Instituto Politécnico de Setúbal
Escola Superior de Tecnologia de Setúbal

A Conversational Agent in mHealth for Self-Management of Parkinson's Disease

Master of Science in **Software Engineering**

Pedro R.S. Mota

President: Prof. Cláudio Sapateiro, PhD, Instituto Politécnico de Setúbal
Arguer: Prof. Rossana dos Santos, PhD, Instituto Politécnico de Setúbal

Advisor: Prof. Patrícia Macedo, PhD, Instituto Politécnico de Setúbal
Co-Advisor: Prof. Rui Neves Madeira, PhD, Instituto Politécnico de Setúbal

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Resumo

Nos dias que correm vivemos rodeados de tecnologia, onde os "smartphones" preenchem um espaço muito importante nas nossas vidas. O uso de serviços móveis pelos "smartphones" no âmbito da saúde tem sido cada vez mais próspero, com um uso acessível por parte de todos. Com os avanços ao nível de inteligência artificial, especialmente no que toca à criação de sistemas inteligentes que comuniquem de forma natural com os humanos, torna-se possível criar agentes de conversação adequados para uma interação pessoa-máquina com distintos objetivos.

Um dos objetivos que o projeto ONParkinson tem é o de aumentar a adesão terapêutica por parte das pessoas com doença de Parkinson. Sendo que a execução recorrente de exercício físico é essencial na gestão dos sintomas da doença de Parkinson. Por isso, existe a necessidade de interagir, educar e motivar os pacientes com doença de Parkinson para uma maior adesão aos exercícios terapêuticos.

Este trabalho propõe uma solução, no âmbito do projeto ONParkinson, que envolve a criação de um agente de conversação com unidades de conhecimento mais focadas nos exercicios terapêuticos e com unidades que visam motivar e manter a pessoa com doença de Parkinson motivada para a realização de exercícios terapêuticos.

A avaliação da solução envolve fisioterapeutas e pessoas com doença de Parkinson. O plano de avaliação estabelece o estudo do desempenho técnico, da experiência do utilizador e da investigação na área da Saúde. Grande parte do conjunto dos pacientes com doença de Parkinson tem uma idade avançada, o que poderia levar a uma maior resistência ao uso das novas tecnologias. No entanto, os valores obtidos nos indicadores referentes à perspetiva de utilidade, facilidade de uso e satisfação da utilização demonstram um bom nível de usabilidade da solução proposta. Como a investigação de eficácia clinica ainda não foi conduzida, não é possível concluir a eficácia da solução proposta no aumento da adesão terapêutica por parte dos pacientes com doença de Parkinson.

Palavras-chave: Agentes de conversação, Inteligência artificial, Dispositivos móveis, doença de Parkinson, mHealth, modelo de motivação

Abstract

Nowadays, we live surrounded by technology, where smartphones fill a very important space in our lives. The use of mobile services by smartphones in the health sector has been increasingly prosperous, with accessible use by everyone. With advances in artificial intelligence methodologies, regarding the creation of intelligent systems that communicate naturally with humans, it is possible to create conversational agents for person-machine interaction with different objectives.

One of the goals of the ONParkinson project is to increase therapeutic adherence by people with Parkinson's disease. The recurrent execution of physical exercise is essential in the management of the symptoms of Parkinson's disease. Therefore, there is a need to interact, educate and motivate patients with Parkinson's disease for greater adherence to therapeutic exercises.

This work proposes a solution, within the scope of the ONParkinson project, which involves the creation of a conversation agent with units of knowledge more focused on therapeutic exercises and with units aiming to motivate and keep the person with Parkinson's disease motivated to perform therapeutic exercises.

The evaluation of the solution involves physical therapists and patients with Parkinson's disease. The evaluation plan establishes the study of technical performance, the study of user experience and Health research study. A large part of the set of patients with Parkinson's disease is of advanced age, which could lead to greater resistance to the use of new technologies. However, the values obtained in the indicators referring to the perception of usefulness, ease of use and interaction satisfaction demonstrate a good level of usability of the proposed solution. As the investigation of clinical efficacy has not yet been conducted, it is not possible to conclude the effectiveness of the proposed solution in increasing therapeutic adherence by patients with Parkinson's disease.

Keywords: Conversational agents, Artificial Inteligence, mobile, Parkinson's disease, mHealth, motivation model

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Acronyms

AI Artificial Intelligence. 12, 21, 28, 30

ANN Artificial Neural Network. 18

APDPk Associação Portuguesa de Parkinson. 4, 9, 12, 46, 47, 63, 67

API Application Programming Interface. 25

ASR Automatic Speech Recogniser. 21, 25, 40

ECA Embodied Conversational Agent. 37

ESSCVP Escola Superior de Saúde - Cruz Vermelha Portuguesa. 67

ICT Information and Communications Technology. 9, 10

MARS Mobile App Rating Scale. 68

NLDQ Natural Language Database Query. 2, 4, 16–20, III

NLP Natural Language Processing. 14–16, 18, 21, 26, 53

NLU Natural Language Understanding. 21, 24, 25, 28, 29, 40

OS Operating System. 12, 31, 40

PoC Proof of Concept. 12, 39

SUS System Usability Scale Adapted for Portuguese Language. 66

Glossary

Android is a mobile operating system based on a modified version of the Linux kernel and other open source software, designed primarily for touchscreen mobile devices such as smartphones and tablets. 12, 27, 31, 40, 71, 72

artificial neural network is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. 18

base of knowledge is a technology used to store complex structured and unstructured information used by a computer system. 16

conversational agent (also known as dialogue system) is a computer system intended to converse with a human. Dialogue systems employed one or more of text, speech, graphics, haptics, gestures, and other modes for communication on both the input and output channel. 2, 4, 8, 12, 13, 20–32, 37–43, 45–56, 58–64, 69–71, 73, 75, III

eHealth is a relatively recent healthcare practice supported by electronic processes and communication. 14, 32–34, 36, 37, 39

Facebook Messenger Facebook Messenger is an American messaging app and platform developed by Facebook, Inc. 27, 28

Heroku is a platform as a service (PaaS) that enables developers to build, run, and operate applications entirely in the cloud. 40

hidden Markov model is a statistical Markov model in which the system being modeled is assumed to be a Markov process. It assumes that there is another process Y whose behavior "depends" on X. 18

Hoehn and Yahr scale is a commonly used system for describing how the symptoms of Parkinson's disease progress including stages 1 through 5. 67, 71, 72

HTTP is an application layer protocol for distributed, collaborative, hypermedia information systems, being the foundation of data communication for the World Wide Web. 40

iOS iOS (formerly iPhone OS) is a mobile operating system created and developed by Apple Inc. exclusively for its hardware. It is the operating system that powers many of the company's mobile devices, including the iPhone and iPod Touch. 27, 72, 73

lexicon A lexicon, word-hoard, wordbook, or word-stock is the vocabulary of a person, language, or branch of knowledge (such as nautical or medical). 16

Machine Learning Machine learning (ML) is the study of computer algorithms that improve automatically through experience, seen as a part of artificial intelligence. 29

mHealth is an abbreviation for mobile health, a term used for the practice of medicine and public health supported by mobile devices. 8, 9, 12, 63

Mindfullness Mindfulness is the practice of purposely bringing one's attention in the present moment without evaluation. It's a skill one develops through meditation or other training. 39

morphemes are the smallest meaningful units in a language. The main difference between a morpheme and a word is that a morpheme sometimes does not stand alone, but a word, by definition, always stands alone. 15

n-gram is a contiguous sequence of n items from a given sample of text or speech. The items can be phonemes, syllables, letters, words or base pairs according to the application. 18

Parkinson's disease Parkinson's disease (PD) is a long-term degenerative disorder of the central nervous system that mainly affects the motor system. The symptoms usually emerge slowly, and as the disease worsens, non-motor symptoms become more common. 8, 9, 12, 31, 34–36, 39–43, 48, 52, 58, 63, 65, 67, 69, 71, 72, 75, 76

probabilistic context-free grammar is a grammar theory to model symbol strings originated from work in computational linguistics aiming to understand the structure of natural languages. 18

Chapter 1

Introduction

This chapter describes the motivation, description and context, and the foreseen solution in the scope of this dissertation.

1.1 Motivation

Parkinson's disease is growing faster in disability, prevalence and mortality over 20 years, among a diverse number of neurological diseases, making up to six million people affected [Dorsey et al., 2018]. Parkinson's disease treatment, diagnosis and management have a very complex nature, requiring constant monitoring, where the informal caregiver is a key element in monitoring the patient progress. The use of mobile technology motivates and empowers an increase in therapeutic adherence [Lakshminarayana et al., 2017] and a better-informed decision ability, according to [Bendig et al., 2022] and [Rayment, 2022].

Parkinson's disease is the second most frequent neurodegenerative disease after Alzheimer's disease. The potential benefits and risks associated with mHealth make space for a need for official regulation and further research in the field. The use of mHealth would provide reliable tools for the healthcare and management of Parkinson's disease for health professionals and patients [Linares-Del Rey et al., 2019].

The use of conversational agents for healthcare purposes has shown potential benefits in several areas [Laranjo et al., 2018] [Montenegro et al., 2019]. Systematic reviews on mHealth applications for Parkinson's disease show a lack of support for an integrated way of Parkinson's disease diagnosis, treatment and management process with the triad, composed of patient, caregiver and health professional, according to [Linares-Del Rey et al., 2019] and [Gatsios et al., 2020].

1.2 Research Context

The research work presented in these documents was done on the scope of the ONParkinson's project, which aims to develop Information and Communications Technology (ICT) methods, models and tools that promote the self-management of Parkinson's disease by patients and their caregivers, as seen in [Pereira et al., 2015] and [Madeira et al., 2016].

The project intends to develop tools to facilitate access to knowledge and to ease professional support outside the clinical environment. A survey undertaken at the Associação Portuguesa de Parkinson had shown that all user groups reported difficulty finding trustworthy information about Parkinson's disease, even health practitioners having difficulty finding reliable information to support clinical decisions. The ONParkinson project emerged to support the triad, composed of patients with Parkinson's disease, their caregivers and health professionals, in finding relevant knowledge to support their clinical issues, monitor patient's daily routines and give recommendations for daily exercises [Madeira et al., 2017].

The ONParkinson project presents a web app targeted at health professionals and integrates a mobile app as a central tool for self-management by patients and their caregivers. The ONParkinson mobile application was built using Flutter technology to empower its users to present and help perform the therapeutic exercises prescribed by the healthcare professional. The mobile application developed included a conversational agent named ParkinsonBot, which aims to respond to questions about Parkinson's disease posed by patients and their caregivers. ParkinsonBot was implemented using the IBM Watson Assistant platform [Macedo et al., 2019].

1.3 Problem

One of the project goals is to solve the need to increase Parkinson's disease patient's therapeutic adherence. Several studies demonstrate that continuous performance of physical exercise is essential in the management of Parkinson's disease symptoms. As a result, the MoveOnParkinson project was created to address the need to better engage patients and their caregivers in performing therapy exercises, to help and keep the patients motivated and to help educate and train the patients for health-related aspects of their lives.

This dissertation aims to explore and develop solutions to better solve the ONParkinson's mHealth platform need to engage patients and their caregivers in performing therapy exercises. Specifically, to guide the patients and motivate and keep them motivated in doing the therapeutic exercise programs.

1.4 Research Methodology

The research methodology adopted, the conceptual frameworks and their instantiation, according to the current research context, are introduced and explained in this section.

Research in engineering and information systems is often applied research, and its objective is to produce results that are applicable in the real world, according to [Galliers and Land, 1987], which requires a different research approach from what is traditional within the natural sciences. The informatics field has seen a proliferation of Design Science Research, which following Simon's (1996) original concept, aims to solve significant practical problems through purposeful synthesising or construction of Information and Communications Technology (ICT) and other artefacts based on existing scientific knowledge.

According to [Kasanen et al., 1993] and [March and Smith, 1995], natural science deals with explaining natural phenomena and answering questions like how and why, while design science, on the other hand, attempts to create artificial artefacts that serve human purposes. These artefacts have to be evaluated to conclude the success of these artefacts in line with the different devised measures.

According to [Vaishnavi, 2007], the design research structures the work in five steps:

1. Developing awareness of the problem and a proposal for definition.
2. Finding suggested solutions and forming tentative design.
3. Building, testing and developing of (partial) solution artifacts.
4. Evaluation of the performance of (alternative) artifacts and possible design iterations.
5. Conclusion and communication of the result.

However, Henver and his colleagues [Hevner et al., 2004] defended that not just design science but also behavioural science is required for research in information systems. Since behavioural science addresses research through the development and justification of theories that explain or predict phenomena related to the identified society/business need, design science addresses research through building and evaluating artefacts designed to meet the identified problem. Therefore, according to Henver and his colleagues, both paradigms are foundational to the Information System discipline, positioned at the confluence of people, organisations, and technology. They proposed a conceptual framework (see figure 1.1) for understanding, executing, and evaluating Information Systems that include both paradigms.

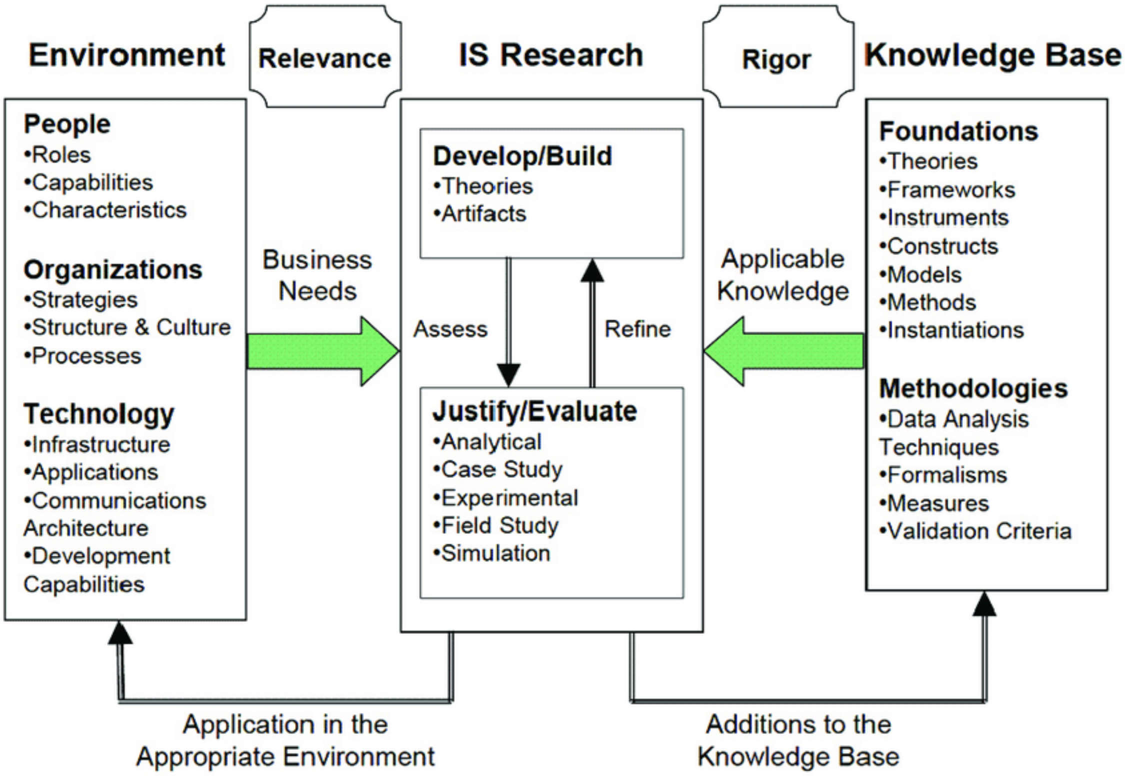


Figure 1.1: Conceptual Framework (from [Hevner et al., 2004])

Because the main research topic of this thesis is the confluence of people, organisations, and technology, this framework was selected to support the research process of this thesis. It is presented in figure 1.2, the instantiation of the framework into this research work.

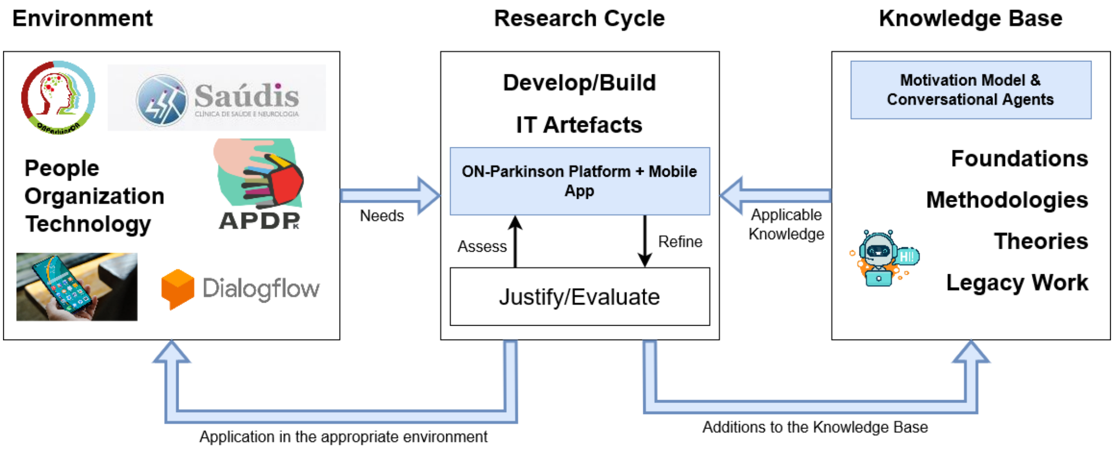


Figure 1.2: Research Methodology

Following this research approach, the developed artefacts are validated according to a validation plan. The findings obtained from the validations will be added to the knowledge base, further improving the artefacts. According to [Hevner et al., 2004], the knowledge base provides the raw materials from and through which information system research is accomplished, while being composed of foundations and methodologies, and prior research and works (legacy work).

