Type 2 Diabetes Management in Primary Healthcare

Using a Microsoft Power Virtual Agent

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Abstract

With type 2 diabetes being one of the most predominant chronic diseases worldwide, it is of extreme importance to learn how to effectively manage this condition and promote self-management strategies. In this study we conducted a Systematic Literature Review to identify the main challenges and benefits of using chatbots to help manage type 2 diabetes in primary healthcare. The problem addressed under the scope of this thesis is patients' poor adherence to complex and difficult chatbot solutions as well as lack of self-management, concluding that chatbots can have the potential to improve type 2 diabetes patients' lives, besides improvements in patient treatment. Chatbots also have the prospect to be of great service to healthcare professionals' jobs by promoting treatment plan adherence. The development of this solution is guided by the Design Science Research Methodology. The main goal of this research is to develop a chatbot solution to help improve T2D patients' lives by impacting their self-care techniques and improving habits. The chatbot was developed using Microsoft Power Virtual Agents and implemented in Microsoft Teams.

Keywords

Type 2 Diabetes; T2D; Chatbot; Power Virtual Agents.

Resumo

Sendo a diabetes tipo 2 uma das doenças crónicas mais predominantes a nível mundial, é de extrema importância aprender a gerir eficazmente esta condição e promover estratégias de autogestão. Neste estudo realizamos uma Revisão Sistemática da Literatura para identificar os principais desafios e benefícios do uso de chatbots para ajudar a gestão de diabetes tipo 2 nos cuidades de saúde primários. O problema abordado sob o âmbito desta tese é a baixa adesão dos pacientes a soluções complexas e difíceis de chatbots, assim como falta de autogestão por parte dos pacientes, concluindo que os chatbots podem ter potencial para melhorar a vida dos pacientes, além de melhorias no tratamento. Os chatbots também têm a perspectiva de serem uma grande ajuda ao trabalho dos profissional de saúde, promovendo a adesão ao plano de tratamento. O desenvolvimento desta solução é guiada pela Metodologia Design Science Research. O objetivo principal desta tese é desenvolver uma solução de chatbot para ajudar a melhorar a vida dos pacientes com DM2, impactando as suas técnicas de autocuidado e melhoramento de hábitos. O chatbot foi desenvolvido utilizando Microsoft Power Virtual Agents e implementado em Microsoft Teams.

Palavras Chave

Diabetes tipo 2; DM2; Chatbot; Power Virtual Agents.

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Acronyms

AI	Artificial Intelligence
BMI	Body Mass Index
DSRM	Design Science Research Methodology
HbA1c	Glycated hemoglobin
PVA	Power Virtual Agents
RQ	Research Questions
SLR	Systematic Literature Review
T2D	Type 2 Diabetes
WHO	World Health Organization

1

Introduction

The burden of Type 2 Diabetes (T2D) is recognized globally as one of the fastest growing and the most common chronic health conditions in the entire world. According to the World Health Organization (WHO), there are 422 million estimated diabetes cases worldwide, 95% of which are from T2D alone. In 2019, with an estimated 1.5 million deaths caused, diabetes was the ninth leading cause of death[1].

With expenditures for patients with diabetes at a rate 2.3 times higher than those without the disease, diabetes is both a financial and emotional burden, considering the negative impact on quality of life and the incidence of depression. This in turn, negatively affects the patient's ability to carry out self-management which can lead to significantly worse glycemic control [2].

Type 2 diabetes is a demanding illness to live with since it requires complex treatment, strong patient commitment, and continuous adherence to the treatment plan. However, it can be successfully managed, especially if detected and treated early, through dietary and lifestyle changes, allied with oral hypoglycemic agents. Essential self-care behaviors in people with diabetes, besides healthy eating, physical activity and compliance with medications, are monitoring of blood sugar, coping skills, and risk-reduction behaviors. All of these self-care behaviors have been found to be positively correlated with adequate glycemic regulation [3–5].

The goal of this research is to create a chatbot solution using Microsoft Power Virtual Agents, implemented in Microsoft Teams, which intends to help patients improve their health by reminding them to regularly exercise and measure their weight and blood sugar levels regularly. The development of this solution will follow the Design Science Research Methodology.

The **Design Science Research Methodology (DSRM)** offers a set of guidelines for evaluation and iteration with applications in the fields of engineering and computer science, offering a pragmatic approach [6].

Peffers et al. [1] collected several papers about the development of said methodology and established the six main activities:

- **Problem identification and motivation**: Define the specific research problem and justify the value of a solution;
- **Define the objectives for a solution**: Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible;
- **Design and development**: Create the artifact, which can be defined as constructs, models, methods, instantiations and design theories;
- **Demonstration**: Demonstrate the use of the artifact to solve one or more instances of the problem;

[1] https://www.who.int/news-room/fact-sheets/detail/diabetes

- **Evaluation**: Observe and measure how well the artifact supports a solution to the problem, comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration;

- **Communication**: Communication of the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences.

Figure 1.1 summarizes the DSRM process, specifying the work that will be developed in each of the different phases.

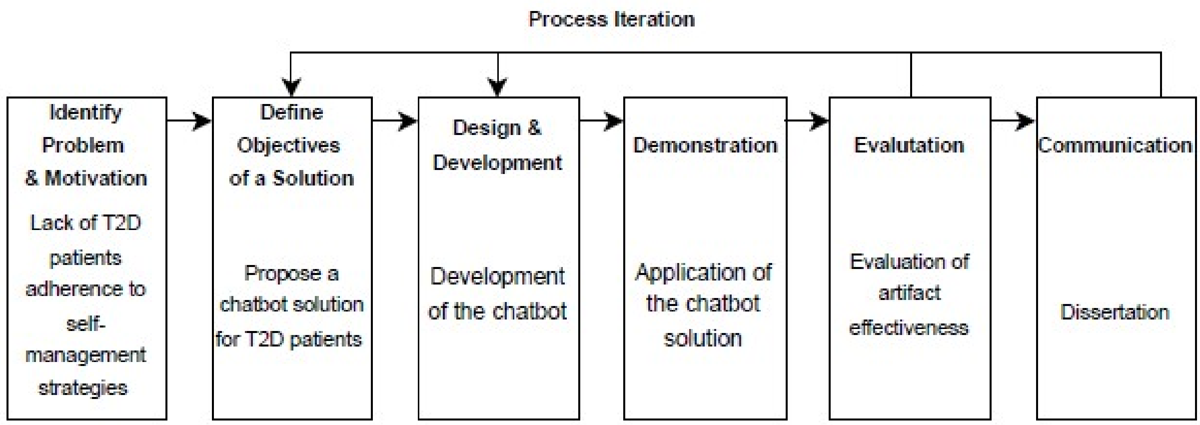

Figure 1.1: Phases of the Design Science Research Process, adapted from [1].

The remainder of this document is structured as follows: Chapter 2 concerns the Research Background of the thesis, concerning type 2 diabetes, communication in healthcare, and chatbots. Chatbots and type 2 diabetes are further discussed in Chapter 3, through a Systematic Literature Review (SLR), in order to come across current challenges and benefits in the literature.

The Research Problem of this thesis is presented in Chapter 4. The objectives and description of this research is introduced in Chapter 5.

The demonstration of how the chatbot was created and the description of the technologies that were used are detailed in Chapter 6, and its evaluation is done in Chapter 7. Finally, Chapter 8 details the conclusion of our research, as well as our main limitations and intentions for future work.

2

Research Background

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This chapter discusses the state of the art regarding type 2 diabetes, communication in healthcare and chatbots.

The first subsection introduces the chronic disease, type 2 diabetes, its effects on patients, and how to manage such condition. This introduction also discusses commonly used communication channels between patients and healthcare professionals.

We then introduce the concept of a chatbot, what they are and can do, and the different types of technologies they can be applied to. To finalize this chapter, some examples of chatbots in the healthcare domain are presented.

