [2,19].

IF blood glucose levels $<$ 100 mg/dL (5.6 mmol/L)
OR feeling hunger and nausea
OR blurred/impaired vision
THEN Recheck your blood glucose after 15 minutes, if hypoglycemia continues, repeat once blood glucose returns to normal, eat a small snack, if your next planned meal or snack is more than an hour or two away

5 Expected Challenges

Academic researchers can expect to face challenges in any area of investigation. Anticipating challenges and seeking suitable solutions in the early stages of research serves to help the researcher manage difficulties more efficiently. The anticipated challenges of this study include:

- Understanding of patient's behaviour and behaviour change in different age groups, and designing the persuasive technology with these differences in mind.
- Identify the specified barriers based on features of barriers (psychological, medical or personal), and then produce a motivational consultation based on the identified barriers.

6 Conclusion and Future Work

Helping patients with T2D perform regular physical activity to result in lifestyle modifications is a challenge faced by health organisations and researchers. At the individual level, a patient's regularly partaking in physical activity contributes to the maintenance of a healthy lifestyle and in assistance with T2D management; however, barriers often prevent meaningful physical activity. The framework described in this paper proposes a system by which to manage barriers to physical activity, improving lifestyle changes and supporting T2D management. Both artificial intelligence and persuasive technologies integrate with this framework, which works to identify physical activity barriers and providing a motivational consultation at the end. Developing and testing the preliminary framework, which is based on understanding patient behaviour and behaviour changes, will be conducted in future work.

Diabetes is only one of many chronic conditions impacting people's lives. The preliminary proposed framework can be applied to different chronic diseases, including obesity and high blood pressure. The method of identifying physical activity barriers according to features can also be applied to other chronic diseases.

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