The validations are also done in the appropriate environment, specifically, the Associação Portuguesa de Parkinson (APDPk), the Saudis clinic, and the physiotherapy team of the ONParkinson project. It consists of 3 phases, intending to show the relevance of the produced artefacts, and in what measure it contributes to facilitating the exercise execution continuously, by Parkinson's disease patients. Each phase will focus specifically on technical performance, user experience and final health research.

1.5 Solution

In order to solve the mentioned needs, the proposed solution aims to develop a Proof of Concept (PoC) application to empower Parkinson's disease patients and their caregivers in managing the disease and evaluate the application as a means to prove its validity. To achieve a practical and robust solution, the system should be designed under the technical constraints associated with mobile technology and the user's mobile device capabilities.

The proposed solution considers the development of an embedded system, to be integrated inside the ONParkinson's mobile application, as PoC, being a conversational agent named Pandora, with Artificial Intelligence (AI) capabilities. Differently from the conversational agent mentioned in the legacy work that aims to educate its users on the daily life aspects of Parkinson's disease, the proposed conversational agent aims to guide, motivate and keep the patients motivated in performing therapeutic exercises. The foreseen choice of a conversational agent is justified by the effect it has on its users, specifically Parkinson's disease patients. Studies have shown that the use of conversational agents in healthcare improved medication adherence and the general likeability of use by patients, hence increasing the patient's commitment to the treatment [Chaix et al., 2019].

Given the ONParkinson's mHealth application specifications, the system is going to be developed over Flutter technology, justified by the existence of previous work, already made in this context. In addition, market share studies made by the European Parliamentary Research Service show Android OS as the world leader, holding 87.7% of the market share [Maradin et al., 2020], furthermore justifying the system's development over a technology with cross platform capacity.

1.6 Document Structure

This dissertation is structured into four more chapters:

- Chapter 2: Background & Related Work

- Chapter 3: Proposed Solution
- Chapter 4: Evaluation & Results
- Chapter 5: Conclusions & Future Work

Chapter 2: Background & Related Work presents the corpus of knowledge where this research is grounded.

Chapter 3: Proposed Solution presents the creation of the solution concept, aiming to solve the needs described in section 1.3. The need to better engage patients and their caregivers in performing therapy exercises, to help and keep the patients motivated and to help educate and train the patients for health-related aspects of their lives. Also describes the technologies adopted, the motivation model and the implementation of the conversational agent system envisioned, reflecting its behaviour and structure.

Chapter 4: Evaluation & Results aims to describe the validation plan designed to assess the implemented system and to present and discuss the obtained results.

Chapter 5: Conclusions & Future Work aims to wrap up and extract conclusions regarding the system implementation and how it performed in the validation results while also giving awareness of its limitations and future work.

Chapter 2

Background and Related Work

This chapter describes studies and research related to the scope of this dissertation. The chapter is divided into the following sections:

- Natural Language Processing
- Conversational Agents
- Human-Machine Communication in eHealth
- Discussion

2.1 Natural Language Processing

Natural Language Processing (NLP) is a computerised approach to analysing, understanding and producing human languages [Allen, 2003].

According to [Allen, 2003], the task of Natural Language Processing might be to translate to another language, understand and represent the content of a text, build a database or maintain a dialogue with a person, and interface to support operations for database/information retrieval.

2.1.1 Language Levels

For Natural Language Processing to process language, it must comprehend the various levels of human language to gain understanding and to produce capable results. According to [Liddy, 2001], these levels are identified as:

- Syntactic
- Semantic

- Phonology
- Morphology
- Lexical
- Pragmatic
- Discourse

Syntactic

The syntactic level focuses on analyzing words and groups of words to detect the grammatical structure. Requiring a grammar and a parser, Natural Language Processing output at this level shows the relational dependency between words in a sentence.

Semantic

Semantic processing detects the sentence meaning by analysing interaction word meanings. This level of processing can include the semantic disambiguation of words. Some methods accomplish semantic disambiguation by requiring information regarding the sense frequency in the local context or by requiring the use of pragmatic knowledge of the domain.

Phonology

At this level, Natural Language Processing interprets speech sounds into a digitized signal for interpretation using language models. The process of interpreting the speech sounds uses phonetic rules for the words sounds, prosodic rules for the fluctuation in stress and intonation in a sentence and phonemic rules for variations in the pronunciation of sequences of words.

Morphology

This level analyses words through their structural nature. Words are structurally composed of morphemes. Therefore, a Natural Language Processing system can perceive the word's meaning by collecting and identifying the morphemes composing the word.

Lexical

Natural Language Processing systems interpret the individual meaning of words by assigning a single part-of-speech tag to each word. Sometimes, some words can be assigned more than one part-of-speech tag, hence, those words are assigned the part-of-speech with the most probability score base on the context in which they appear.

Words with only one meaning can be replaced by a semantic representation, varying from the semantic theory used by the Natural Language Processing system. Natural Language Processing may require a lexicon, having the semantic class of the word, its arguments, limitations and the definition of the set of senses used in the specific context.

Pragmatic

At the Pragmatic level, the context is overly used by comparing to the sentence's content to understand. Requiring a base of knowledge and interfering modules, a Natural Language Processing system may detect intentions, plans or goals by detecting extra meaning that is not evident or encoded in the words.

The city councilors refused the demonstrators a permit because ***they*** *feared violence.*

The city councilors refused the demonstrators a permit because ***they*** *advocated revolution.*

Figure 2.1: Sentences with the different use of the word "they" (from [Liddy, 2001])

For instance, the use of the anaphoric term "they" requires the resolution with the use of pragmatic processing or a base of knowledge, as seen in figure 2.1.

Discourse

At the Discourse level, NLP systems does not process and verify each sentence one by one, but it processes and verifies the whole text to gain insight by relating the meanings of component sentences. Anaphora resolution and discourse/text structure recognition are the two most common types of discourse processing, as anaphora resolution is the replacement of semantically vacant words with the entity to which they are referring, and discourse/text structure recognition is the determination of the functions of the text sentences adding to the representation of the text.

2.1.2 Natural Language Database Query

Natural Language Database Query (NLDQ) systems deal with isolated questions regarding their database knowledge context, while most of these systems are widely spread. For this reason, they are commercially available.

The core process flow on Natural Language Database Query systems is implemented and perfected, as shown in the following figure:

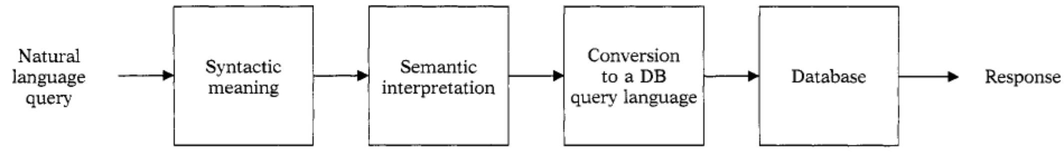


Figure 2.2: NLDQ systems core process flow (from [Allen, 2003])

As seen in figure 2.2, the process starts with the input in the form of a natural language query. The Natural Language Database Query system then processes and extracts the syntactic meaning of the input.

In the light of previous studies with the intent of reviewing Natural Language Database Query systems, it is possible to explain the different approaches and architectures that some NLDQ systems have been based in the same fashion as it is also possible to clarify and enumerate the advantages and disadvantages of using NLDQ systems.

According to [Nihalani et al., 2011], several Natural Language Database Query systems have been based on the following approaches:

- Symbolic Approach
- Empirical Approach
- Connectionist Approach

Symbolic Approach

In natural language, communication is done by sending and receiving messages in the form of sentences, therefore, in the form of groups of words, symbolic in our communication. To put it another way, words are representations of concepts and objects in the real world. When put together obeying grammar rules, sentences are born, and therefore, communication.

The knowledge of the language is expressed in rules and other forms of representation, and as a result, the human language includes rule-based reasoning. The Symbolic Approach has a rule-based approach when processing natural language, as it forms rules for every level of linguistic analysis to capture the sentence's meaning.

Empirical Approach

The Empirical Approach is corpus-based, as it uses raw data in the form of text corpora to perform statistical analysis and other data-driven analyses.

Based on statistical probabilities, Natural Language Database Query systems using empirical approaches can perform syntactic analysis on the given sentences. On the other hand, lexical ambiguities are resolved by considering the likelihood of the multiple interpretations on a context basis.

According to [Nihalani et al., 2011], the empirical approach methods are the most promising approach to developing robust, efficient Natural Language Processing (NLP) systems. In the event that empirical approach methods employ statistical techniques such as probabilistic context-free grammar, n-gram models and hidden Markov models.

Connectionist Approach

The connectionist approach tries to reproduce the brain's neural network by using artificial neural networks (ANN), providing a starting point for modelling language processing.

This approach is not based on symbols but rather based on distributed representations that correspond to statistical regularities in the language.

Natural Language Database Query Architectures

According to [Nihalani et al., 2011], Natural Language Database Query (NLDQ) systems are based on one of the following architectures:

- Pattern Matching Systems
- Syntax Based Systems
- Semantic Grammar Systems
- Intermediate Representation Languages

Pattern Matching Systems - As the name suggests, these systems work on the basis that if the input is one of the patterns, then the system can build a query to the database. Its main advantage is its simplicity due to its nonexistent need for elaborate parsing and interpretation modules and its easiness of implementation.

Syntax Based Systems - These systems analyse the user input in a syntactically based way, resulting in a parse tree directly mapped to an expression to be stored in the database query language, as can be seen in the following figure 2.3.

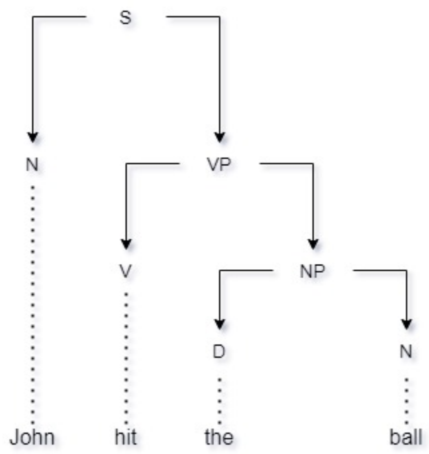


Figure 2.3: Syntax Parse Tree

These syntax-based systems also use grammar to describe the possible syntactic structures. The main advantage of systems using this kind of approach is that detailed information can be provided about the sentence structure.

Semantic Grammar Systems - Similarly to syntax-based systems, semantic grammar systems obtain the result query by mapping the parse tree from a sentence to the database query. The focus of this system is to simplify the parse tree as much as possible. The simplification is achieved by combining some nodes or by removing unnecessary nodes. As a result, the production rules in this system are not necessarily general syntactic concept correspondences.

The drawback of using a semantic grammar system is the prior knowledge of the elements in the domain context requirement, therefore it is hard to port concepts into another domain of application of knowledge.

Intermediate Representation Languages - Most current Natural Language Database Query (NLDQ) first transforms the natural language question into an intermediate logical query, expressed in some internal meaning representation language, according to the work of [Nihalani et al., 2011].

The intermediate logical query is mapped to an expression and stored in the database query language. Finally the expression is evaluated, as seen in figure 2.4.

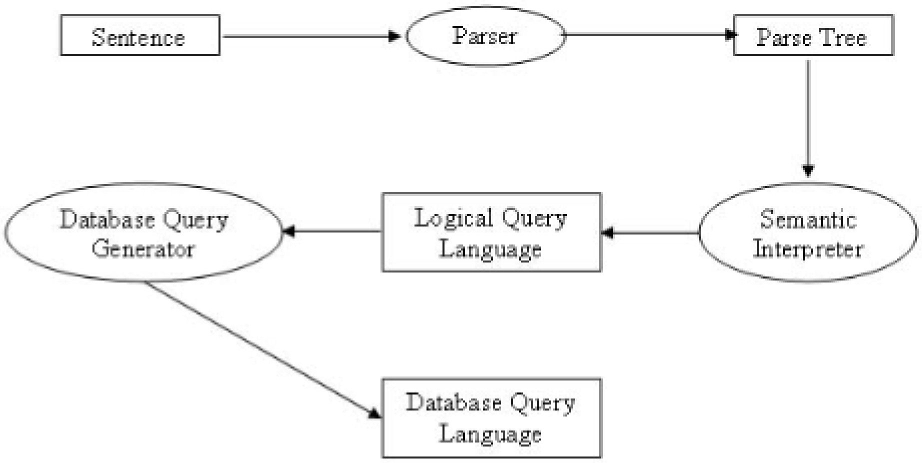


Figure 2.4: Intermediate Representation Language Architecture

The system can be divided into two parts, one part deals with the sentence up to the logical query generation, and on the other hand, the other part deals with the logical query mapping into the database query.

Advantages and Disadvantages of NLDQ Systems

Also, according to [Nihalani et al., 2011], the use of Natural Language Database Query (NLDQ) systems brings the following advantages and disadvantages, as seen in table 2.1:

Advantages	**Disadvantages**
No artificial language	Linguistic coverage is not obvious
Simple and easy to use	Linguistic vs Conceptual failures
Better for specific questions	False expectations
Grammatical error tolerance	
Easy to use with multiple database tables	

Table 2.1: Advantages and Disadvantages of NLDQ systems

2.2 Conversational Agents

The focus of this dissertation in this section is to describe what a conversational agent is and to point out other established conversational agents in healthcare, additionally, this dissertation tries to extract the *modus operandi* and the architecture used on those conversational agents.

2.2.1 What is a conversational agent?

A conversational agent is a computer system powered by Artificial Intelligence (AI) capabilities to conduct Natural Language Processing and respond automatically using human language. The response made by conversational agents can be delivered in multiple communication channels, notably by speech, virtual gestures, graphics, or physical gestures with haptic-assisted capabilities.

According to [Nuseibeh, 2018] *"a conversational agent is a software program which interprets and responds to statements made by users in ordinary natural language. It integrates computational linguistics techniques with communication over the internet."*

2.2.2 How does a conversational agent work?

According to [Vishnoi, 2020], a conversational agent first must capture the user's input and convert it to its digital representation with the help of a keyboard or a microphone to capture text and an Automatic Speech Recogniser (ASR).

In the meantime, the newly digital converted user input is sent to the Natural Language Understanding (NLU) unit, where it will be deciphered. This process uses Natural Language Processing (NLP) capabilities, as well as including speech tagging, semantic and a syntactic parser and including name identification.

At the same time as the Natural Language Understanding (NLU) process, a dialogue manager iterates through and stores the dialogue state and history to maintain the dialogue coherence.

By the end of the NLU process and the dialogue management process, the response is processed and delivered to the output generator. The processed response is chosen by a set of rules in the dialogue. If the rules give a match to the input's processed knowledge, then a correspondent response is processed and delivered, as can be seen in the following figure 2.5. If no match happens, then a fallback response is delivered.

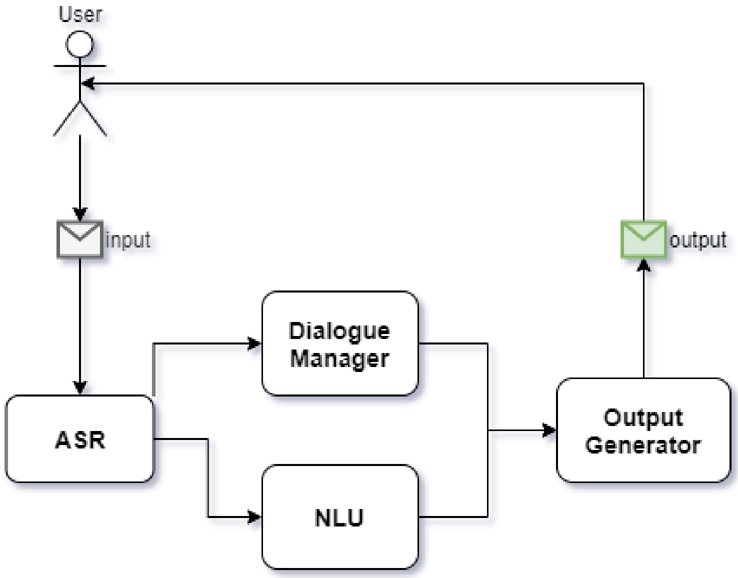


Figure 2.5: Conversational Agent Work Process

2.2.3 Taxonomy

According to [Laranjo et al., 2018], a characterisation of conversational agents can be made to compare different conversational agents with the following characteristics:

- Type of Technology
- Dialogue Management
- Dialogue Initiative
- Input Modality
- Output Modality
- Task Oriented

Each of these characteristics can be seen by the following table 2.2.