2.1 Type 2 Diabetes

Diabetes Mellitus, commonly known as diabetes, occurs when an individual cannot naturally produce sufficient insulin or becomes insulin-resistant. Insulin is a hormone that regulates blood sugar levels, by facilitating cellular glucose uptake, regulating carbohydrate, lipid and protein metabolism and promoting cell division and growth through its mitogenic effects [7].

Hyperglycemia is the medical term for a high blood sugar (glucose), with blood glucose levels greater than 126 mg/dL while fasting and greater than 200 mg/dL 2 hours postprandial. A patient has impaired glucose tolerance, or pre-diabetes, with a fasting plasma glucose of 100 mg/dL to 125 mg/dL [8].

According to WHO, Glycated hemoglobin (HbA1c) reflects average plasma glucose over the previous 8 to 12 weeks. The test is used to monitor long-term glycemic control, adjust therapy, assess the quality of diabetes care and predict the risk for the development of complications. To determine if the patient has developed T2D, the HbA1c has a level of 6.5% or higher. HbA1c bellow 5.7% means the person is not diabetic, and levels between 5.7% to 6.4% means pre-diabetes [8, 9].

Like many other chronic diseases, T2D is a demanding illness to live with since it requires complex treatment, strong patient commitment, and continuous adherence to the treatment plan [3]. Type 2 diabetes can be successfully managed, especially if detected and treated early, through dietary and lifestyle changes, allied with oral hypoglycemic agents [4].

Other essential self-care behaviors in people with diabetes, besides healthy eating, physical activity and compliance with medications, are monitoring of blood sugar, coping skills, and risk-reduction behaviors. All of these behaviors are positively correlated with glycemic regulation [5].

Patients usually face some difficulties in adhering to self-management programs, due to lack of knowledge and understanding of self-care activities, absence of individualized and coordinated care, inconvenient and costly education sessions, and difficult patient-provider communication [10]. Umpierre et al. [11] evaluated in a systematic review and meta-analysis the ability of at least 150 minutes of exercise per week combined with dietary advice can lead to a HbA1c decline.

Health literacy promotes participation, access to education and information and is essential to achieve effective participation and the empowerment of people and general health [12]. Improving health literacy may also reinforce the motivation of individuals to solve personal and health problems by enabling them to apply skills in response to various health problems arising thorough life [13].

There are several ways for T2D patients and medical teams to communicate. The quality of the interaction and communication between patients and health care professionals is an important determinant of the quality of healthcare [14].

According to this Portuguese research [15], improvements in patient-professionals communication is needed, and depends on the created relationship, patients' participation and involvement, as well a training providers' communication skills. Both patients and providers agreed on some constraints, like power imbalance, avoidance of criticism, disease minimization, use of jargon, and insufficient competencies and consistency among providers.

There can be a lot of ways to complement in-person communication. One example is automated telephone communication systems, which can be interactive or not. These procedures can change patient's health behaviors and have the potential to improve health outcomes [16].

Mobile applications can also have a crucial role in the communication between patients and healthcare professionals, by providing a more convenient way of communication [17].

2.2 Chatbots

Dialogue systems otherwise known as conversational agents communicate with users through natural language (text, speech, or both), and fall into two categories [18]:

- Task-oriented dialogue agents use conversation with users to help complete tasks, such as: giving directions, controlling appliances, finding restaurants, or making calls.
- Chatbots, are systems designed for extended conversations, set up to mimic human-human interaction, for practical purposes like making task-oriented agents more natural.

When implementing chatbots, developers usually employ Chatbot Frameworks, to facilitate the integration of multiple channels and provide Natural Language Understanding services able to map user utterances to structured intent specifications [19]. These services are provided by third parties, such as Microsoft's with Microsoft Bot Framework[1], Google's DialogFlow[2], or IBM's Watson Assistant[3], that allow conversational agents to be designed using fewer resources.

[1] https://dev.botframework.com/
[2] https://cloud.google.com/dialogflow/
[3] https://www.ibm.com/products/watson-assistant/

Microsoft also offers Power Virtual Agents (PVA)[4] within its Power Platform, which lets the user create chatbots able to answer questions posed by end users, with no coding required. PVA can be integrated with a great amount of channels, with Microsoft Teams[5] being free and a relatively easy way to integrate the chatbot with. We have leveraged Microsof Teams during this research given its numerous features such as ease of use, data security, being highly adopted by the industry, together with its many device options.

2.3 Chatbots in Healthcare

Healthcare chatbots are already being studied according to a recent systematic review [20], concluding that these agents have the potential to benefit healthcare across a broad range of application domains. This review found three articles that concern type 2 diabetes:

- **Black et al.** [21]: Development of an intelligent, automated remote monitoring system which involves patients proactively in the care of their condition by using spoken dialogue technology, in 8 weeks with 5 patients;
- **Griol et al.** [22]: Consists of a set of different systems that generate the data required to retrain a dialog model, using the aforementioned dialog system [21], 6 participants followed a set of 150 scripted scenarios;
- **Harper et al.** [23]: Based on previous study [21], a system was created that allows patients to use their own phones to input and record their measurements using speech, while the web-based view allows consultants to monitor the patients on a daily basis and respond to alerts, in 16 weeks, and 13 patients asked to call the conversational agent once a week.

All aforementioned studies showed that chatbots were successful, there was self-reported behavior change [23], along with patients appreciation for the level of personalization achieved by the system [21].

In the last couple of years, the number of health chatbots multiplied with incredible speed. That also shows what bright future chatbots can have in healthcare and how wide the scope is where they can be a tool to both patients and healthcare professionals. Some examples [24], according to Medical Futurist, of the most popular solutions are presented in Table 2.1.

[4] https://powervirtualagents.microsoft.com/en-us/
[5] https://docs.microsoft.com/en-us/microsoftteams/
[6] https://keenethics.com/project-one-remission
[7] https://www.youper.ai/
[8] https://www.babylonhealth.com/en-gb
[9] https://florence.chat/
[10] https://www.livehealthily.com/

Table 2.1: Well-known chatbots in the healthcare domain.

Bot	Channels	Description
One Remission [6]	Mobile App	Empowers cancer patients by providing lists of diets, exercises and post-cancer practices so that users don't need to constantly rely on a doctor.
Youper [7]	Mobile App	Monitors and improves users' emotional health with short personalized conversations using psychological techniques. Also features personalized meditations and the ability to monitor mood and emotional health.
Babylon Health [8]	Mobile App	Users can report their symptoms to the bot, which consults a database of diseases to offer an appropriate course of action.
Florence [9]	Messenger, Skype, Kik	Reminds patients to take their medication, notifying them at the appropriate times of the day. Can track the user's health, such as, body weight, mood or period, helping users reach their goals.
Healthily [10]	Mobile app, Messenger, Slack, Kik, Telegram, browser	Offers actionable health information based on highly accurate sources and lets the user make the best choices for their health. Excellent source of online medical service providers, such as pharmacies, test centres, doctors' offices or recommendations for mental health apps.

3

Systematic Literature Review

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This chapter corresponds to the performance of a Systematic Literature Review (SLR), which is defined as a "means of identifying, evaluating and interpreting all available research relevant to a particular research question, topic area or phenomenon of interest" [25]. In this research, an SLR was chosen due to its trustworthiness and beneficial summarization of existing evidence concerning type 2 diabetes and the use of chatbots, and corresponding challenges. In addition, it also allows the identification of any gaps in the current research, providing some background knowledge to locate new research activities.

The SLR conducted was based on Kitchenham's Procedures for Performing Systematic Reviews [25], which contains the following phases:

1. **Planning**: Identification of the need for a review, and development of a review protocol, which is required to reduce the possibility of researcher bias. This phase also defines the Research Questions.
2. **Conducting**: Selection of studies, data extraction analysis, monitoring and synthesis.
3. **Reporting**: Summarizing of the relevant information from the selected studies.

This systematic literature review was managed and documented using Parsifal[1], an open-source web application based on the steps suggested by Kitchenham and Charters [26] for performing systematic literature reviews in software engineering.

In essence, the Systematic Literature Review is conducted to help identify the problem and define objectives for a solution, simplifying the tasks of finding answers for the proposed Research Questions, concluding with a discussion of the obtained results.

3.1 Planning the Review

This section corresponds to the first step of the SLR Methodology. First, the study's motivation is exposed, followed by the objectives and corresponding research questions intended to be answered with this research. Finally, the review protocol is presented.

3.1.1 Motivation

Type 2 diabetes causes plenty of problems in patients, so, its management in primary healthcare is of extreme importance, therefore the research proposal is the use of a chatbot to communicate with the patients.

This Systematic Literature Review has the intention of finding what work has been done using chatbots in healthcare, mainly with type 2 diabetes. In addition, contemplating how user motivation and engagement work with chatbot solutions, as well as healthcare related processes simplification.

[1] https://parsif.al/

3.1.2 Research Questions

The objective of this search is to understand how chatbots can be used to help type 2 diabetes patients. In order to achieve this end, the following Research Questions (RQ) were formulated:

- **RQ1:** What are the challenges in implementing a chatbot for type 2 diabetes management?
- **RQ2:** What are the benefits of using a chatbot for type 2 diabetes management?

3.1.3 Review Protocol

The Review Protocol is required to reduce the possibility of researcher bias. Its first step is to define the search string, which will be used in multiple search databases, in order to find a relevant number of studies to answer the proposed research questions. The search string used to conduct the search, as well as the databases that were selected, are listed below:

- **Search string** : "Diabetes" AND "Chatbot"
- **Databases** : EBSCO Discovery Service, Scopus, ACM Digital Library, and PubMed.

The chosen string takes into consideration the title and abstract of the papers. Then, the abstracts must be screened to evaluate their relevance to the research, following the inclusion and exclusion criteria, presented in Table 3.1.

Table 3.1: Inclusion and Exclusion Criteria.

Inclusion Criteria	**Exclusion Criteria**
Written in English	Not written in English
Studies with type 2 diabetes	Studies with only type 1 diabetes
Studies using virtual Chatbots	Studies using physical robots
Studies focused on the use of Chatbots	Studies only focused on Machine Learning Algorithms

3.2 Conducting the Review

This section regards the second phase of the Systematic Literature Review methodology. After the aforementioned review protocol is applied, the analysis of the extracted data is performed.

3.2.1 Selection of Studies

Following the search of the selected databases with the search string defined in the review protocol, a total of 28 papers were obtained. With the filtering of duplicates, there were 20 articles left, which were then screened by analyzing the title and abstract, while applying the inclusion and exclusion criteria, table 3.1, leading to 14 papers. After all 14 papers were thoroughly reviewed, a total of 11 were selected for further research.

All primary papers selected from the digital libraries were analyzed using a snowballing strategy, as recommended by Webster and Watson [27] and based on Wohlin's guidelines [28]. Both snowballing strategies were applied: backward snowballing, by analyzing the reference list of each primary paper, and forward snowballing, by analyzing the citations to each primary paper, searched using Google Scholar. The snowballing technique was applied on this set of papers to obtain a more complete set, which resulted in an addition of 3 new papers, making a final set of 14 papers. Table 3.2 contains the whole list of the selected studies, including the ones found by snowballing [29–31].

The identification of studies is represented in Figure 3.1.

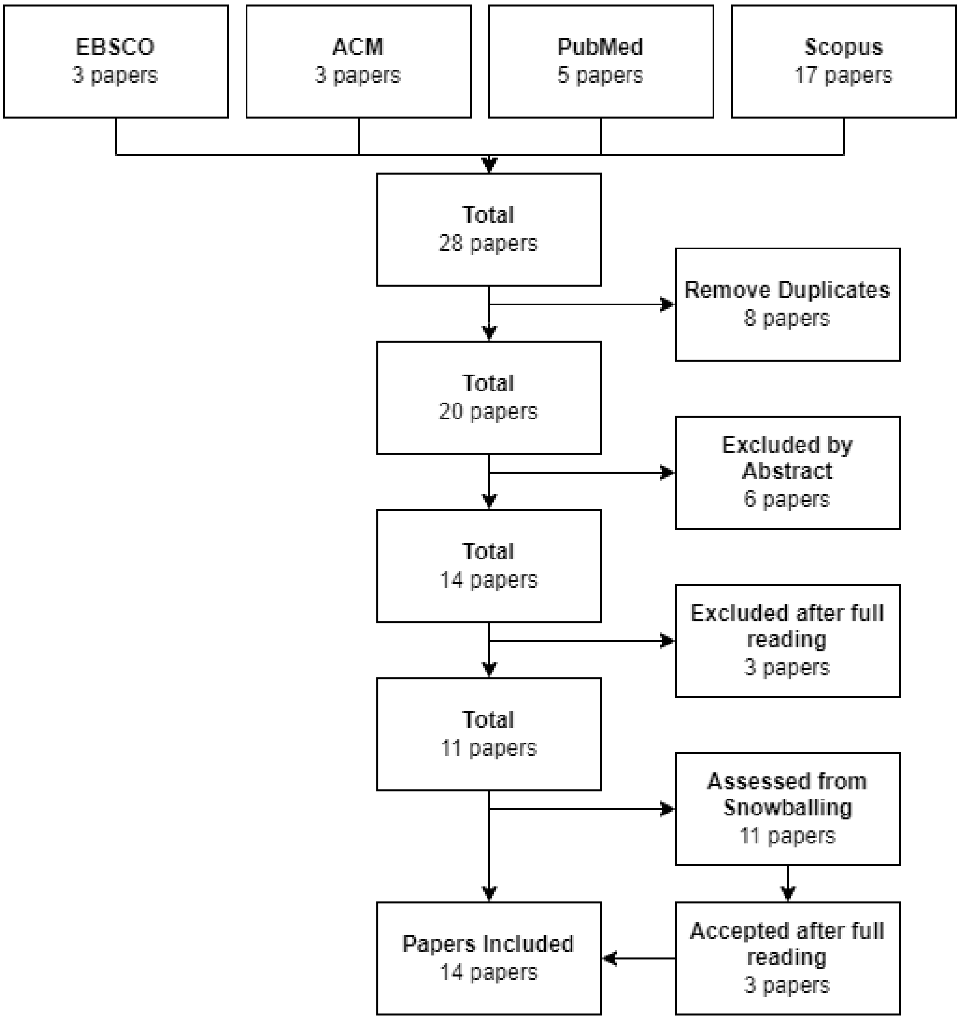

Figure 3.1: Selection of papers process.

Table 3.2: List of the obtained studies through the SLR.

Authors and Ref	Title	Year
Bali et al. [32]	Diabot: A predictive medical chatbot using ensemble learning	2019
Brinkman et. al [29]	Virtual Health Agents for Behavior Change: Research Perspectives and Directions	2016
Cole-Lewis et al. [30]	Participatory approach to the development of a knowledge base for problem-solving in diabetes self-management	2016
Essers et al. [33]	Assessing the POSTURE Prototype: A Late-Breaking Report on Patient Views	2018
Fadhil et al. [34]	Addressing challenges in promoting healthy lifestyles: The Ai-Chatbot approach	2017
Hussain et al. [35]	Extending a conventional chatbot knowledge base to external knowledge source and introducing user based sessions for diabetes education	2018
Krishnakumar et al. [36]	Evaluating glycemic control in patients of South Asian origin with type 2 diabetes using a digital therapeutic platform: Analysis of real-world data	2021
Lokman et al. [37]	Extension and prerequisite: An algorithm to enable relations between responses in chatbot technology	2010
Mitchell et al. [38]	Automated vs. Human Health Coaching: Exploring Participant and Practitioner Experiences	2021
Randine et al. [39]	The house of carbs: Personalized carbohydrate dispenser for people with diabetes	2020
Sherifali et al. [31]	Evaluating the Effect of a Diabetes Health Coach in Individuals with Type 2 Diabetes	2016
Sowah et al. [40]	Design and Development of Diabetes Management System Using Machine Learning	2020
Stephens et al. [41]	Feasibility of pediatric obesity and prediabetes treatment support through Tess, the AI behavioral coaching chatbot	2019
Thompson et al. [42]	Chatbots as extenders of pediatric obesity intervention: an invited commentary on “Feasibility of Pediatric Obesity & Pre-Diabetes Treatment Support through Tess, the AI Behavioral Coaching Chatbot”.	2019

3.2.2 Data Extraction Analysis

In Data Extraction Analysis, we will examine the selected papers by year. It is possible to recognize, in fig. 3.2 that most selected papers were published in the recent years, with an exception from 2010, since chatbots are a recent technology.