Characteristic	**Possible Values**
Type of Technology	Platform supporting the conversational agent Mobile software application Web browser Multimodal platform Telephone SMS
Dialogue Management	Frame-Based Finite-Based
Dialogue Initiative	User System Mixed
Input Modality	Spoken Written
Output Modality	Written Spoken Visual
Task Oriented	Yes No

Table 2.2: Results of initial experimentation on conversational agents

Dialogue Management - Frame-Based: The user is asked questions that enable the system to fill slots in a template in order to perform a task.

Dialogue Management - Finite-Based: The user is taken through a dialogue consisting of a sequence of pre-determined steps or states.

Dialogue Management - Agent Based: These systems enable complex communication between the system, the user and the application.

Dialogue Initiative - User: The user leads the conversation.

Dialogue Initiative - System: The system leads the conversation.

Dialogue Initiative - Mixed: Both the user and the system can lead the conversation.

Input Modality - Spoken: The user uses spoken language to interact with the system.

Input Modality - Written: The user uses written language to interact with the system.

Output Modality - Written: The conversational agent respond using written language.

Output Modality - Spoken: The conversational agent respond using spoken language.

Output Modality - Visual: The conversational agent respond using non-verbal communication like facial expressions or body movements.

Task Oriented - Yes: The system is designed for a particular task and set up to have short conversations, in order to get the necessary information to achieve the goal.

Task Oriented - No: The system is not directed to the short-term achievement of a specific end-goal or task.

2.2.4 Architecture

According to [Rahman et al., 2017], conversational agent architectures can be composed of entity recognition, intent classification, candidate response generator and response selector.

The entity recogniser and intent classification are located in the Natural Language Understanding (NLU) and the dialogue manager. Also, the candidate response generator and response selector are located in the output generator. Therefore, all the foundation components of a conversational agent work process are present.

The recent work of [Roca et al., 2020] proposes a microservice structure in a conversational agent architecture, as seen in figure 2.6.

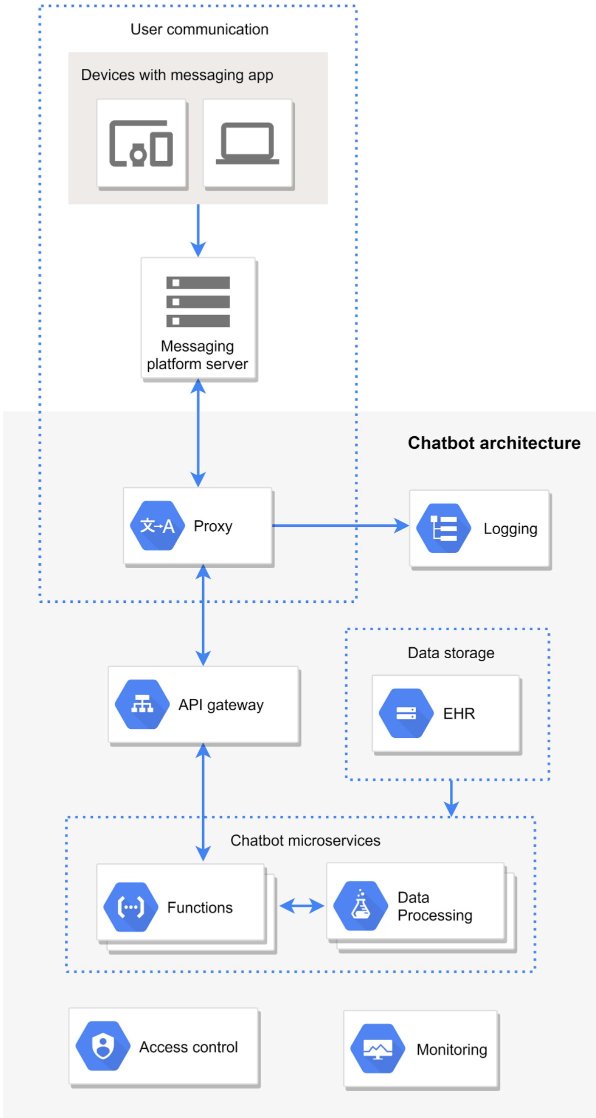


Figure 2.6: Conversational Agent Microservice Architecture ([Roca et al., 2020])

The user input and the Automatic Speech Recogniser (ASR) process are located in the devices communicating with the conversational agent platform. The proxy redirects the input to a logging system, where it stores data for further analysis and redirects to the Application Programming Interface (API), where it's delivered to the conversational agent microservices.

This conversational agent microservices components, alongside the data storage, is where the conversational agent Natural Language Understanding (NLU) unit, dialogue manager and output generator are located.

According to [Roca et al., 2020], the logic based on microservices in the proposed architecture is to process the user information and perform automatic tasks to improve and provide scalability.

Cognitive Services to build conversational agents

There are cognitive services already provided to ease the process of building a conversational agent, according to [Mota, 2019], those described in the following table 2.3.

Service	Languages Supported	Usability	Programming Languages	Automatic Context
Wit.ai	50	Medium	3	No
LUIS	10	Medium	4	No
Watson Assistant	12	High	6	Yes
Amazon Lex	English	Low	9	Yes
Recast.ai	16	Medium	7	No
Dialogflow	32	High	8	Yes

Table 2.3: Cognitive services for building conversational agents from [Mota, 2019]

However, according to [Gantenbein, 2014] and [Ahmed et al., 2017], the IBM Watson Assistant service is the only service successfully used in research projects in the healthcare domain, while also pointed as the best in terms of Natural Language Processing (NLP), according [Linares-Del Rey et al., 2019].

In addition to table 2.3, there is one more cognitive service for building conversational agents worth of notice, Google's Dialogflow. There has been some research done by [Reyes et al., 2019], [Singh et al., 2019] and [Muhammad et al., 2020] in successfully developing conversational agents with Google's Dialogflow services, assuming as a competitor for IBM's Watson Assistant services. The free version of Google's Dialogflow is more flexible than IBM's Watson Assistant.

2.2.5 Established Conversational Agents in Healthcare

Recent studies show numerous established conversational agents in the healthcare domain, according to [Kramer et al., 2020], those being:

- Vik
- Lark
- HelloJoy
- HealthTap
- Ada

Vik

Vik is a conversational agent to empower patients with breast cancer and their relatives by communicating via text messages. According to [Chaix et al., 2019], the main focus of conversational agent Vik is to give information about breast cancer, its treatments and side effects and quality of life, to point out information about sports, fertility, sexuality and diet.

Being available for free on the Web and for iOS and Android, and using the mobile application Facebook Messenger, Vik's platform is designed to address patients needs, as seen in figure 2.7.

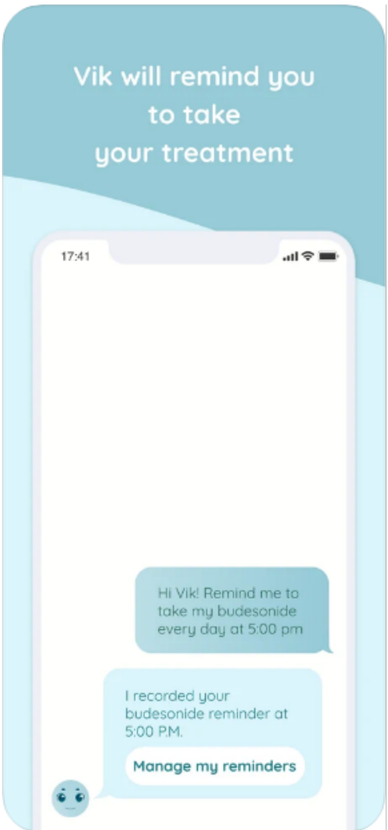


Figure 2.7: Vik usage example (from https://wefight.co - seen at Jan 2021)

Architecturally, Vik is composed of plenty of technology components which allow fine analysis of the question given by the patient and adapt its response.

[Chaix et al., 2019] studies found that the use of a conversational agent can allow an effective of intimate and sensitive information before the need for an actual conversation between the patient and the doctor or therapist. Additionally, the usage of conversational agent Vik improved patients adherence on medication.

Lark

Lark is a mobile platform to empower patients with chronic disease with medication and disease management.

The Lark Prevention module is a conversational agent that tries to help its users prevent future chronic disease by using behavioural health methods, helping them in performing weight management, tobacco cessation, and general health coaching, as can be seen in the figure 2.8.

Figure 2.8: Lark usage example (from https://www.lark.com/prevention/ - seen at Jan 2021)

Hello Joy

Hello Joy is a conversational agent, with its communication channel based on Facebook Messenger, uses Artificial Intelligence (AI) methods and Natural Language Understanding (NLU) processes to offer clinical assessment, behavioural analysis, and actionable insights, according to [Fernandes, 2019].

An usage example can be seen in the following figure 2.9.

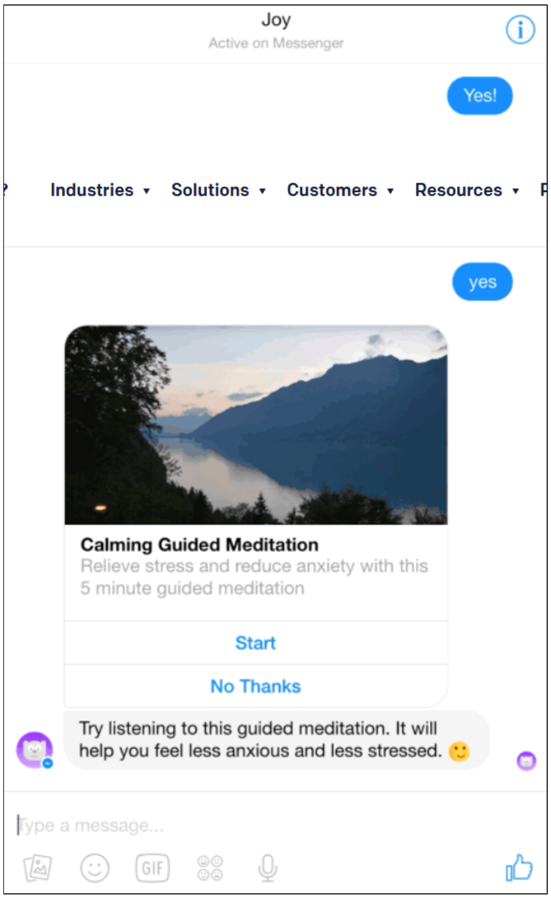


Figure 2.9: Hello Joy usage example (from [Fernandes, 2019])

HealthTap

HealthTap is a Machine Learning powered conversational agent to serve as a first-line diagnosis channel. The user types the symptoms, and the conversational agent will use NLU to cross-reference through its database to provide personalized resources.

As it uses Machine Learning algorithms, the conversational agent will learn from its experience to better suit the real-world models.

A usage example of the HealthTap conversational agent can be seen in the following figure 2.10.

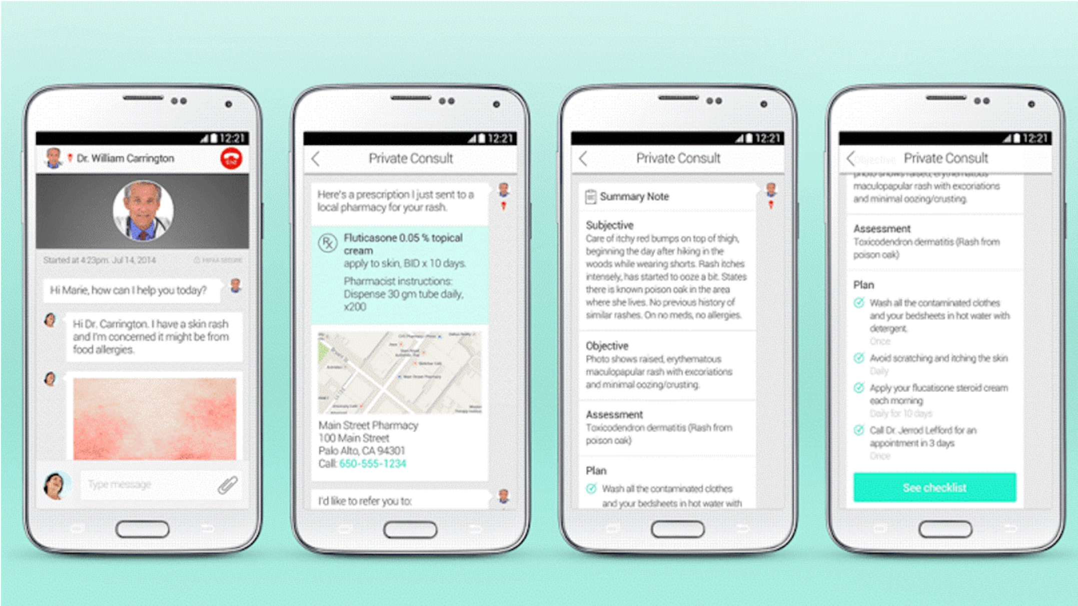


Figure 2.10: HealthTap usage example (from https://www.healthtap.com/ - seen at Jan 2021)

Ada

Ada is a platform for medical and healthcare purposes, with a conversational agent integrated inside and named after inspiration by Ada Lovelace. Ada Lovelace was the first computer programmer and pioneer of computer's potential exploration in the early 19th century.

Ada conversational agent is meant to perform the basic clinical assessment by cross-referencing the user's input, with the help of Artificial Intelligence (AI) capabilities, along with the thousand medical conditions in their database.

Ada is an established conversational agent, having over ten million users worldwide, according to Ada's website [Health, 2020]. A usage example can be seen in the following figure 2.11.

Figure 2.11: Ada usage example (from https://ada.com/pt/ - seen at Jan 2021)

Initial Experimentation Discoveries

To the effect of further gain insight into those established conversational agents, brief experimentation has been made, resulting in the results shown in the following table 2.4.

Conversational Agent	Type	Purpose	Text	Speech
Vik [1] [2]	Free	Assistant (Health)	Yes	No
Lark [1]	N/D	Coaching (Weight)	Yes	No
Hello Joy [1] [2]	N/D	Assistant (Health)	Yes	No
HealthTap	Freemium	Assistant (Health)	Yes	No
Ada	Free	Assistant (Health)	Yes	No

Table 2.4: Results of initial experimentation on conversational agents

[1] Could not install or test.
[2] Not available for Android Operating System (OS).

Given these points, it is possible to see that there is room to form a conversational agent to empower people with Parkinson's disease and their caregivers in managing Parkinson's disease.

Additionally, the qualities and explorations made by other studies and the described established conversational agents can help to guide the development and further increase the quality of the envisioned solution.

2.3 Human-Machine Communication in eHealth

In this section, this dissertation focuses on the human-machine communication channels in eHealth by conversational agents.

As pointed out in the previous section, conversational agents have an output generator meant for generating and delivering the response to the users. But it is important to realise the delivery channel also plays an important role in eHealth. In other words, the way that conversational agents deliver the response can impact the acceptance by the end users, specifically by patients in need of healthcare empowerment.

This section will focus on pointing out the following topics:

- Communication in eHealth
- User Interface Design
- Motivation in eHealth
- Motivation for Therapy Exercises

Conversational agents also deliver their responses in a diverse set of communication channels, notably by speech, virtual gestures, graphics or physical gestures with haptic-assisted capabilities.

2.3.1 Communication in eHealth

As [Ahmad and Mozelius, 2019] studies point out, technological systems are not self-taught. For this reason, without proper training, context adaptation and support, users will tend to show resistance, technological discomfort, and low adherence rates.

Additionally, [Ahmad and Mozelius, 2019] studies point out the following critical factors in communication in eHealth:

- Trust
- Personal Integrity
- Technology Acceptance
- eHealth Literacy
- Accessibility

Trust

Some of the problems of eHealth are a misunderstanding of information, technical, security, and privacy issues. Therefore, user trust in the service provider is a possible way to overcome these issues. Trust has been proven to be a crucial issue in eHealth, according to [Hossain et al., 2017].

Personal Integrity

According to [Henkemans et al., 2007] it is recommended to avoid using more monitoring technologies than the monitoring needs, as users perceived benefits are weight against the perceived privacy issues.

Although this may be true when the perceived usefulness is high, there seems to be a trade-off between user preferences and privacy. Therefore, there must be a balance between autonomy and promoting monitoring [Courtney et al., 2008].

Technology Acceptance

As [Jung and Loria, 2010] study show, the intention of using eHealth technologies depends on the perceived usefulness, ease of use and their general posture towards eHealth technologies.

Together with the sense of usability and easiness, [Lee and Coughlin, 2015] uncover affordability, accessibility, independence, support, emotional experience and confidence as important factors for technology acceptance.

eHealth Literacy

Education and training for using eHealth services are not enough. Modern interactive techniques such as voice activation, haptic gestures or touch screens can help in using eHealth services, according to [of Health et al., 2009].

According to [De Veer et al., 2015] study, there's an increase in the chance of continuous use of eHealth services in the future if a person starts using eHealth services earlier in life.

Accessibility

The base of eHealth services is the use of the internet for the connectivity of people and machines. The assumption that the infrastructure is taken for granted in numerous countries is not in other countries. In other words, regions with low-income population make a technological barrier requiring special design and consideration, according to [Latulipe et al., 2015].

Finally, [Heart and Kalderon, 2013] recommended that eHealth services must have a simple technical design and emphasize on demonstrating the valuable benefits.

2.3.2 User Interface Design

According to [Nunes et al., 2016], when designing a mobile application for people with Parkinson's disease, the following factors have to be taken into account:

- Bradykinesia
- Rest tremor
- Rigidity
- Dyskinesia
- Postural instability and gait impairment
- Hindered speech
- Visual disabilities
- Depression and apathy
- Dementia
- Variability of symptoms
- On/Off phenomenon
- Lost autonomy

Bradykinesia consists of a progressive slowness of movement, speed and amplitude while performing sequential and simultaneous tasks. Because of it, fine motor control wavers and impacts tasks requiring fine motor control such as repetitive movements, voice and handwriting.

Bradykinesia can make movements slow and progressively less wide, while this may occur in gross and fine motor movements. Because Bradykinesia can slow repetitive movements, fine motor control tasks like selecting a button multiple times are likely to become slow and difficult.

Rest tremor is an involuntary oscillating movement that occurs when the muscles are relaxed or supported by a surface. It does not affect fine motor tasks as it is attenuated or disappears when the action starts.

Rigidity consists of increased resistance to the passive movement of a limb that occurs during the whole duration of the movement, regardless of its speed. It affects fine motor control, making interaction more imprecise and slower. But while it makes movement more difficult, stiffness also is responsible for body pain.

Dyskinesias are involuntary, erratic, and writhing movements of the face, arms, legs or trunk. This symptom derives from a type of medication rather than Parkinson's disease itself. Its often described as fluid and dance-like, but may also cause rapid jerking or slow and extended muscle spasms, which make interaction very difficult.

Postural instability and gait impairment are common symptoms in advanced Parkinson's disease stages. As Parkinson's disease stages advance, gait becomes slower and unstable and may freeze in crowded or narrow spaces. Sometimes walking a series of steps without being able to stop before hitting an obstacle can happen, known as "festination".

In the early stages of Parkinson's disease, this symptom can pass unnoticed but further down the road impacts speech to the point of being completely not understandable. That is because Parkinson's disease also affects the muscles responsible for speech.

Although Parkinson's disease doesn't cause significant visual damage, blurred and double vision is expected to occur, being explained by the muscular lack of coordination, impacting colour and contrast discrimination.

Depression and apathy are common symptoms among Parkinson's disease patients, sometimes even before any motor symptom appears. With the presence of these symptoms, a person with Parkinson's disease may feel lost or more frustrated when facing new situations and may not be so motivated to use new technologies.

Although the estimated prevalence of dementia in the overall population of Parkinson's disease patients is around 15%, the cognitive degradation causes them to lose the ability to be functionally independent.

Parkinson's disease is variable because symptoms and progression vary differently from person to person. Building a representation of a person with Parkinson's disease is hard, and designs should be flexible enough to adapt to multiple situations and the different characteristics of every patient.

Along with the progression of Parkinson's disease and its treatment, it is very common to see two phases, the On phase and the Off phase.

The On phase is when a Parkinson's disease patient is medicated and shows promising development and results, therefore, fewer symptoms. On the other hand, the Off phase is when the medication stops being so effective, then the symptoms increase, and their autonomy severely decays.

Basically, when designing the user interface, this differences between On and Off phases and the mutability of a patient, changing from one phase to another, should be considered.

This point is something of a summary of the previous ones since all of them are connected with the Parkinson's disease patient losing its autonomy, greatly impacting its motivation also.

Therefore, the user interface should be able to captivate and keep the patients motivated in pursuing treatment and delaying the decay of their autonomy by pursuing basic daily life activities.

Summing things up

Bearing in mind all the previous key factors to be taken into account when designing an user interface for Parkinson's disease patient, [Nunes et al., 2016] reveals a set of rules.

1. Usage of tap targets with 14mm (around 90 DP) of side.
2. Usage of the swipe gesture, without activation speed.
3. Implementation of controls that use multiple taps.
4. Avoid the usage of drag gestures.
5. Momentary characteristics of the user adaptation.
6. Usage of high contrasted and coloured elements.
7. Careful selection of information to display.
8. Clear information of current location.
9. Avoid controls that are time dependant.
10. Having multiple ways of interaction over a single one is preferably.
11. Consider smartphone design guidelines for older adults.

2.3.3 Motivation in eHealth

One of the biggest struggles is to know when a person is motivated or lacks motivation when enrolled in an eHealth environment.

According to [López-Jaquero et al., 2019]], motivation is a key factor because it influences people's ability to use, learn and make decisions, among other things. What motivation, persuasion and influence mean, if they have different meanings and where those boundaries stand may not be that linear to acknowledge at first, but [López-Jaquero et al., 2019]] specified that :

Motivation is a general desire or willingness to do anything.

Persuasion is a process designed to change the attitude or behaviour of a person or group from their current view to a view that the persuader wants them to hold.

Influence is the power to affect a person or course of events without undertaking any direct action and to be a compelling force on other people's behaviour.

Although motivation is not essential to a patient rehabilitation, there is evidence that motivation helps producing better outcomes. Neglecting or ignoring the design of motivational models, including how that motivation is employed when designing proper eHealth systems, can lead to a design that discourages patients from using it.

The following principles, as seen in the table 2.5 can be employed to motivate and keep a patient motivated.

Principle	Description
Reciprocity	This principle reflects that people feel as if they are in debt to someone who gave them something. Thus, we aim to influence a person by reminding them what was given to them and who did it.
Scarcity	This principle is related to the tendency to prefer those things which are scarce. The fear of losing the potential benefits of the provided scarce element and if it becomes unavailable is a motivating aspect.
Authority	This principle enunciates that people usually respect authority. When using authority principle to influence someone's behaviour, awareness contributing to reinforce authority should be provided.
Consistency	It is easier for us to make commitments if we make them voluntarily and if these commitments are public. Being at least partially responsible for defining the goals will benefit a person's motivation toward those goals.
Liking	Liking can also be understood in the sense of how much the person likes their current goal.
Consensus	It is very usual to do what other people do. This principle aims to influence someone's behaviour by providing feedback about what other people are doing, did, or will do.

Table 2.5: Motivation Principles

2.3.4 Motivation for Therapy Exercises

As pointed out, the motivation to use eHealth services and conversational agents can be highly affected. [Chi et al., 2017] study showed that using an embodied virtual pet enhances companionship. The successful management of the dialogue, technical issues, privacy, and dependency compose some user's adherence issues.

According to [Kramer et al., 2020], in the development of an Embodied Conversational Agent (ECA) for coaching people in eHealth, the use of design approaches centred around humans and including the stakeholders, reporting the design activities in a systematic and understandable way is recommended.

Supporting it, [Easton et al., 2019] states that co-design approaches in the early stages represent a mechanism by which patients and their caregivers can have a voice in the process. Additionally, the benefits of a straightforward and low-cost conversational agent include increased self-efficacy and self-confidence, reduced social isolation and improved illness knowledge.

The potential clinical gains include a decrease in clinical exacerbations and conventional healthcare services usage, reducing costs and avoiding stressing the healthcare services.

Findings to empower motivation

To increase motivation in its users, the conversational agent should have its speech script written beforehand by psychologists, even in the written form, because the multiple ways to form the sentence and the time at which sentences should be employed are major influential factors in the user's motivation. Also, the ability of the conversational agent to employ everyday topics to interact with the users has a bonding effect between the conversational agent and the users, thus making users more prone and more accepting of the conversational agent's help, according to [Ly et al., 2017].

According to [Fitzpatrick et al., 2017], to motivate users and to keep them motivated, the conversational agent should adapt and behave to the following key factors:

- Empathic responses according to the user's state of mind.
- Tailored, specific content is sent depending on your mood.
- Goals to achieve.
- Responsibility, the conversational agent informs the status of the goals.
- Motivation and commitment, the conversational agent send a personalized message daily.
- Reflection, the conversational agent shows a graph of results over time.

Also, [Heldt et al., 2018] state that using a customized conversational agent with both male and female genders can achieve better bonding and acceptance between its user group. Additionally, using sensors to measure steps and guide the users throughout the exercises hand in hand with virtual rewards given to them when completing the exercise, or achieving certain goals, helps to keep patients motivated to perform therapeutical exercises and to continue with the treatment. Using sensors allows the conversational agent to adapt its behaviour to fit its response, to motivate, and keep the patients motivated, according to [Morales-de Jesús et al., 2021]]. It allows the conversational agent to give alerts and detect when a patient is having difficulty when performing a task execution. This way, the conversational agent assists based on the confusion moment context. Additionally, according to [Morales-de Jesús et al., 2021], using a virtual avatar to embody a conversational agent is important to increase the user's acceptance.

According to [Inkster et al., 2018], virtual rewards increase motivation. Employing behaviour reinforcement with virtual rewards while supporting positive behaviour reinforcement plays a major role in motivation. Additionally, using Mindfullness helps maintain the patient's psychological well-fare, thus reinforcing their motivation to continue therapy.

Also, in order to better give meaning to the conversational agent response, the use of emojis and icons can be adopted. According to [Boutet et al., 2021], the use of a positive emoji in a message increased the perceived warmth of the sender by the person who received the message. It shows strong evidence that the use of positive emojis improves communication and makes a positive impact during interactions in a digital environment.

2.4 Discussion

The existence of multiple established conversational agents in the eHealth domain like Vik, Lark, Hello joy, HealthTap, and Ada better emphasises that moving towards an eHealth approach in a conversational agent is a good approach that provides good results in adherence to the overall goal of the conversational agent. Although those conversational agents are well established, there's room to form a conversational agent to empower people with Parkinson's Disease (PD), as can be seen in table 2.4.

For a conversational agent to have great potential for delivering good results, it has to ensure Trust, Personal Integrity, Technology Acceptance, eHealth Literacy, and Accessibility while following the guidelines for designing a user interface for people with Parkinson's disease.

Motivation is a key aspect of the eHealth domain. Therefore, conversational agents must give empathic responses tailored to the context. Conversational agents must show the goals to achieve, transmit responsibility, and empower motivation and commitment with personalised daily messages and reflect the results over time.

A conversational agent paired with sensors can potentiate the information and mechanism quality to assert and employ actions to help patients. Additionally, a customised conversational agent with male and female genders improves the bonding between the patient and the conversational agent. Using icons and emojis in the conversational agent's messages improves bonding.

According to the previous aspects, the conversational agent must be built with the best conversational agent's services. According to table 2.3, the bests services are Google's Dialogflow and IBM's Watson Assistant, considering the number of languages supported, usability levels, number of programming languages supported by client libraries and if can generate context automatically. For creating a Proof of Concept (PoC), Google's Dialogflow free services provide more flexibility to explore and create before going into more robust and paid versions.

Chapter 3

Proposed Solution

The main focus of this chapter is to present the proposed solution designed to assess the context needs using the insights introduced in (Chapter 2), covering the envisioned solution, the requirements validation, the motivation model, technology approach and the developed conversational agent.

3.1 Previous Work

The solution proposed is framed in the previous work done in the scope of ONParkinson project, where a ONParkinson mobile application was built for Android Operating System (OS), to empower its users, namely Parkinson's disease patients and their caregivers, for presenting and conducting the therapeutic exercises prescribed by the Parkinson's disease patient's healthcare professional. Additionally, the ONParkinson mobile application also comes with a calendar to help their users in managing events and therapeutic programs.

The ONParkinson mobile app communicates with the ONParkinson web server by HTTP requests [Carmo, 2019]. The web server serves both the ONParkinson mobile app and ONParkinson web app, by supplying the necessary features of both platforms and by accessing and querying the ONParkinson database, additionally, it is cloud deployed in the Heroku platform.

ParkinsonBot is an integrated conversational agent in the ONParkinson mobile application and is implemented using the IBM Watson Assistant platform for building conversational agents. Also, ParkinsonBot is a rule-based conversational agent. In other words, it is a conversational agent with specific and delimited boundaries in its knowledge, being that knowledge is passed by multiple domain specialized persons, notably one physiotherapy teacher and two physiotherapy students.

The conversational agent uses Google's Services as an Automatic Speech Recogniser (ASR), translating speech input into the text and sending the input to the Natural Language Understanding (NLU) and dialogue manager located in the IBM Watson Assistant platform. Finally, the response is generated by an output generator inside the IBM Watson Assistant platform and sent back to the ONParkinson mobile app as text where it is shown and translated into speech to be reproduced by the device's audio, as seen in Appendix G.

The implemented ParkinsonBot conversational agent is not task-oriented, to put it differently, does not have a final objective goal in its dialogue. Additionally, it is supported for Portuguese language, text and spoken, and its process starts with the user's initiative (the user communicates first), looking like the following figure 3.1.

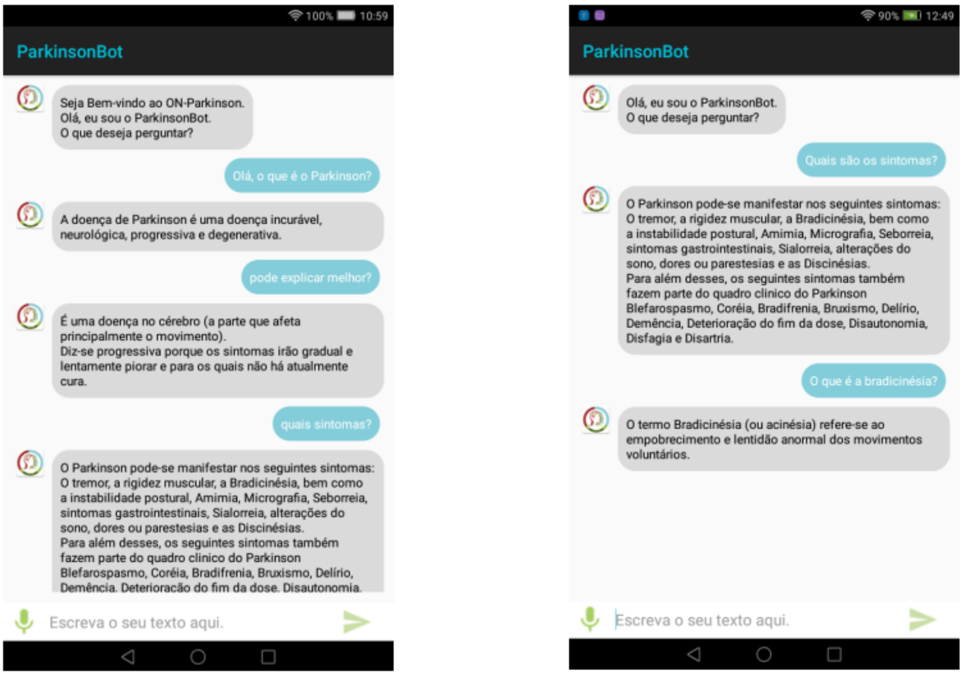


Figure 3.1: ParkinsonBot usage example (from [Macedo et al., 2019])

3.2 Envisioned Solution

The envisioned solution is a conversational agent to better engage patients with Parkinson's disease and their caregivers in performing therapy exercises and to help keep the patients motivated in training and educated for health-related aspects of their lives.

3.2.1 Features

The conversational agent to be developed should:

- Allow users to write the input.
- Allow users to dictate the input.

- Allow users to listen the response.
- Allow users to read the response.
- Understand natural language.
- Guide the patient through the exercise.
- Adjust motivational speech according to patient's characteristics.
- Guide the patient through the correctness of the exercise execution.
- Capture patient's feedback at the end of each exercise.
- Use Portuguese language.
- Be accessible to patients.
- Be understandable.
- Motivate and keep patients motivated.

3.2.2 Mockups

The process of designing the mockups was based on [Nunes et al., 2016] guidelines for user interface design of mobile applications for people with Parkinson's disease regarding user interface design guidelines, as described in chapter 2.

Given the established features, mockups started to get created and, with it, the vision of how the conversational agent would look. Those mockups can be seen in the following figures 3.2 and 3.3.