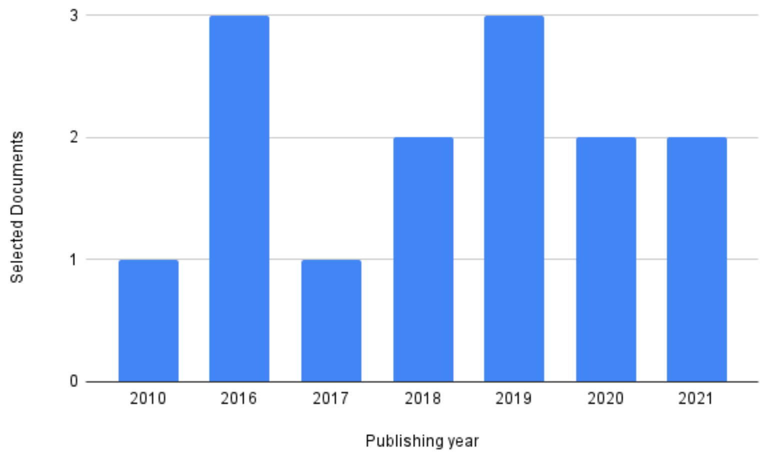

Figure 3.2: Distribution of the selected documents per year.

3.3 Reporting the Review

This section summarizes the concepts extracted from the selected papers, dividing the results into different topics. These topics answer the RQ, previously introduced in the Planning phase of the SLR.

3.3.1 RQ1: Challenges

Table 3.3 contains the challenges and problems identified in the selected articles, followed by a brief summary of the papers contents.

Table 3.3: Challenges using chatbots in diabetes management.

Challenges	Papers
Chatbot should be trained to make disease predictions	[32], [34]
Lack of adherence to program	[29], [41]
The user may share too much information with the chatbot	[42]

Chatbots need to be trained for more specialized disease prediction beyond the generic prediction to be suitable for real-time implementation [32]. Advances in several Artificial Intelligence fields are required to produce chatbot solutions suitable for the healthcare domain, especially in terms of machine learning, sentiment analysis and intent detection [34].

The limitations of this 2019 study [41] include program adjustments, limited generalizability, and a lack of an experimental design to control for factors (known and unknown) to ensure detection of treatment effect. Although this technology seems very promising, there are risks, as chatbots learn more about the user and become highly responsive to inputs, it is likely they will share increasingly more personal information [42].

According to this article [29] there are four research challenges on virtual health agents from a technological perspective situation interpretation: intervention reasoning, generating of informative, educative, and/or persuasive behaviors, and engineering generic solutions.

3.3.2 RQ2: Benefits

Table 3.4 contains a general analysis of the benefits of using chatbots in diabetes management found in the selected studies.

Table 3.4: Benefits of using chatbots in diabetes management.

Benefits	Papers
Automate personalized messages	[34], [41], [33], [38]
Help patients education	[30], [31], [35], [37]
Help cutting-down the visit of patients to hospitals	[32], [34]
Reach a broad audience	[34], [38]
Reminders to take medication and blood glucose readings	[40], [41]
Prediction of disease with machine learning	[32], [41]
Establish connection between patients and healthcare professionals	[33], [40]
Chatbot connected to hardware	[39]

Sowah et. al [40] used chatbots to remind their patients to take their medication and blood glucose readings for doctor's interventions via mobile app. According to Fadhil et. al [34], the biggest advantages of chatbots include being able to reach a broad audience on messenger apps and the ability to automate personalized messages.

In this 2018 study [33], the patients liked the "chat" aspect of the design, which can be translated to the computational argumentation-based dialog used in this study. The healthcare professionals were glad with the prospect of being able to know more about what happens to patients in between visits.

This study [41] examined one psychological Artificial Intelligence (AI) service, Tess, which has been used to address different facets of mental health, such as anxiety and depression. Tess deliver customized, integrative support, psychoeducation, and interventions through brief conversations via existing communication channels.

Mitchell et. al [38] concluded that when comparing an automated chatbot with humans, the chatbot was able to cultivate an equivalently coach-like experience, and was advantaged by sticking to the script to offer choices, and persistently checking in.

In this article [32], the studied chatbot was observed to be able to interact seamlessly with all patients based on the symptoms sought. To predict diseases, classification algorithms in Machine Learning which can be used based on their precision, specifically this paper used ensemble learning, which is a meta-algorithm that combines several weaker models and averages them to produce one final stronger model. Another approach to chatbots is having an application to remotely control hardware, in this research, it's a juice dispenser that gives the user the needed amount according to blood glucose levels, that way, being able to prevent hypo- and hyperglycemia [39].

The primary outcome of this 2021 study [36] was the change in HbA1c levels in participants who reported more than one blood sugar reading, and weight change in participants that reported more than one weight log. Creating association between program engagement, measured as the total number of interactions with the health coach and the AI-powered chatbot, and the the changes in HbA1c.

Diabetes health coaching has an emerging role in healthcare that facilitates self-care, behavior change and offers frequent follow up and support, while being an effective intervention for improving glycemic control [31].

3.4 Lessons Learned

In regard to the challenges and benefits of using chatbots in diabetes management, the main issues is the training of chatbots with machine learning, lack of users adherence to the program, and the type of information shared with the chatbot. The main solution to these issues is to automate personalized messages with the chatbot.

The benefits of using chatbots may include reminders to take medication, to weigh oneself and take blood glucose readings, which can be beneficial to the patient's health, along with facilitating the connection between patients and doctors, which can bring the benefit of cutting-down patients' hospital visits, in addition to helping patients education in their disease, since they can consult the chatbot when needed. Chatbots also reach a large audience, now that phone and internet access are broadly accessible.

4

Research Problem

This chapter corresponds, as per the Design Science Research Methodology, to the ”Problem Identification and Motivation” step, which calls for the definition of the research problem proposed, and its value as a solution [1]. Specifically, the research problem here contained relates to the usage of chatbots to improve and supplement the treatment of type 2 diabetes, aiding both patient and doctor. Given the potential health risks involved in the theme of this research, it is clear that extending and perfecting the tools available to physicians and patients proves its value as a solution.

Whilst conducting the Systematic Literature Review, it was found that this particular research problem has not been fully explored, with most articles covering such themes being focused on the application of machine learning algorithms to train models that support the chatbots. The research problem here described, although not specifically related with these algorithms, can add to them, building a better overall solution.

The literature review also showed shortcomings due to the lack of adherence to programs, and patients often not wanting to share too much information, which makes detecting optimal treatment effects harder for chatbots. This withholding may omit certain key information that would be valuable for the chatbots to acquire a more complete and thorough profile of the patients. The lack of adherence to programs is also a challenge due to the potentially affected results obtained thereafter. Combined, these issues can generate cases where the chatbots, and related models, are mislead due to faulty information, tainting the research analysis.

Although there are some challenges there are also some benefits in the use of chatbots, such as reminding type 2 diabetes patients to take their medication and blood glucose readings [40]. By having a more personalized and habitual intervention with patients, the chatbots can assist doctors in obtaining a better account of their patient's health. Given the importance of correct and timely medication for diabetics, these chatbots augment the physician's ability to appropriately tailor and adapt treatments.

In short, the problem addressed under the scope of this thesis is the poor adherence of patient's to complex and difficult solutions, concluding that chatbots can have the potential to improve type 2 diabetes patients' lives. Not only that, but the improvements in patient treatment also have the potential to be of great service to healthcare professional's jobs by promoting program adherence.

Therefore, and in conclusion, the application of chatbots to aid the treatment of type 2 diabetes proves to be a valuable solution, despite the limited research available on the subject. Through the Systematic Literature Review conducted, certain key points were found in previous research that can be addressed and refined.