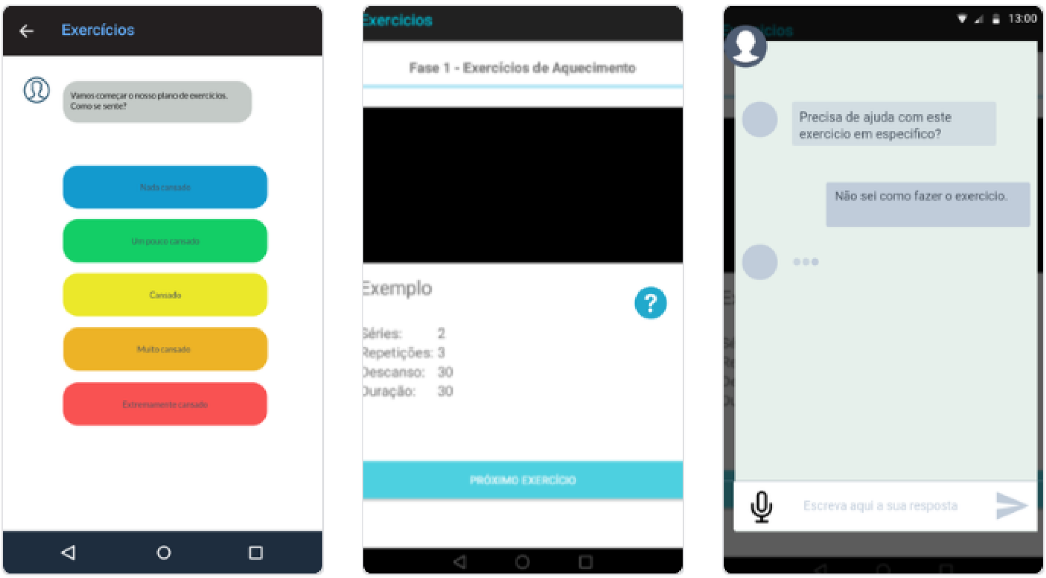


Figure 3.2: Tiredness levels and opening conversational agent mockups

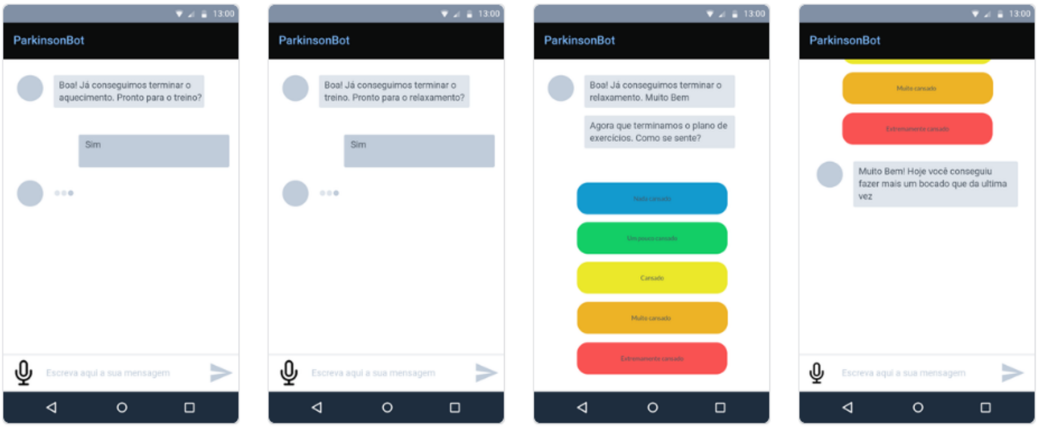


Figure 3.3: Dialog iterations mockups

After the first mockups emerged, the ONParkinson's physiotherapy team provided feedback and proposed that the interaction between the conversational agent could be performed via text, speech, and also buttons would be of great value for people with Parkinson's .

At the early stages of the disease, the user can provide text and audio input without many constraints. But, when we start to travel down the line of the Parkinson's disease stages, it becomes clear that by using this kind of approach, the interaction is greatly jeopardized. So, the idea is to include buttons with input suggestions to help them get the idea of what can they "talk" with the conversational agent but also to enable them an easier way to interact with the conversational agent, just by the click of a button.

This kind of interaction would be based on the mockup where the tiredness level is obtained, as seen in figure 3.4.

Figure 3.4: Tiredness level mockup

In figure 3.4, the interaction in which the tiredness level is obtained is by the click of one of the button sets, from a top-down perspective, where the patient could measure from "Not tired" (depicted in blue) to "Extremely tired" (depicted in red).

And finally this was refined into the final mockup, represented by figure 3.5. This mockup displays multiple input modalities, being able to write, dictate or tap an option, and being able to read and/or listen the response. Additionally, bigger button sizes and high contrasted and coloured elements were used.

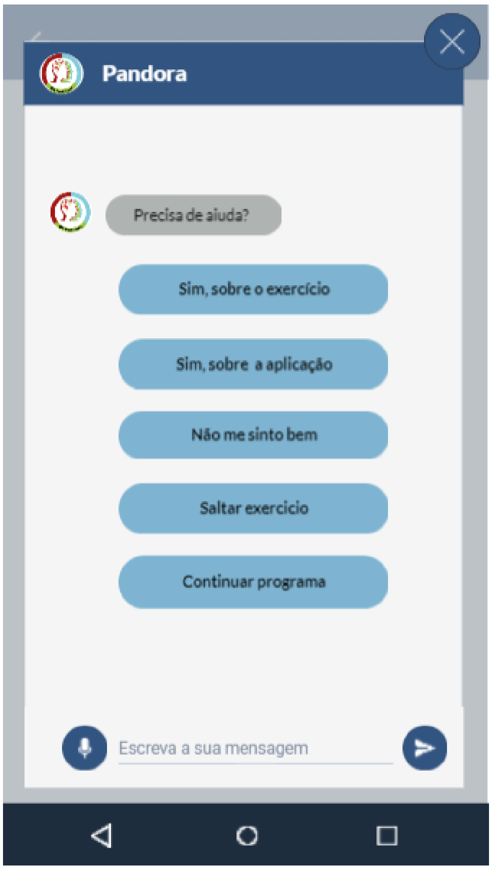


Figure 3.5: Conversational agent conversation mockup

3.2.3 Use Case Scenarios

Since the conversational agent aims to motivate and keep the person with Parkinson's motivated in doing therapeutic exercises, the question is when should the conversational agent interact with the person.

Several meetings with the physiotherapy team aiming to figure out the best moments when the conversational agent should interact with the person with Parkinson's were held. The first use case scenarios started to gain form, and they can be interpreted in the following figure 3.6.

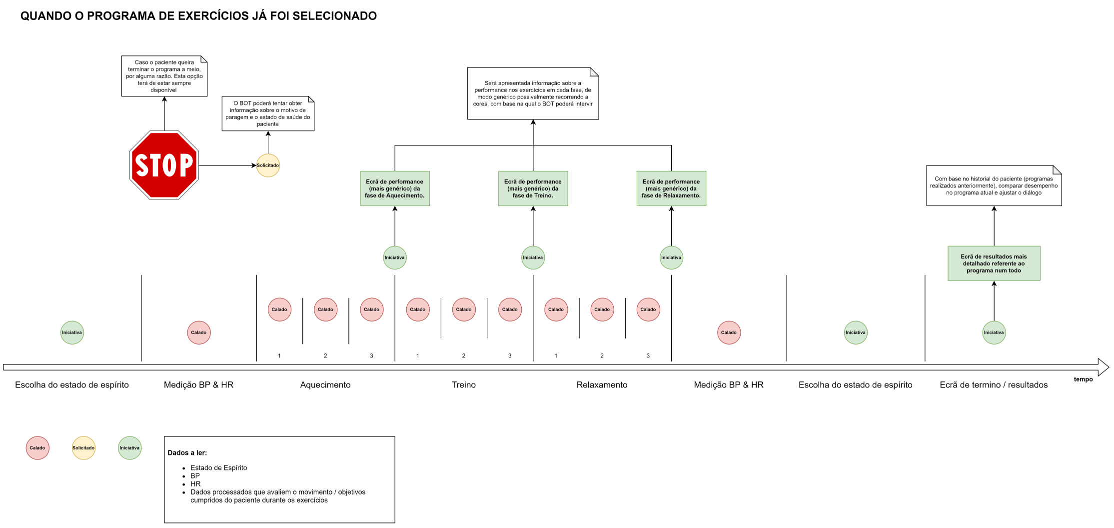


Figure 3.6: Use Case Scenario

As figure 3.6 shows (in the Portuguese language), there are three types of action from the conversational agent's point of view. The first type of action (depicted in red circles) is the action of performing no action. Specifically, this is the case where the conversational agent should not perform any interaction with the person with Parkinson's. The second type of action is the by-request action (depicted in yellow circles), which basically, is the interaction from the conversational agent when requested by the person with Parkinson's. The third and last action type is the automatic action (depicted in green circles), where the conversational agent's interaction with the person with Parkinson's is done automatically. In any given case where the user input is not recognised by the conversational agent, then the conversational agent will reply to the user by saying it did not understood the question.

When a therapeutical exercise program begins, the patient is requested to input in a sort of a 5 Likert scale, going from "Not tired" to "Extremely tired", like in figure 3.4. This tiredness level input is done with the assistance of the conversational agent being a scenario where the action type is automatic.

After being able to get the tiredness level, the conversational agent's action type is now to be quiet and does not perform anything, in the meantime, the patient will have to introduce the blood pressure and heart rate bio-metrics into the system, and when it is done, the patient will move on to the execution of the therapeutical exercise program.

3.3 Requirement Analysis Validation

Some interviews with people with Parkinson's disease, their caregivers, and physiotherapists were scheduled at Associação Portuguesa de Parkinson (APDPk) and the Saudis clinic, inside the scope of the ONParkinson's project. The main focus was to let users get the look and feel of the legacy work already made and to provide feedback on that.

They provided feedback in the form of questionnaires and as a recorded spoken interview, which lately was transcribed into text for better understanding and to better point out keywords or suggestions to be studied and discussed.

These interviews played a significant role in building a baseline, from which a starting point could be established to determine the needs and details that should be met. By obtaining feedback from patients, caregivers, and professional physiotherapists, some concerns were raised on how the interaction between the conversational agent and the person with Parkinson's should be.

Some of the needs and concerns raised, aligned within the scope of the conversational agents, with those interviews, are the following table 3.1.

ID	**Need/Concern**
NC1	Patients feel motivated when they get the feeling of progress.
NC2	Patients feel motivated when they receive feedback about how therapeutic exercises impact their daily lives.
NC3	It is recommended to make buttons bigger.
NC4	It is recommended to define targets or objectives for patients.
NC5	There is a special need to take a closer look at colours and contrasts to be shown to the patients.

Table 3.1: Needs and concerns raised with APDPk & Saudis interviews

Alongside the proposed features to be described next, these concerns and needs are taken into account in the thinking process in order to think of a way to deliver a good solution to the triad, composed of patients, caregivers and healthcare professionals.

3.4 Motivation Model

The conversational agent aims to motivate and keep the patient motivated in doing the therapeutic exercises, as described in section 3.2.

But how can we translate motivation into a conversational agent? How can we define motivation? What key factors or key metrics can we use to understand if a patient is motivated or not? These questions don't have simple answers because we are trying to translate into data/metrics what we humans usually do subconsciously, and even so, we don't always get it right.

Motivation is considered a key factor because it influences people's ability to use, learn and make decisions, among other things. Following the motivation principles described in sub section 2.3.3, it was possible to pinpoint entities and events that fit into some of the principles.

Healthcare professionals and caregivers are the key entities to empowering motivation in Parkinson's disease patients. Whereas the patient's motivation comes from:

- Their own character, willpower, and perseverance.
- The healthcare professional ability to monitor the patient and keep the patient engaged.
- The caregiver's closeness to the patient, in the sense of a more personal/human presence on a day-to-day basis.
- The healthcare professionals and caregivers own persuasion/influencing capabilities over the patient.
- The conversational agent's ability to fill the gap when human involvement is unavailable.

After this was raised and agreed upon, the conversational agent's motivational cases were defined, as seen in figure 3.7.

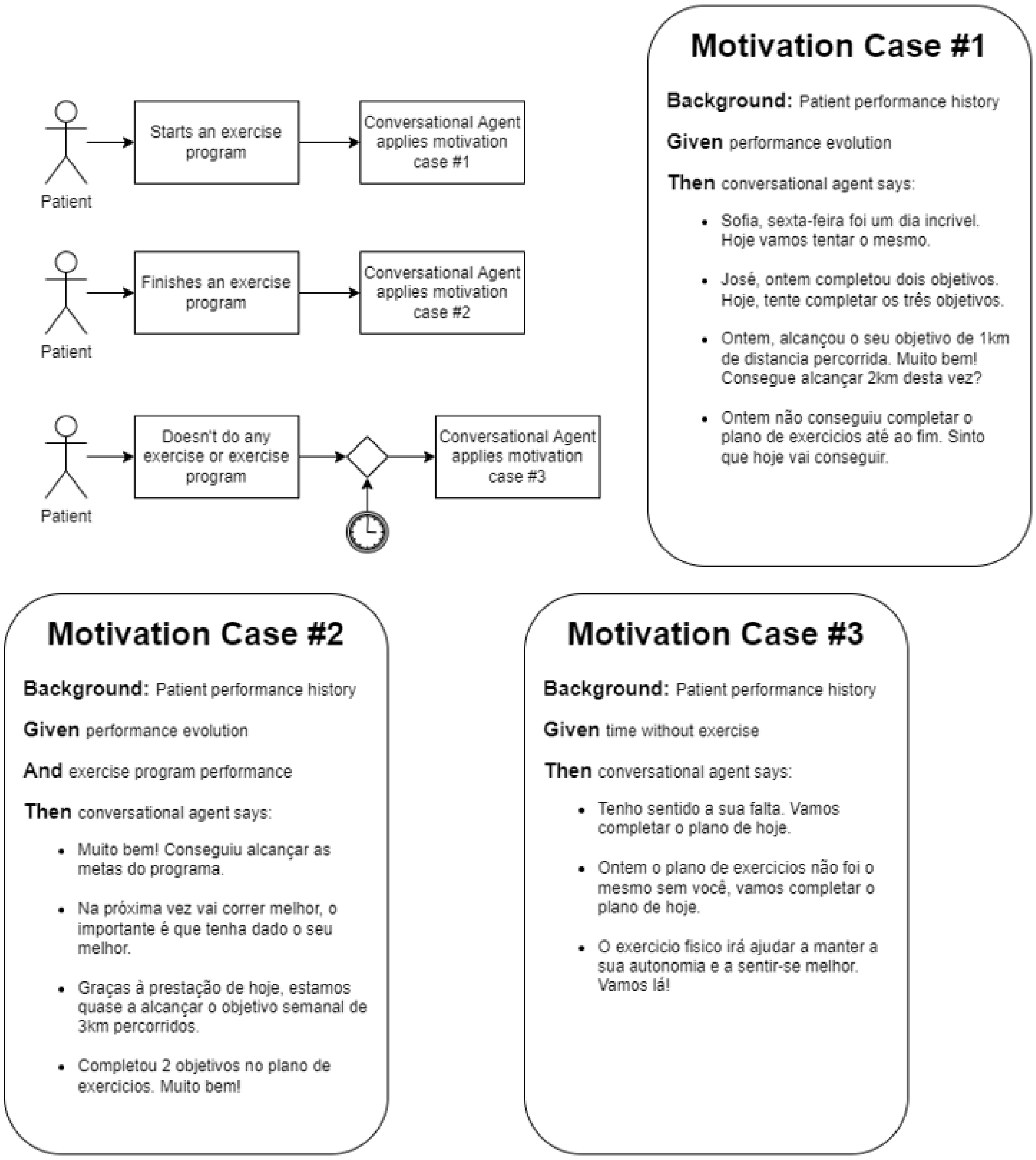


Figure 3.7: The conversational agent's motivation cases

There are three scenarios (cases) where the conversational agent can come into play to empower the patient's motivation.

Motivation Case #1: In this case, the conversational agent action is triggered given the patient's performance regarding their set goals. The conversational agent has a motivational speech and provide positive reinforcements when it knows the patient is already motivated to keep it that way.

Motivation Case #2: Although very similar to **Motivation Case #1**, this case also checks the current exercise program performance. The output varies, similarly given if the patient is motivated or not.

Motivation Case #3: Differently from the other two cases, in this case, the conversational agent will come into play if it knows that the patient went through a period without exercise. In that case, the conversational agent will try to motivate and bring the patient back into performing the therapeutic exercises.

Given the motivation cases are established, then the main question keeps being: "What can we use to measure motivation?", "What metrics can help us to do that?".

All motivation cases are to be delivered via notifications so that it does not disrupt the application's workflow. In those notifications, there will not be just plain text, but there will be emojis present to empower the patient's motivation and encourage them to do therapeutic exercise programs and to encourage them to keep doing so. As described in section 2.3, the use of positive emojis in a message, according to [Boutet et al., 2021], increases the perceived warmth of the sender by the person who receives the message.

Pairing the conversational agent's capabilities with the work regarding the use of sensors to get data while the patient is performing the therapeutic exercises, some key metrics to try to measure if the patient is motivated or not were defined, as described in table 3.2.

Metric	**Description**	**Insight**
Duration	Allows the conversational agent to understand if the patient is doing the program for an acceptable duration.	If the duration is outside an acceptable threshold, then the patient is not motivated (too slow or just clicked until the end of the program).
Program Completed	Allows the conversational agent to understand if a patient is actually following the established exercise programs.	If the patient is not completing the programs, then the patient is not motivated.
Tiredness Level	Allows the conversational agent to detect if the patient is feeling tired or not.	If the patient is constantly feeling tired before doing the program, then the patient is assumed to be less motivated.
Steps Distance Calories Flights of Stairs	Allows the conversational agent to detect if a patient is achieving or not their established objectives.	If the patient is always failing to meet the goals established by their therapist, then it is assumed that the patient is not motivated.

Table 3.2: Motivation Metrics

3.5 Technology Approach

In this section, technologies adopted on the main ONParkinson project are explained, being the following:

- Conversational Agent Technology Adopted
- Mobile Technology Adopted

3.5.1 Conversational Agent Technology Adopted

As described in section 3.1, there was a conversational agent specific for a FAQ style approach built using IBM's Watson Assistant services. But due to changes in the strategic approach of the ONParkinson's management regarding IBM's licensing policy, there was a need to change the sub-modules to use a technology other than IBM Watson, which allows for a more cost-effective solution.

Google's services were chosen because they are one of the bests services for building a conversational agent, as can be seen in section 2.4. Additionally, Google's Dialogflow can be paired with the existing Google's text-to-speech (TTS) and speech-to-text services(STT).

The new process flow of the conversational agent resulted in the following figure 3.8.

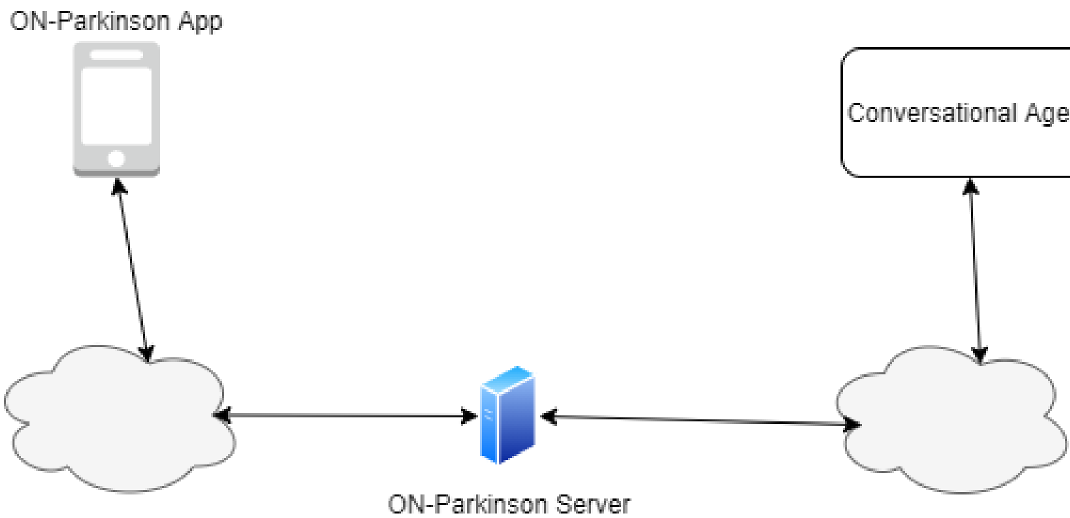


Figure 3.8: New ONParkinson conversational agent information flow

With this centralised approach, if a need to create or change the conversational agent to a new or an updated conversational agent emerges, the need to perform migrations is limited to the scope boundaries of the ONParkinson server. In other words, there's no need to perform migrations and changes in the mobile application and its installation or update on every mobile device.

3.5.2 Mobile Technology Adopted

Differently from the application built previously, new mobile technology was adopted to build the new application.

The ONParkinson project management opted to adopt the use of the Flutter technology to develop a brand new, revamped version of the legacy mobile application for ONParkinson. Flutter is an open-source framework built by Google for building multi-platform applications from a single code base.

Flutter is a technology that enables fast development, as it includes a "hot reload" feature which provides a real-time reflection of the code changes in the app the moment those changes are saved while preserving the current application state. [Google, 2017]

It supports a conditional user interface, and every widget available follows the well-established and robust Material Design guidelines and Apple's Cupertino looks, resulting in a drastic decrease in the development time used to style the looks to follow those guidelines. Additionally, widgets are capacitated with animations, scrolling and accessibility features, and on top of that, they are customisable.

The choice of deprecating the adoption of native Android Java development in favour of Flutter technology was an easy choice. There's a need to better reach Parkinson's disease patients, but Android Java technology did not provide the ability to reach mobile devices other than Android OS ones. Now, with Flutter, it is possible to reach patients with mobile devices using not only Android but also iOS, better accommodating the new design options with ease.

The adoption of Flutter technology for mobile development did not change much in the data flow and processing of information described in sub section 3.5.1, but due to various differences between the old and the new technology, a period of learning, designing and implementing had to take place to accommodate the new designs and to accommodate the necessary structure for the conversational agent.

3.6 Pandora - The Conversational Agent System

In this section, a description of the developed conversational agent system named Pandora takes place, alongside the description of the modules, data structuring and dialogue structure. With that, this section is sectioned into the following topics.

- Information Flow
- Knowledge
- Profiles
- Motivation Recogniser

The conversational agent system is named Parkinson Assistant in Natural Dialogue and Oriented by Rules and Assessments (Pandora). Although the name is not visible in the actual system, and because the conversational agent has multiple profiles, the whole conversational agent system is identified as Pandora.

3.6.1 Information Flow

As described in sub section 3.5.1, the user communicates with Pandora within the ONParkinson mobile application. The message is sent from the ONParkinson mobile application to the ONParkinson server where it also sends a message to Dialogflow platform, where the Natural Language Processing (NLP) and Dialogue Management unit handles the user input.

The output generation is triggered by the Dialogue Management premises. The generated responses usually contain customised tags to identify information needed in the text or to identify actions that Dialogflow does not have access to. The response is received and redirected by the ONParkinson server to the ONParkinson mobile application.

The message is passed to Pandora's Knowledge units before reaching the user, where it is treated and refined. There can be actions to be done automatically that the Knowledge units will detect and execute. This whole process can be seen in the figure 3.9.

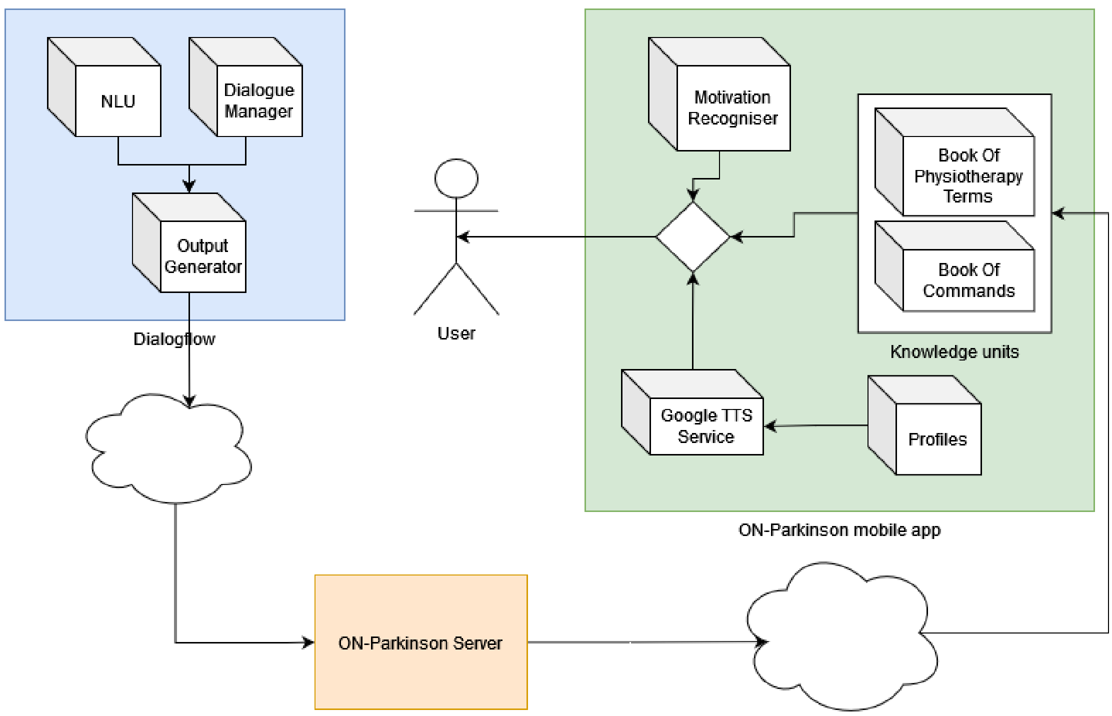


Figure 3.9: Pandora Information Flow

3.6.2 Knowledge

The conversational agent's message is analysed and treated by the Knowledge units when it arrives at the ONParkinson mobile app. The Knowledge units are responsible for giving Pandora the knowledge of the current context, like the patient's exercise program or the current exercise. The units are comprised by:

- Book of Physiotherapy Terms
- Book of Commands

Book of Physiotherapy Terms is a knowledge unit responsible for analysing the conversational agent message text in order to detect customised tags and compare them with a conversion dictionary. A conversion dictionary is a dictionary that maps the customised tag with the book attribute name. For example, a tag ”¡number repetitions¿” is mapped to the attribute ”numberOfRepetitions”. The Book of Physiotherapy Terms will replace the tag with the mapped attribute value inside the message text.

Book of Commands is a knowledge unit responsible for analysing the conversational agent message text to detect customised action tags. Similar to the Book of Physiotherapy Terms, the Book of Commands will map the action tag with the attribute's name. Instead of replacing the tag in the message text, the Book of Commands will only remove the tag or tags from the text, returning a collection of actions that the application will execute afterwards.

3.6.3 Profiles

Pandora has a set of four different Portuguese language voice profiles, two male and two female voices, obtained through Google's Text-to-Speech services. The profiles can be used to choose a voice option and to identify the conversational agent's name.

The ability to allow the user to choose from a set number of profiles gives them a sense of control in which they feel more prone to continue using the Pandora system. Also, it keeps them engaged in performing therapeutic exercises prescribed by their physiotherapist. The available profiles are:

- Apolo
- Angelia
- Atena
- Hermes

Why were these profile names chosen? The answer lies in the symbolism of these names in Greek mythology, where all of them are Greek god names.

Apolo is the god of the sun and light (truth) and the source of life and healing. The conversational agent is supposed to be an agent of knowledge and truth while helping the patients with their therapy.

Angelia is the personified spirit of messages, tidings, and proclamations. Therefore, represents the message exchanges between the Pandora system and the patient.

Atena is a goddess associated with Wisdom, therefore is a good fit for a name due to Pandora having knowledge units in its system.

Hermes is a messenger god and the father of Angelia.

Each profile can be picked from the settings page on the ONParkinson mobile application, as can be seen in the following figure 3.10.

Figure 3.10: Pandora Profiles

Each individual profile has a unique speaking voice, so, there are four available speech voices to choose from. The definition of a profile comes with a speaking voice, speech pitch, and speech velocity. Given that, the Pandora system architecture has these four profiles already developed and defined within, so the user only needs to choose one. The chosen profile is stored in the ONParkinson mobile application configuration files, maintaining the persistence of the chosen profile, whether a new instance of the mobile application opens.

3.6.4 Motivation Recogniser

The Motivation Recogniser is a unit with assertive behaviour of Pandora's system. It is a system unit designed to analyse and assert whether the patient is motivated or not motivated.

Following the motivation model described in section 3.4, the Motivation Recognizer will detect the patient's motivation by scoring all the different metrics, as described in table 3.2.

After scoring each metric and calculating the overall score, the Motivation Recogniser will assert the motivation status of the patient as motivated, normal, or not motivated. The motivation status is used for deciding the message that the conversational agent will give to the patient, in the form of a notification, according to the current motivation case. The motivation cases are not related to the patient's profile but are heavily dependent on the patient's motivation status, as can be seen in figure 3.11.

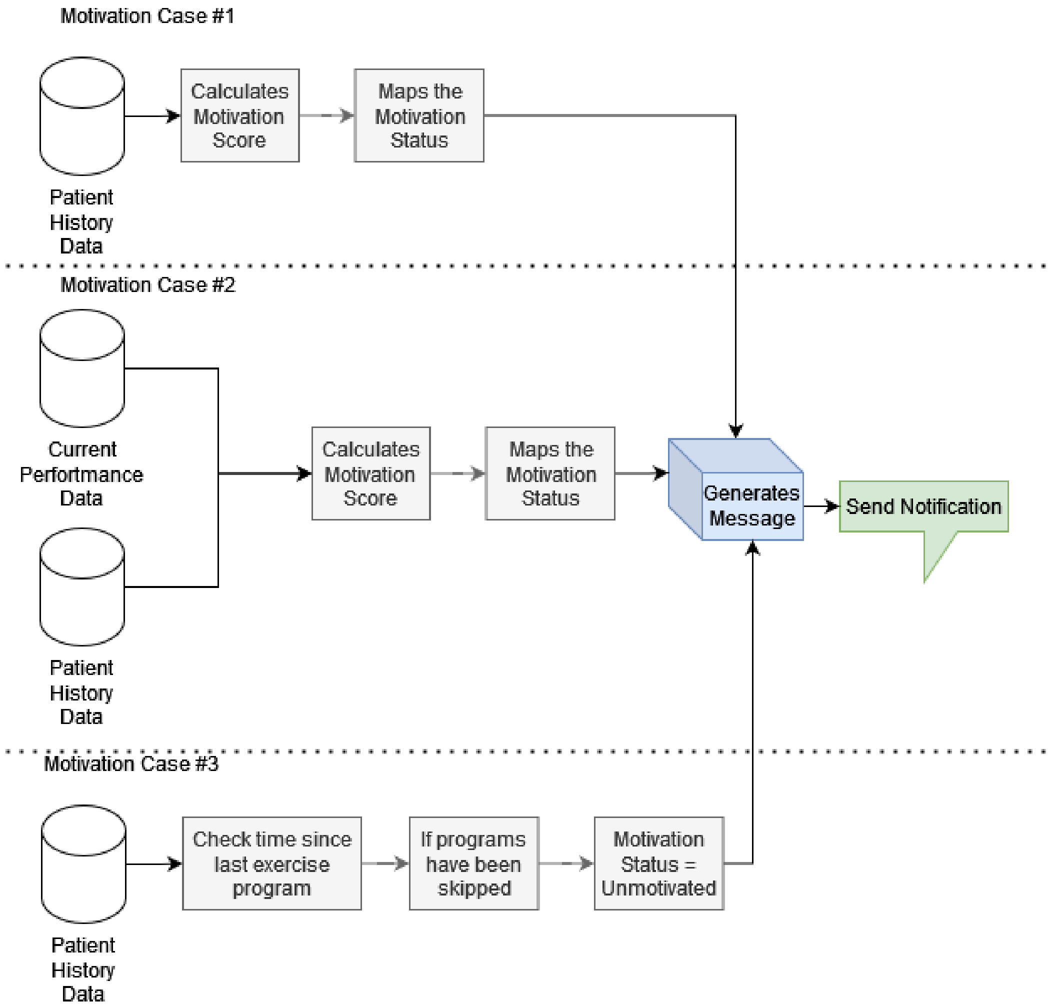


Figure 3.11: Motivation Recogniser Process

The notification will be displayed with the motivation message, the application logo and the name of the chosen profile. Additionally, some notification messages display emojis to positively impact the patient's motivation, as verified in related work section 2.3. Some examples can be seen in the following figures 3.12a, 3.12b, 3.13 and 3.14.

(a) Pandora Motivation Case 1

(b) Pandora Motivation Case 2

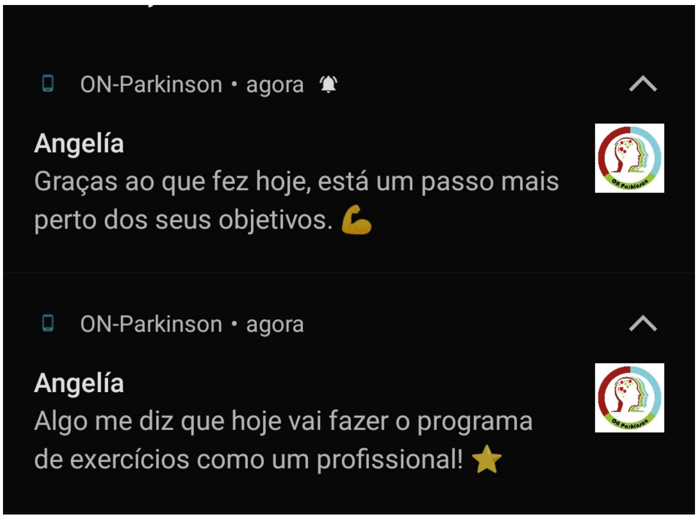


Figure 3.13: Pandora Motivation Cases 1 and 2 notifications

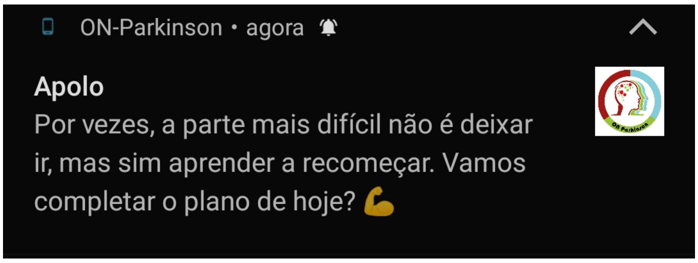


Figure 3.14: Pandora Motivation Case 3

Although the Motivation Recogniser will assert the motivation status based on the metric and overall score, the actual heuristics from which those scores are calculated are outside the scope of this dissertation and are the object of study to the ONParkinson's research project.