5

Proposal

Contents

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This section corresponds to the second and third steps of the Design Science Research Methodology, “Define the objectives for a solution” and “Design and development”, respectively. First, we will describe the objectives for a solution to the problem identified in Chapter 4, followed by a description of our solution proposal and finishing by outlining how the proposal will be used to solve the identified problem.

5.1 Objectives

The main goal related to this research is creating a chatbot solution to help improve T2D patients’ lives by impacting their self-management techniques and improving habits in regards of health.

With a chatbot solution, patients can improve their health by implementing better habits, for example, by weighing themselves patients can feel their efforts rewarded, by remembering to measure their blood sugar everyday (when recommended by a doctor), or having a personal coach asking them how much exercise time they completed in a day.

5.1.1 Behavior Change and Motivation

Since the biggest problem regarding T2D patient’s health is the lack of self-management, it is crucial for patients to change their behaviors. The best way to achieve this is by turning self-management into a habit. A habit is a repeated behavior that is triggered by cues in our environment. It occurs outside of conscious control, in an automatic way. Habits arise in three steps [43]:

1. **Cue**: Tells our brain to go into automatic mode and which habit to use;
2. **Routine**: Combination of all the actions we do once we receive the cue;
3. **Reward**: Something good that happens at the end of the routine, the reward offers a reason to repeat the behavior.

We can build habits through simple repetition, whenever we see X (a cue), we do Y (a routine). Once the habit forms, the reward doesn’t directly drive the behavior, as the habit is automatic and outside of conscious control. The mind, however, still “remembers” previous rewards in subtle ways, craving them [43]. Habit creation is important for our research since we intend to motivate and engage patients to naturally incorporate self-management tasks in their daily routines by communicating with the chatbot daily and seeing rewards in their health.

To be motivated means to be moved to do something. We can define two main types of motivation: intrinsic and extrinsic [44]. Intrinsically motivated behaviors are performed out of interest and satisfy the innate psychological needs for competence and autonomy, and are the prototype of self-determined behavior. Extrinsically motivated behaviors are executed because they are instrumental to some separable consequence, and can vary in the extent to which they represent self-determination, even becoming self-determined through internalization and integration.

For our chatbot approach to work, it is of extreme importance to get the patients intrinsically motivated, so they can really enjoy feeling healthier by communicating with the chatbot and doing their self-care tasks.

5.2 Description

In order to fulfill the previously mentioned objectives and solve our research problem, we proposed the development of two chatbot solutions using Microsoft Power Virtual Agents (PVA). The first one, designated “DiaBot”, interacts with the users on a first instance and saves the responses, and the second, “DiaBot2”, interacts on a regular basis to help the users improve their habits.

As we identified in chapter 3, patients can have a problem with the complexity of chatbots, so to have patients adherence, our solution must be intuitive and easy to use.

The chatbot “DiaBot” asks for the user’s:

- Name;
- Age;
- Height;
- Medication;
- Last measures of HbA1c;
- Health recommendations given by doctors;
- Weight;
- If the user exercises regularly, and if yes, what kind of exercise they do;
- If the user measures fasting blood sugar, and what their last levels were.

Periodically, repeating some of the questions that can have different answers, the chatbot “DiaBot2” asks the user’s:

- New weight;
- How much exercise the user did or plans to do on the day;

- Fasting blood sugar test results.

Once the chatbot has collected the user's height and weight, it can then calculate the user's Body Mass Index (BMI), returning the following answers depending on the result:

- BMI $\geq$ 25 : The user is overweight;
- 18,50 $>$ BMI : The user is underweight;
- 18,50 $\leq$ BMI $<$ 25: The user has a normal weight.

With fasting blood sugar, the chatbot provides the subsequent messages depending on the given results: if the glycemia levels are higher than 126 it warns the patients the levels are too high; in other cases, a message is displayed indicating the levels are fine.

The chatbot also reviews the user's exercise time, giving positive messages when the user has exercised, or is planning to, at least 30 minutes in the day. As well as giving motivation and advising the user to be physically active, to the users who replied with zero exercise time, and have no plans to perform it in said day.

6

Demonstration

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This chapter is related to the DSRM demonstration phase and illustrates how our research proposal is used to solve the research problem described in 5. To demonstrate that the proposal can be used to solve the research problem, we developed a chatbot solution using Power Virtual Agents.

6.1 Technology Stack

In this section the technology stack used in this research will be explained, and compared to other platforms, describing their strengths, benefits and functionalities.

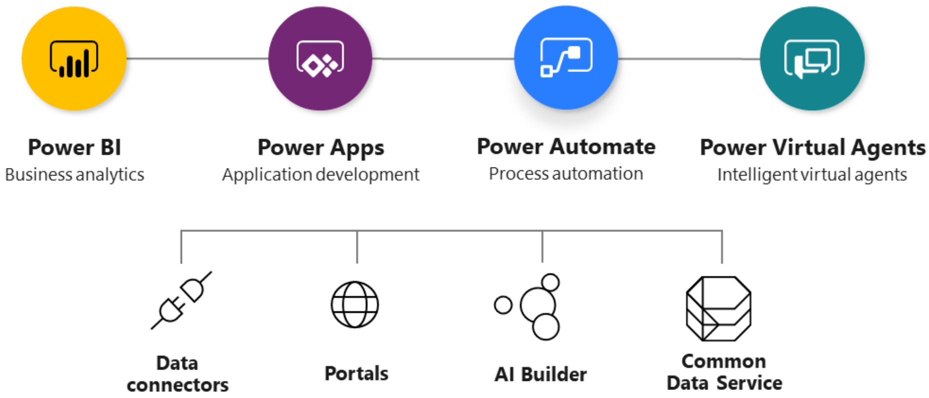


Figure 6.1: Microsoft Power Platform Technologies.

Power Platform[1] includes the following Microsoft products to develop and build complex business solutions, analyze, and draw data visualizations, automate a business process, or build virtual agents for communication, as represented in Figure 6.1:

- **Power Virtual Agents** (PVA) [2] is a no-code framework to build chatbots. It can be integrated with a multitude of channels, such as: Microsoft Teams, custom websites, mobile apps, Skype, Facebook, Cortana, Slack, Telegram, Twilio, Line, Kik, GroupMe and Email;

- **Power Automate**[3] can be connected to PVA to add automation of recurring tasks to the chatbot. It can, for example, create flows to populate databases and set a time for the chatbot to communicate with the patients;

- **Power BI** [4] is an analytics tool. For this project, it can be helpful to healthcare professionals to analyze the data, since it allows for data visualization with a plethora of different charts;

[1] https://powerplatform.microsoft.com/en-us/
[2] https://powervirtualagents.microsoft.com/en-us/
[3] https://powerautomate.microsoft.com/en-us/
[4] https://powerbi.microsoft.com/en-us/

- **Power Apps** [5] is a suite of apps, services, and connectors, that provide a rapid development environment to build custom apps for anything. This tool can be appealing for healthcare professionals considering that it creates an easy and engaging way to look at user's data.

Although Microsoft offers a lot of different ways to store data, **Microsoft Excel**[6] was the chosen one, since it is free of cost, convenient, easily to operate and create tables, can store large amounts of data and is overall a very flexible tool. Excel can be used with every Platform's product mentioned above:

- a Power App can be created to display the Excel sheet's information to whoever may need to see it;
- Power Automate with its flows connects a Power Virtual Agent to an Excel data sheet;
- Power BI is a powerful tool, that can read any Excel file and easily transform it into a chart.

Microsoft Teams[7] was the used channel to communicate with users. Teams was chosen since it is free, has an easy integration, offers data security and has many device options. PVA offers three options when it comes to security and authentication[8], having one option for Teams only. That option automatically creates an "UserId" and has access to the user's display name, without having to configure anything else. All of this eased the decision of which communication channel to choose from.

6.2 Prototype

The chatbots were made with Power Virtual Agents and as explained above on Section 5.2, two chatbots were created, the first for the initial contact with the users, and the other for a repeatedly contact, designated "DiaBot" and "DiaBot2" respectively.

PVA comes with a set of prebuilt entities, which represent the most commonly used information in real-world dialogues, such as names, age and numbers, so there was no need to create new entities. With the knowledge granted by entities, the chatbot can recognize the relevant information from a user input and save it.

Topics define how a bot conversation plays out, some of the prebuilt topics include the beginning of conversation, when to activate the bot, and the end of conversation. This is where chatbots were built differently, the first one was divided into five topics to get the user's name, age, medication, health recommendations, last measure of HbA1c, height, weight, if the user exercises, if the user tests fasting blood sugar levels, and if so what's their latest measure. The second chatbot has less topics, three,

[5] https://powerapps.microsoft.com/en-us/
[6] https://www.microsoft.com/en-us/microsoft-365/excel
[7] https://ww.w.microsoft.com/en-us/microsoft-teams/group-chat-software
[8] https://docs.microsoft.com/en-us/power-virtual-agents/configuration-end-user-authentication

since it only asks for exercise performed on the day, fasting blood sugar levels, and weight, in order to record the answers.

Figure 6.2 demonstrates “DiaBot”’s first Topic, that introduces the chatbot to the user and asks for the name and age, following to the next topic called “Medication and Health Measures”.

Figure 6.3 shows the process to integrate the PVA with Microsoft Teams, and how it generates a link that is easy to share with users. That way making the chatbot accessible to anyone who has a Microsoft account and a device with Microsoft Teams app installed, or even the web app can be used.

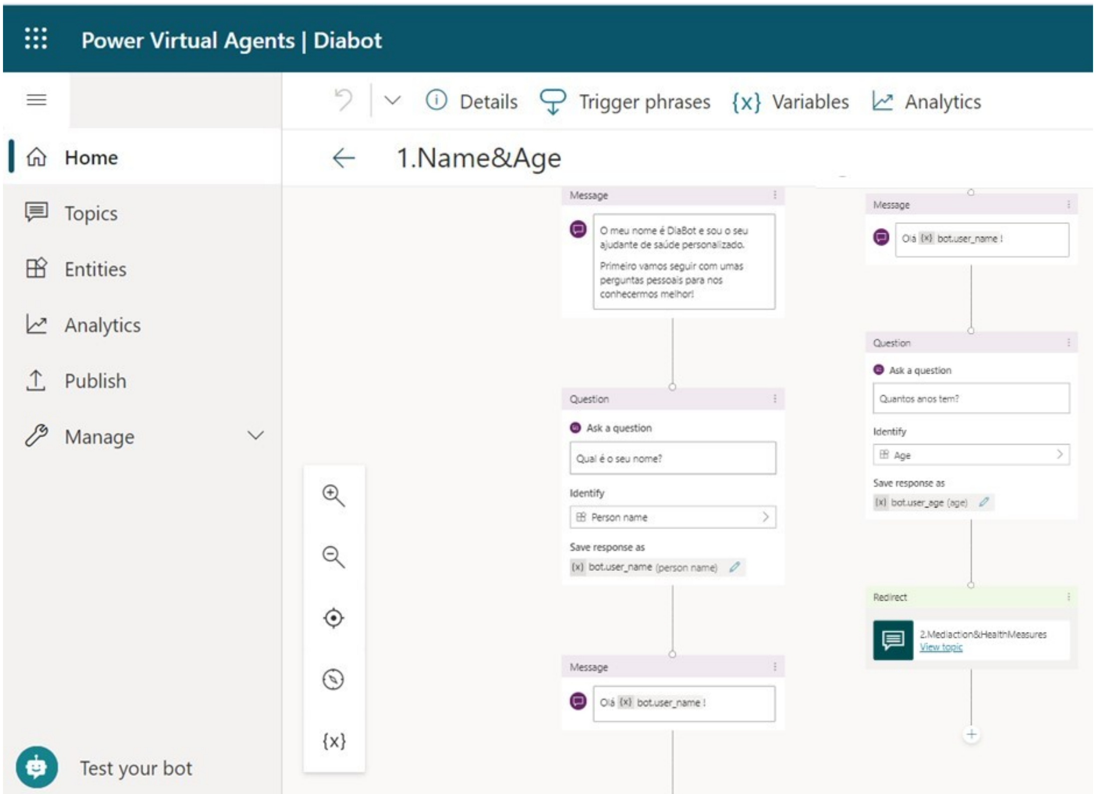


Figure 6.2: Demonstration of a page in Microsoft Power Virtual Agents.

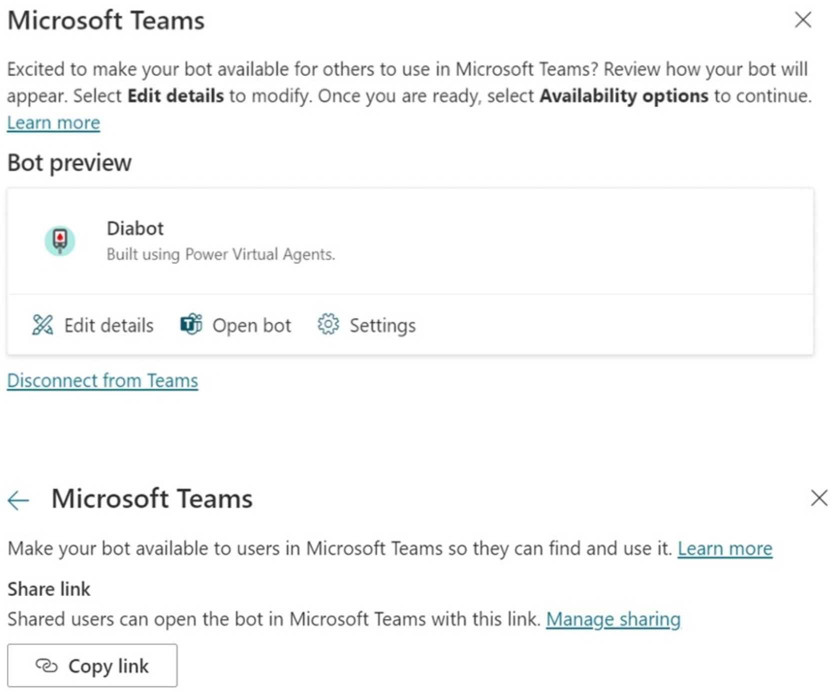


Figure 6.3: Connection of PVA with Microsoft Teams (top) and Availability Options (bottom).

An example of the use of the chatbot is demonstrated in Figure 6.4, using fictitious responses based on real T2D patient's replies.

Power Automate populates the excel. There is an option in PVA to call Power Automate's flows. The biggest use for this is to populate the Excel Table, an example is seen on Figure 6.5. Each user has a unique Id, automatically generated by Teams and added to the table by the flow. "Diabot2" calls another flow, where it gets the row that's linked to the unique ID of the user and can access all the user's information. When "DiaBot2" asks about the new weight, fasting blood sugar levels and exercise time, new columns are created in the table, in the user's corresponding row. Figure 6.6 shows the Table populated with the data, asked by the first chatbot and integrated into the table by a power automate flow. The table data was inspired by the collected inputs from 5 interviewed T2D patients, keeping them unnamed.

With Power Apps, an app was built with the user's details, creating an attractive way to look at each user's data, this was made taking the data from the user's excel. Figure 6.7 shows a demonstration of this, displaying the first screen on the left, which is a list of users, and the second screen on the right is the demonstration of a patient's details.

PowerBI, although mentioned on the previous section wasn't relevant to the prototype since it only makes sense using with a bigger sample of users.