3.6.5 Interaction Examples

In order to illustrate how Pandora works the following three interaction examples are presented:

1. Skipping exercise
2. Asking for help
3. Well-being fallback

Interaction Examples 1: Skipping exercise is a example where the patient is performing an exercise and requests Pandora's conversational agent to skip the current exercise and move on with the exercise program.

Interaction Examples 2: Asking for help is a core example where the patient is performing an exercise and requests Pandora's conversational agent's help.

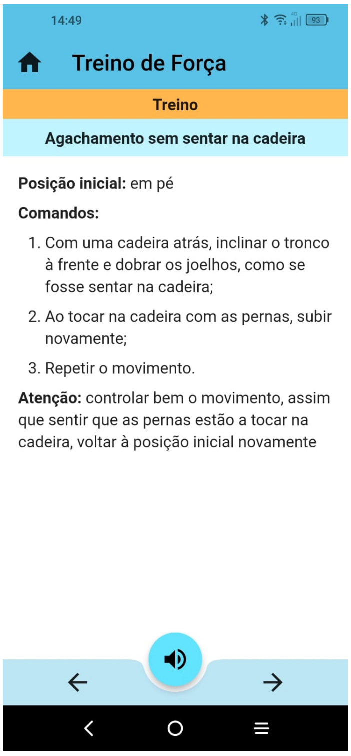
For example, a patient with Parkinson's disease is going to do a strength exercise program, so the patient enters the exercise programs list (see figure 3.15a). For this example purpose, the request for Pandora's conversational agent's help is done on the first exercise in the training stage, named "Agachamento sem sentar na cadeira" (see figure 3.15b).

(a) Choose Exercise Program

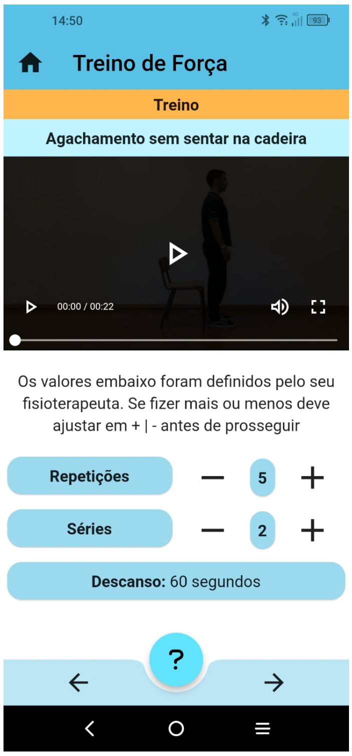
(b) See exercise list

Figure 3.15: Starting the program

The patient performs the exercise program normally, and when the patient reaches the first exercise of the training stage, the patient will see the exercise introduction screen (see figure 3.16a). In the exercise introduction screen, the patient can read the exercise description or hear Pandora's conversational agent dictate the exercise description if the sound button in between the back and next buttons is clicked. In the exercise screen (see figure 3.16b), the patient requests Pandora's conversational agent's help by clicking in the help button in between the back and next buttons. These screens appear for every exercise, but it is only shown for this specific exercise to explain this interaction example.



(a) Exercise introduction

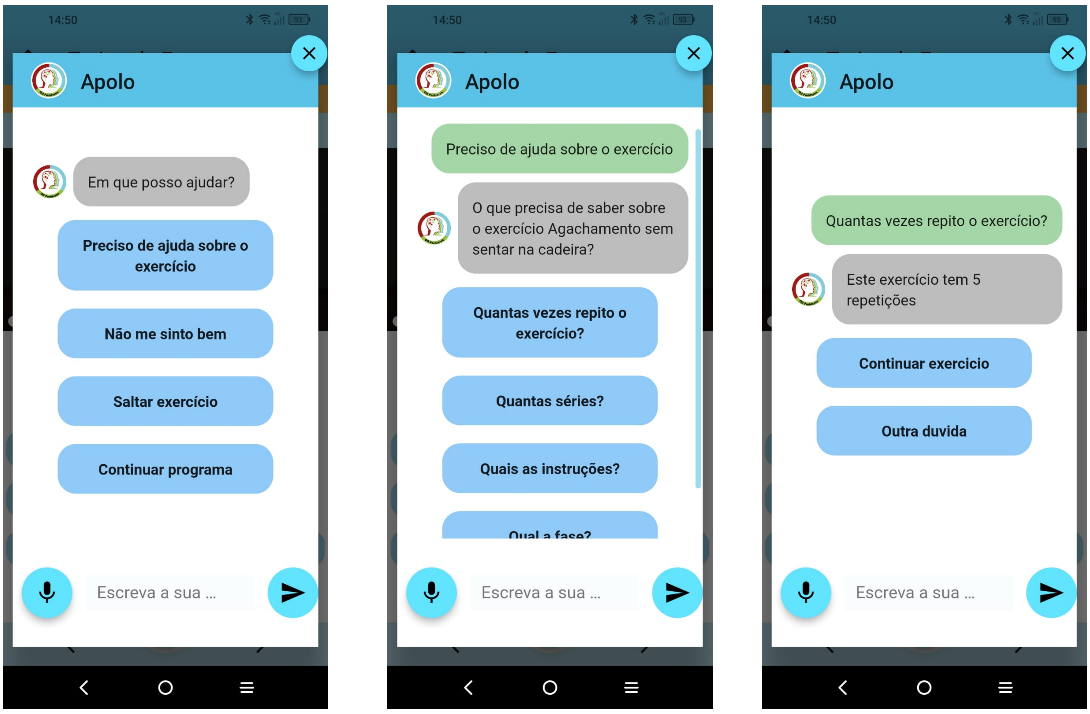


(b) Exercise screen

Figure 3.16: Doing an exercise

When the patient opens Pandora's conversational agent's dialogue, Pandora will greet the patient by asking how it can help the patient (see figure 3.17a). From this dialogue node, the patient has several options to choose from. The patient can click on the microphone button and dictate the question, click in the text field and write the question, or the patient can click one of the blue option buttons that appear just below Pandora's conversational agent's message. The choices are if the patient needs help with the exercise, doesn't feel good, wants to skip the exercise, or wants to resume the exercise program. In this example, the patient asks for help on the current exercise (first blue options button).

After the patient asks for help with the current exercise, Pandora's conversational agent replies by asking what the patient needs to know about the exercise (see figure 3.17b) and showing a set of options for the patient to choose from. The choices are how many times the patient should repeat the exercise, how many sets, what are the exercise instructions and at which stage the exercise is. In this case, the patient asks the patient should repeat the exercise (first blue options button).



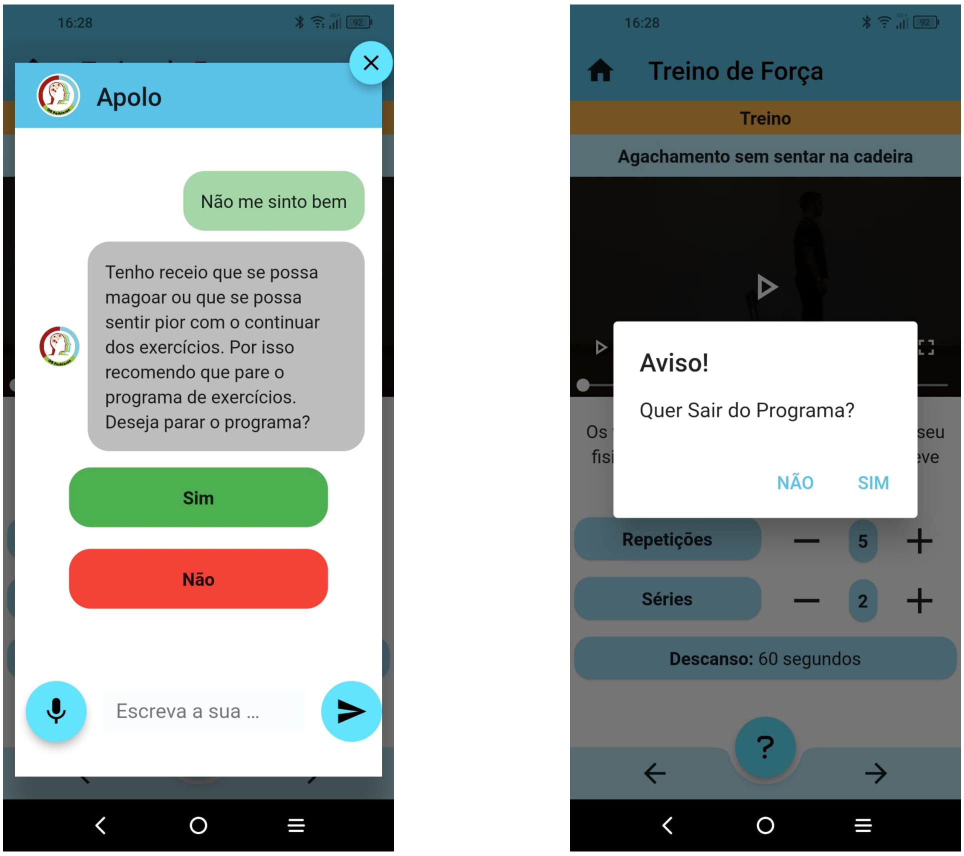
(a) Pandora opening (b) Exercise help (c) Exercise repetitions

Figure 3.17: Asking Pandora about the exercise

After the patient asks how many times the patient should repeat the exercise, Pandora'sconversational agent replies with the number of times the patient should repeat the exercise and offers two options for the patient to choose from, as seen in figure 3.17c. The patient can choose between asking another question to Pandora's conversational agent or resuming the exercise program.

Interaction Examples 3: Well-being fallback is a core example where the patient is not feeling well while performing an exercise and requests Pandora's conversational agent's help.

Using the same example as in the previous interaction example, the patient will do the same steps until reaching the first exercise of the training stage and open Pandora's conversational agent's dialogue (see figure 3.17a). This time, the patient will instead tell Pandora's conversational agent that is not feeling well (second blue options button). Pandora's conversational agent replies by showing concern that the patient might feel worse or get worse if the patient continues with the exercise program, so it recommends stopping the exercise program.



(a) Not feeling well (b) Stopping exercise program

Figure 3.18: Well-being fallback

At last, Pandora's conversational agent asks if the patient wishes to stop the exercise program while showing two options (see figure 3.18a). After the patient chooses to stop the exercise program, the patient will be prompted with a confirmation dialogue asking if the patient wants to exit the exercise program (see figure 3.18b). If the patient presses "Yes", the exercise program will be stopped, and the information of that action will be stored to notify the patient's physiotherapist about what happened.

Chapter 4

Evaluation and Results

This chapters presents the evaluation plan performed over the developed solution and the subsequent obtained results. Therefore, the chapter starts by detailing the evaluation plan and, afterwards, a twofold results analysis is presented taking into consideration the technical performance and the user experience.

4.1 Evaluation Plan

There is no standard for evaluating conversational agents in the healthcare area, eHealth and mHealth, nor does the literature presents a systematic evaluation model for conversational agents. Because the nature of a conversational agent is very different from a conventional software system, a validation plan to evaluate a conversational agent in a mHealth and web-based environment that also integrates standards was designed and proposed in [Macedo et al., 2019] article.

This validation plan is comprised by three phases that are done sequentially where the last two phases will be conducted with people with Parkinson's disease and their caregivers in Associação Portuguesa de Parkinson (APDPk) and Saudis clinic.

- Technical Performance Study
- User Experience Study
- Health Research Study

The three steps of validation are described in subsections bellow. Since, User Experience study and Health Research study involves patients in clinical contents, all the validation process has been submitted to the Ethical committee. Ethical approval was obtained from the Ethics Committee of the Health School of the Polytechnique Institute of Setúbal (76/CC/2021).

4.1.1 Technical Performance Study

Technical Performance study is comprised by a set of tests. These tests aim to assess the conversational agent's domain coverage, coherence and ability to respond properly, and the dialogue management capacity using a set of metrics (See Appendix A and B).

To evaluate the technical performance of a conversational agent, a set of technical evaluation measures for conversational agents are essential to have. The set of technical evaluation measures is comprised by domain coverage, coherence response capacity and dialog management capacity, according to [Laranjo et al., 2018], [López-Cózar et al., 2011] and [Walker et al., 1997].

Domain Coverage - This characteristic defines the knowledge boundaries, such as information regarding the exercise, the conversation evolution, and the motivational state. Those requests can be like *"I don't know what to do"*, *"What are the number of sets?"*, etc...

Coherence Response Capacity - This characteristic defines the coherence to validate if the response is comprehensible and relevant.

Dialog Management Capacity - This characteristic defines edge cases of the conversational agent's dialogue, such as the chain of conversation, the well-being fallback and non-understandable messages. Various conversation scenarios were established to validate this characteristic, such as:

A. Happy scenario with three independent questions.

B. Scenario with one chaining questions.

C. Scenario with two known questions and an unknown question.

D. Scenario with not understandable questions.

The description of the domain coverage, coherence and ability to respond, and the dialogue management capacity alongside a direct mapping of the key factors/metrics are described in the following table 4.1.

Characteristic	Metric (Nº of)
Domain Coverage	Exercise names correctly identified Exercise stages correctly identified Repetitions correctly identified Sets correctly identified Exercise descriptions correctly identified Motivation asserts correctly performed
Coherence Response Capacity	Coherent responses
Dialog Management Capacity	Conversations chained correctly Well-being fallback correctly recovered Non-understandable inputs correctly detected

Table 4.1: Technical Performance Evaluation Plan

To move on to the next validation phase, the system must have at least 85% accuracy for each characteristic.

The accuracy of each item is asserted and accounted, for, and then the accuracy is calculated using the following formula:

$$Accuracy = \frac{TruePositive}{TruePositive + FalsePositive}$$

These tests should be executed by experts on the domain (in this case, physiotherapists) since some evaluations require knowledge of the domain field. For example, a physiotherapist tests if the system delivers the correct exercise names, stages, repetitions, sets, exercise descriptions and the correct notifications for a specific motivation state. Another example is the need for a physiotherapist to test if the system provides coherent responses, for instance, if the system provides a response that fits the context in which the request is provided.

4.1.2 User Experience Study

In the User Experience stage, Parkinson's disease patients and their caregivers perform the tests and record the results as logs and user feedback surveys. The logs are stored within the mobile application, with the help of a Flutter library called "FLogs". This library eases the interaction logging and remain within the device until the devices are collected and their logs extracted.

This stage is divided in two phases. The first phase is conducted in a one-day controlled environment following a previously defined screenplay to find significant problems. The second phase occurs in the field for a time range of 30 days to let users use Pandora freely and according to their needs.

Design

At the end of each phase, users fill up user satisfaction questionnaires using a 5-Likert scale and System Usability Scale Adapted for Portuguese Language (SUS) from [Martins et al., 2015] (See Appendix D, E and F). Other objective measures are registered normally through the use of the mobile app, regarding the performance of the user when performing loose/free exercises or defined exercise programs, their subjective perception of tiredness level, their objectives and achievements.

In the one-day controlled environment phase, the patients use and test Pandora following a defined screenplay. This screenplay is defined in the tests guide (See Appendix C) guiding users on the tests (the test conductor, and the observer) and specifying the required material and the estimated time per interaction, as can be seen in the following figure 4.1.