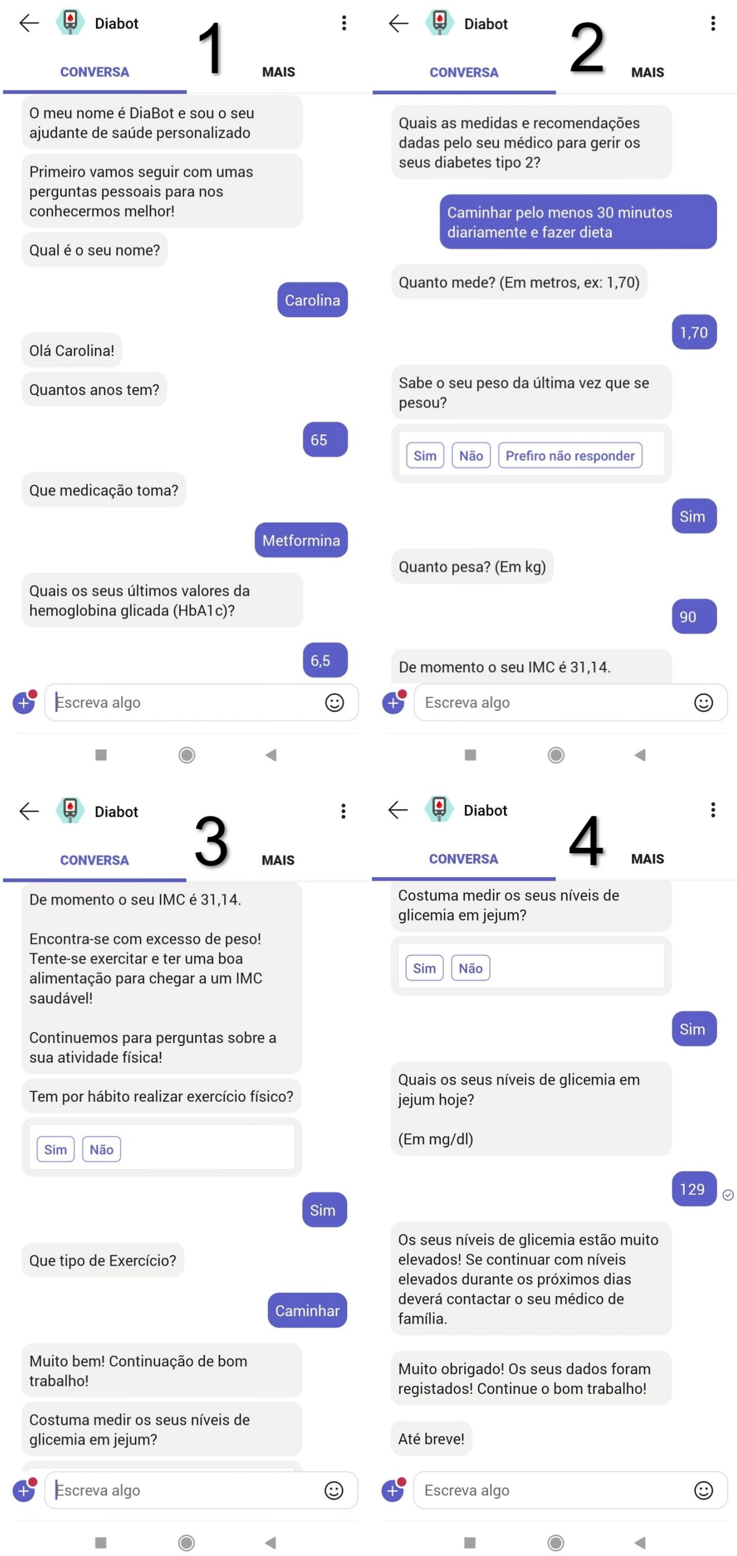


Figure 6.4: Chatbot demonstration through Microsoft Teams.

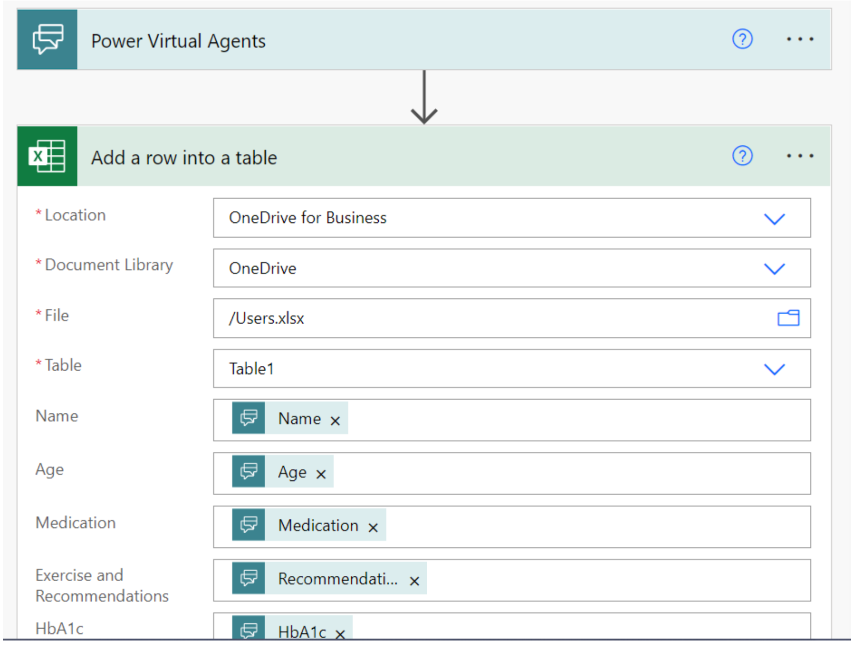
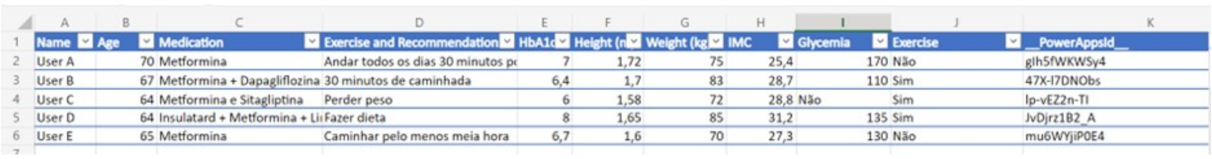


Figure 6.5: Demonstration of adding a row into a table with Power Automate.



	A	B	C	D	E	F	G	H	I	J	K
1	Name	Age	Medication	Exercise and Recommendation	HbA1c	Height (n	Weight (kg	IMC	Glycemia	Exercise	__PowerAppsId__
2	User A	70	Metformina	Andar todos os dias 30 minutos pc	7	1,72	75	25,4	170	Não	glh5fWKWSy4
3	User B	67	Metformina + Dapagliflozina	30 minutos de caminhada	6,4	1,7	83	28,7	110	Sim	47X-I7DNObs
4	User C	64	Metformina e Sitagliptina	Perder peso	6	1,58	72	28,8	Não	Sim	Ip-vEZ2n-TI
5	User D	64	Insulatard + Metformina + Li	Fazer dieta	8	1,65	85	31,2	135	Sim	JvDjrz1B2_A
6	User E	65	Metformina	Caminhar pelo menos meia hora	6,7	1,6	70	27,3	130	Não	mu6WYjiP0E4

Figure 6.6: Microsoft Excel table with anonymous personal data.

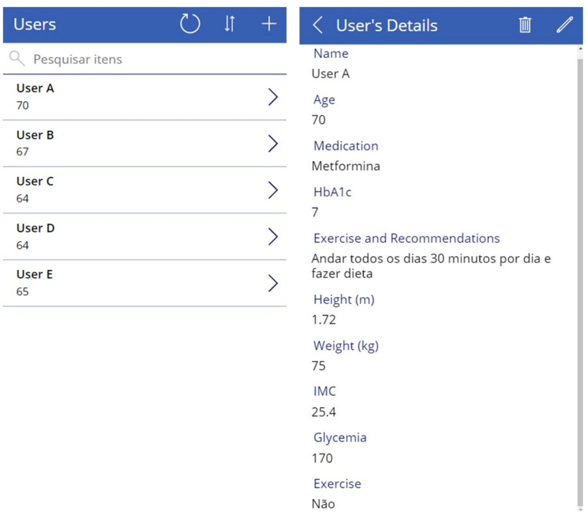


Figure 6.7: Power App with List of Users (left) and User's Details (right).

7

Evaluation

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This Chapter addresses the evaluation phase of DSRM. Demonstrating the artifact's use in one or more cases is a standard means of ensuring that the artifact meets its goal [45], by presenting the results of the first design demonstration, both to some T2D patients and a doctor.

7.1 Interviews with Patients

In this subsection, we will go over the feedback given by five T2D patients after being given a demonstration of the chatbot working on Microsoft Teams. The general user population was evenly divided according to gender, had an age range of about 64-70 years old, and everyone had a smartphone with internet access. The table demonstrated in Figure 6.6 was populated according to the questions asked to this sample of people with T2D, but the names aren't displayed for privacy reasons.

After the demonstration of the chatbot, the targeted users answered a few questions individually regarding data privacy, which messaging platforms they use, and how available they were to interacting with the chatbot periodically.

- When asked if they would be open to share personal information, such as age, height, weight and blood sugar levels, most users said they would be fine with it, as long as their identity stayed anonymous, although one person was skeptical about sharing data with the chatbot, which means a privacy policy making clear how data is treated must be distributed before asking people to use the chatbot.

- When inquired about social media networks and messaging applications currently used, three users said they use Facebook Messenger and Whatsapp, the others said they don't use any messaging apps (they said they mostly use phone calls and phone messaging). Regardless, everyone knew what Whatsapp and Facebook were.

- When asked about whether they knew what Microsoft Teams was, the answer was unanimously negative, however, everyone was open to installing it in order to have access to the chatbot. Two people said they would have no problem installing the application, while the rest said they normally asked family members for help to install apps for them or struggled a bit with app stores. The people that admitted having problems with installing apps said they would also be fine with an healthcare professional doing it for them.

With the possibility of installing Microsoft Teams, there also comes a need for a Microsoft account, which isn't a problem for three of the users, since they already use outlook or hotmail emails on their computers, although not immediately associating that these are Microsoft services. The other two have google accounts, with one of them being receptive to the idea of creating a Microsoft account, and the other not being as pleased with the suggestion.

- When it comes to how much the interviewees would use the Microsoft Team's app to communicate with the chatbot, some users answered they would try to use it as much as possible but would probably forget about it. Some said they would use it everyday, and everyone said having the doctor looking at the information at their next appointment was a great motivating factor for using the chatbot .

Overall the feedback was positive, everyone thought the chatbot was intuitive and had no problem with the interface, and thought it was fun to help them better themselves by reminding them to exercise and reminding them to measure their fasting blood sugar levels. The user that takes insulin said the chatbot should be a bit more inclusive when asking for medications at the beginning. Most users said they don't measure their fasting blood sugar everyday since they don't need to, which was also not taken into account when developing the chatbot.

7.2 Interview with Doctor

The chatbot prototype was presented, explained in detail, and demonstrated with Microsoft Teams to a medical professional (T2D expert with PhD), who gave feedback and shared professional opinions and ideas. Below are the doctor's recommendations, notes and some corrections.

The first note was that there should be an option to take multiple measures of blood sugar per day, since sometimes these may be needed. Over the creation of this chatbot, fasting blood sugar levels were taken into account, as they were needed by T2D patients, while non fasting values weren't. The doctor also alerted for the fact that the chatbot only gave warnings to patients when glycemia levels were greater than 126mg/dL, forgetting about low blood sugar (hypoglycemia), that is also a serious condition.

HbA1c levels should be updated within the chatbot database every 3 months, while at the moment are only being asked on a first instance.

Weight values aren't useful when measured daily, since weight normally doesn't fluctuate that fast. So the recommendation in this case was for the weight to be updated weekly.

The chatbot only asks the patients what medication they take at the moment, and doesn't make a distinction between patients who take oral medicines and patients who may need insulin. This can be a problem when asking daily blood sugar levels since patients who take oral medicine don't need to do it daily, while the ones taking insulin may need to. In these circumstances, where patients measure the values daily, it makes sense for the chatbot to ask everyday, when on the other case patients could be approached up to about three times per week.

The medical professional also stated that positive reinforcement is very necessary, even giving some ideas: the chatbot could tell the patient how their weight loss progress was going, by telling them how much weight they had lost since the last measure. The same could be done for the exercise time, giving incitement for the patient to keep it or push themselves even harder. While talking about exercise and physical activity, the doctor recommended a new functionality: The chatbot could ask patients how many steps they take everyday, suggesting that 6000 steps could be a good starting point.

After the doctor's evaluation, we asked what the best time to communicate with users was. The doctor advised interacting with users during the morning, since it can help patients who need to measure fasting blood sugar remember it, and it is also the best time for them to weigh themselves. In cases in which users must measure their blood sugar levels more than once per day, this approach would not work as well. We also think that by communicating with the chatbot in the morning, the user can be more motivated to exercise, since they have the whole day ahead of them.

After the interview, the doctor demonstrated interest in doing a test in a Geneva hospital with Portuguese speaking patients, following the implementation of the recommendations and corrections.

8

Conclusion

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This chapter provides a summary of the work performed during this thesis. Lessons learned from this research and its contributions are also highlighted. Main limitations are presented along with future work suggestions.

8.1 Research Contributions

Overall, chatbots can be a useful and simple way to help patients that suffer from diseases that require weekly or even daily checkups and alerts such as type 2 diabetes. From reminding patients to take their medicine, to try and motivate them to do more exercise and lose weight, it can be a way for the doctors to know that even when the patient leaves their office, there will still be "someone" who will try to make sure that the patients are still keeping up with their treatment and self-care. Another benefit is keeping the doctors updated with a detailed database of the patients progress over time.

With the advances in chatbots technology and the overall population becoming more familiar with technology in general, healthcare chatbots and applications can become even more useful, making long-term treatments easier for both patients and doctors. With the creation of more complex chatbots, with more attributes and features, every user can have a personalized experience adapted to their health needs and doctors can follow their progress from a distance, spending less time getting information in-person from their patients and getting a better understanding of the work the patient has been putting into their treatment, wasting less time and turning every trip to the primary healthcare facility as time-efficient as possible.

We applied the Design Science Research Methodology to develop an artifact to solve our research problem. A chatbot was created using Microsoft Power Virtual Agents with the goal of helping T2D patients, and evaluated through interviews with potential users and an expert, confirming that the objectives for this research were accomplished and the feedback was positive.

8.2 Main Limitations

During the development of this work, some limitations were found. Although many papers address chatbots, it was challenging to find papers on type 2 diabetes and chatbots as seen in the number of papers retrieved from the SLR, it was found that this particular research problem has not been fully explored.

Other limitations include the fact that Microsoft Power Virtual Agents is still a new technology, so it was demanding to find literature regarding this framework, it was also difficult to integrate everything since there isn't a lot of educational material online to help. Furthermore, this work was not fully tested for a long period of time with patients. Due to this, it was not possible to assess the success of the chatbot.

8.3 Future Work

As future work, we intend to do some alterations to the artifact to test it in an hospital, with Portuguese speaking patients.

Following the previous Chapter 7, next are the features the chatbot needs to meet the requirements and recommendations given by the doctor, and feedback given by interviewees.

The first change will be adding a feature to calculate the variation of weight, comparing the new value with the previously introduced one, giving back the difference of weight and offering a positive message. The same with physical activity times by comparing the most recent duration with the previous one, revealing the difference and also giving positive reinforcement when earned. A goal for this chatbot is to create a bigger sense of reward for users, and positive messages can help to check progress.

Other added features will be implementing the capability of asking of how many steps were taken in the day, and creating a privacy policy text to show to users before asking them to interact with the chatbot.

One shortcoming of the chatbot is not discriminating if the patient takes oral medication or insulin, only asking for the former. With the distinction in mind, the chatbot can be more aware of how many times the patient needs to measure their blood sugar, so that question should be implemented at the beginning, in order to adapt when the chatbot communicates with the user. The option to update HbA1c will be given to users, since it can change every three months, as well as an option to update medication since it may also change with time and health progress.

If all these changes are implemented, the chatbot can be more personalized to each individual and have a greater chance of being successful.

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