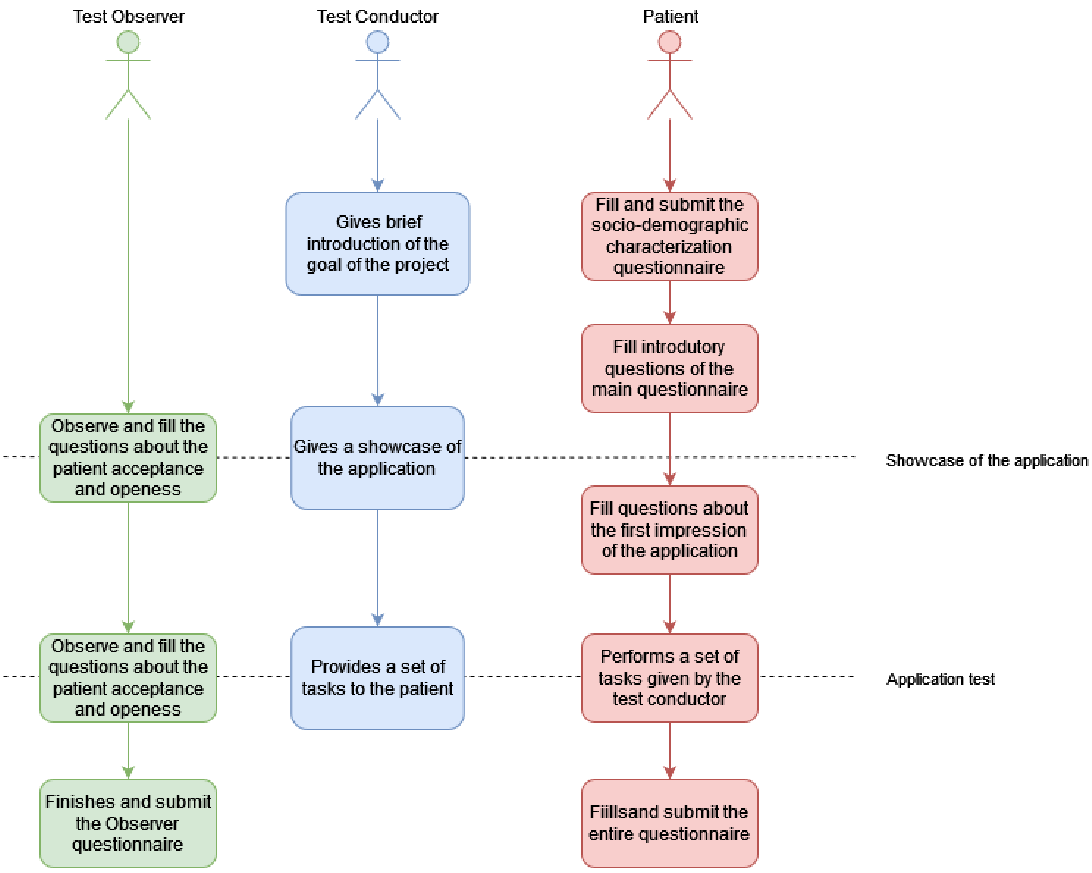


Figure 4.1: User Test Flow

The patient's first contact with Pandora is provided by the test conductor, who provides an introduction, and educates the patients on how to use Pandora by allowing them to interact with Pandora in a guided way. By that time, the patients fill out part of the feedback survey meant to obtain the patient's first impression of Pandora.

After filling up part of the feedback survey, the patients has to follow a screenplay without any intervention of the conductor, unless they get confused or lost on the task at hand. After the patients finish the screenplay, they finish filling up the rest of the feedback survey.

At the time of the tests, the test observer has the task of observing the whole process and filling in a specific survey. This survey is designed to provide data to analyse whether the answers given by the patient (on the feedback survey) correspond to what was expressed, verbally or by body language.

Additionally, the application registers logs regarding the user interaction with Pandora to understand what generally suits the user's needs and which type of user and their disease stage.

Sample criteria

People with Parkinson's disease are recruited from Associação Portuguesa de Parkinson (APDPk), Saudis clinic and Escola Superior de Saúde - Cruz Vermelha Portuguesa (ESSCVP). Given that, the following sample criteria are defined based on [Kim et al., 2021], [Landers and Ellis, 2020] and [Siegert et al., 2019]:

- **Acceptance criteria**
  - People are at least eighteen years old and diagnosed with Parkinson's disease by a neurologist.
  - People with Parkinson's disease who can understand the study's aim, compromise with the required tasks and fill out a consent form.
- **Exclusion criteria**
  - People with severe vision or hearing impairments.
  - People that have been diagnosed with other neurologic, respiratory or orthopaedic conditions that significantly impair them into safely complete the required tasks.
  - People with severe neuropsychiatric symptoms, such as major depression.
  - People with severe cognitive or physical impairment (level 5 on Hoehn and Yahr scale) that interferes with the study procedure's participation.
  - Patients clinically unstable within the past six months, with recent history of stroke, acute myocardial infarction and other several health conditions of similar severity.
  - Patients who have not been stable with Parkinson's disease medication and deep brain stimulation within the last 3 months.

Data collection

Patients with Parkinson's disease have to fill out a socio-demographic characterisation questionnaire (See Appendix D). The questionnaire is created and filled on

Google Forms and has closed questions, multiple choices, checkboxes, Likert scales and short answers to lessen the burden on participants and to reduce obtaining incomplete data.

According to [Stoyanov et al., 2015], the app quality can be measured following the Mobile App Rating Scale (MARS) within the following categories:

Engagement refers to the entertainment, customization, interactivity and if it fits in the target group.

Functionality refers to the performance, gestural design, ease of use and navigation.

Aesthetics refers to the visual appeal, graphics and layout design.

Information Quality refers to the quality, quantity, credibility, goals, visual information and description.

Subjective Quality refers to the repeated use stimulus, overall satisfaction rating and if it is worth recommending.

A summary of the user experience evaluation tests can be seen in table 4.2

Source	**Characteristic**	**Metric**
Logs	Engagement	Average time of conversation per exercise/program Average time of use per exercise/program Average number of questions per exercise/program
	Effectiveness	% of effective missing responses
	Input/Output Preference	% of questions using text % of questions using buttons % of questions using speech
Questionnaire	Speech Recognition Satisfaction Speech Generation Satisfaction Message Buttons Satisfaction Aesthetics Information Quality Subjective Quality Ease of Use Perception of Usefulness Interaction Satisfaction Satisfaction with the Answers Given	Average 5 Likert score

Table 4.2: User Experience Evaluation Plan

4.1.3 Health Research Study

In the Health Research study, Parkinson's disease patients and their caregivers perform the tests within a health study to assess the consequences to these patients and caregivers of using the conversational agent in a 4-month health assessment. This dissertation does not include the health assessment, as it falls outside the dissertation scope, however it is contemplated in the ONParkinson project scope.

People with Parkinson's disease and their caregivers are invited to participate in the health study to assess the effectiveness of the ONParkinson mHealth app. They have to give their consent to participate in the study, after to be informed about the details of this study and its objectives.

The participants are split into two groups: one group using the ONParkinson mHealth app (ONParkinson group) and the other not using the app (non-ONParkinson group). The ONParkinson group have to follow an established protocol of using the ONParkinson mHealth app, including the conversational agent capabilities, the exercise modules and the medication management capabilities. The non-ONParkinson group follows the usual routine of Parkinson's disease management, regular medication management, physiotherapy exercises in a clinical environment and one gateway of feedback via conversations with their physiotherapist. Both groups have the same evaluating phases:

The non-ONParkinson group follows the usual routine of Parkinson's disease management, regular medication management, physiotherapy exercises in a clinical environment and one gateway of feedback via conversations with their physiotherapist. Both groups go through the same evaluating phases:

- T0 - Before the beginning
- T1 - Immediately after the beginning
- T2 - One month after the end of the treatment
- T3 - Four months after the end of the treatment

The examiner's team evaluates both teams without knowing to which group each participant belongs, assuring the neutrality of the evaluation of both groups.

4.2 Results Analysis

In this section, the dissertation aims to show and analyse the resulting output of the validation plan.

4.2.1 Technical Performance Results

The therapists assessed the conversational agent's domain coverage, coherence and ability to respond, and dialogue management capacity by using a therapeutic exercise program with a total of 6 exercises and logging in the obtained results from the conversational agent.

After the results collection, the accuracy was calculated for each metric and characteristic, as seen in the following tables 4.3 and 4.4. The overall accuracy was measured, resulting in low accuracy in the technical performance.

Metrics	**Obtained Nº**	**Expected Nº**	**Accuracy**
Exercise names	6	6	100%
Exercise stages	6	6	100%
Repetitions	6	6	100%
Sets	6	6	100%
Exercise descriptions	6	6	100%
Motivation asserts	0	22	0%
Coherent responses	0	50	0%
Conversations chained	0	50	0%
Well-being fallback	0	50	0%
Non-understandable inputs detected	0	50	0%

Table 4.3: 1^{st} Technical Performance Metrics Results

Characteristic	**Accuracy**
Domain Coverage	57.69%
Coherence Response Capacity	0%
Dialog Management Capacity	0%

Table 4.4: 1^{st} Technical Performance Characteristics Results

The goal of having at least 85% accuracy for each characteristic was not met. In order to move on to the next stage, there was a need to do a technical adjustment cycle and another batch of validations. The cause of this failures was the lost of the dialogue context when the conversational agent did not recognise the input, and the "Non-understandable inputs detected" failed because of fuzzy matching on the natural language processing. To solve this issues, more synonyms and more variations of the same questions were added to the conversational agent knowledge base.

After the results collection, the accuracy was again calculated for each metric and characteristic, as can be seen in the following tables 4.5 and 4.6. The overall accuracy was measured, meeting the accuracy prerequisite to move to the next stage.

In this second iteration, the overall number of tests was increased because it was possible to gather more physiotherapists to test the conversational agent.

Metrics	**Obtained Nº**	**Expected Nº**	**Accuracy**
Exercise names	24	24	100%
Exercise stages	24	24	100%
Repetitions	24	24	100%
Sets	24	24	100%
Exercise descriptions	24	24	100%
Motivation asserts	72	72	100%
Coherent responses	122	122	100%
Conversations chained	124	124	100%
Well-being fallback	108	108	100%
Non-understandable inputs detected	77	116	66%

Table 4.5: 2^{nd} Technical Performance Metrics Results

Characteristic	**Accuracy**
Domain Coverage	100%
Coherence Response Capacity	100%
Dialog Management Capacity	89%

Table 4.6: 2^{nd} Technical Performance Characteristics Results

4.2.2 User Experience Results

The first stage of the validation plan was conducted in a one-day controlled environment, following a previously defined screenplay, having the goal of finding significant problems. At the time, 8 patients used the Pandora conversational agent and provided feedback by filling out a user satisfaction questionnaire.

To preserve the patients anonymity, they will be referred them as Patient A, Patient B, Patient C, Patient D, Patient E, Patient F, Patient G and Patient H.

Patient A is a 75-year-old retired administrative. It was diagnosed with Parkinson's disease 9 years ago and is now on stage 3 according to the Hoehn and Yahr scale. Patient A has an 11-year level of schooling and does physiotherapy exercises twice a week. Apart from the exercises, Patient A owns an Android smartphone and a computer and is comfortable using them to access the internet.

Patient B is a 71-year-old retired mechanic. It was diagnosed with Parkinson's disease 17 years ago and is now in stage 2 according to the Hoehn and Yahr scale. Patient B has a 5-year level of schooling and does physiotherapy exercises thrice a week. Apart from the exercises, Patient B owns only a cellphone to call and text.

Patient C is an 82-year-old retired agricultural researcher. It was diagnosed with Parkinson's Disease 4 years ago and is now in stage 2 according to the Hoehn and Yahr scale. Patient C went to university at a younger age and now does physiotherapy exercises twice a week. Outside the physiotherapy programs, Patient C performs the physical activity with a static bicycle and rowing once a week, which started 4 years ago. Apart from the exercises, Patient C owns an Android smartphone and is comfortable using them to take photographs and record videos.

Patient D is a 49-year-old retired tax technician. It was diagnosed with Parkinson's disease 16 years ago and is now in stage 2 according to the Hoehn and Yahr scale. Patient D has a 12-year level of schooling and doesnt́ perform physiotherapy exercises. Outside the physiotherapy environment, Patient D plays handball, football, and ping-pong and swims thrice a week, which started 1 year ago. Patient D also owns an Android smartphone and a computer and is comfortable using them to access the internet, take photos, record videos, play video games and access social networks.

Patient E is a 68-year-old retired hairdresser. It was diagnosed with Parkinson's disease 12 years ago and is now in stage 3 according to the Hoehn and Yahr scale. Patient E has a 9-year level of schooling and does physiotherapy exercises thrice a week. Outside the physiotherapy environment, Patient E does physical activity by walking once a week, which started 12 years ago. Apart from the exercises, Patient E owns an Android smartphone and a computer and is comfortable using them to access the internet, take photos and record videos.

Patient F is a 59-year-old retired medical information and sales officer. It was diagnosed with Parkinson's disease 21 years ago and is now in stage 2 according to the Hoehn and Yahr scale. Patient F has a 10-year level of schooling and does physiotherapy exercises thrice a week. Outside the physiotherapy environment, Patient F does physical activity by fishing, playing ping pong and riding a bike 5 times a week, which started 3 years ago. Apart from the exercises, Patient F owns an Android smartphone, a tablet and a computer and is comfortable using them to access the internet, take photos, record videos, send texts and calling people. Patient F also pointed out that there is a significant struggle using a smartphone because of the touching capabilities of the device, turning out to be imprecise for a person with Parkinson's disease.

Patient G is a 74-year-old retired person. It was diagnosed with Parkinson's disease 5 years ago and is now in stage 1 according to the Hoehn and Yahr scale. Patient G has a 11-year level of schooling and does physiotherapy exercises thrice a week. Outside the physiotherapy environment, Patient G does physical activity by walking twice a week, which started 6 months ago. Apart from the exercises, Patient G owns an iOS smartphone and is comfortable using them to access the internet, take photos and record videos.

Patient H is a 63-year-old teacher. It was diagnosed with Parkinson's disease this year and is in stage 1 according to the Hoehn and Yahr scale. Patient H has a PhD level of schooling and does physiotherapy exercises twice a week. Outside the physiotherapy environment, Patient H does not perform physical activity. Apart from the physiotherapy, Patient H owns a computer and an iOS smartphone and is comfortable using them to access the internet, text and doing phone calls.

The average 5-Likert and overall score were measured for each metric, as can be seen in table 4.7.

Metrics	**Patients Score**							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Speech Recognition Satisfaction	4	4	4	5	4	5	5	3
Speech Generation Satisfaction	5	4	4	5	5	5	4	3
Message Buttons Satisfaction	5	4	4	5	5	4	3	5
Aesthetics	5	5	5	5	5	5	5	5
Information Quality	5	4	4	5	5	4	1	5
Subjective Quality	5	4	4	5	5	5	4	4
Ease of Use	5	4	5	5	5	5	5	4
Perception of usefulness	5	5	4	4	4	5	5	4
Interaction Satisfaction	5	4	4	5	5	5	5	5
Satisfaction with the answers given	5	4	4	5	5	5	5	5
Overall	**4.9**	**4.2**	**4.2**	**4.9**	**4.8**	**4.8**	**4.2**	**4.2**

Table 4.7: User Experience Questionnaires Results

A minimum of thirty observations are needed to conduct significant statistics [Van Belle, 2011]. Because only eight patients have tested the conversational agent, then the metrics are measured patient by patient. With this, the aim is to measure data quantitatively and qualitatively.

According to the World Health Organization [Organization, 2016], to effectively conclude the system's usability, a range between ten to one hundred system users need to test the system. Therefore, it is not possible to effectively conclude Pandora's conversational agent's usability because only eight system users tested it.

Overall, the patients place a high score in the conversational agent system, with a range from 4.2 to 4.9. Given the advanced age of most of the patients and their low level of schooling, lower scores on some of the metrics were expected, namely ease of use, perception of usefulness and interaction satisfaction. Although the advanced age and low level of schooling could negatively affect technology acceptance, the fact that most of them own a smartphone and are comfortable accessing the internet can be a factor that positively affects technology acceptance, therefore, positively affecting ease of use, perception of usefulness and interaction satisfaction.

According to [Chen and Chan, 2011], older adults do not show great interest in adopting new technology as opposed younger adults. The older adult's perceived usefulness and perceived ease of use toward a new technology are key for its adoption, as they value the technology that can make their daily life easier while providing added safety and security. Because older adults are retired, many enhancing job performance technologies are not suitable for them, thus making the perceived usefulness go down. Also, older adults have lower self-efficacy and higher technology anxiety, according to [Chen and Chan, 2011]. They have more difficulty learning and use widely used technologies, like smartphones and the Internet. For older adults to be more likely to accept technologies, the technology needs to have a simple interface design and be easy to learn and use.

Chapter 5

Conclusions and Future Work

This chapter wraps up the research work, presenting conclusions regarding the system implementation and how it performed according to the evaluation results. Moreover, this chapter gives insight on limitations and future work for the research.

5.1 Accomplishments

Several iterations of the development cycle were carried out, proving to be essential for the continuous improvement of the solution. The implemented technological solution can tackle the identified needs without compromising the user's lifestyle and helping her/him throughout the exercise programs.

The conversational agent's architecture has the Book of Physiotherapy Terms, the Book of Commands and the Motivation Recogniser, while the dialogue is built inside Google's Dialogflow, making the architecture scalable and enabling the further expansion, giving room for improvements and new features while having more information available.

Given the advanced age of most of the patients and their low level of schooling, the high scores of ease of use, perception of usefulness and interaction satisfaction indicate a great technology acceptance. It is possible to conclude that the simple interface design that is easy to learn and use and that this technology can make their daily life easier and is a complement to the physiotherapy sessions greatly impacted the technology acceptance by the patients.

Using the set of rules defined in the user interface design and the set of key factors to empower motivation in Parkinson's disease patients influences the conversational agent on having a simple and intuitive interface design, which leads to a great positive impact on the technology acceptance by the Parkinson's disease patients.

5.2 Limitations

The problem that this solution aims to solve is a very complex one. Given the complexity and extensiveness of the proposed solution and being a time-limited work, it is understandable that some limitations would appear. Those limitations are not here to stay, but there are plans to overcome them in the future.

Motivation is one of the core aspects of keeping and maintaining patients engaged in therapeutic exercise programs. There is a need for more information about the patient's behaviour and objective data regarding the patient's motivation status. Also, because there was not time to do the second stage of the user experience phase and the health research phase of the validation plan, there are no confirming results of the solution's effectiveness in solving the current needs.

To conduct significant statistics and to effectively conclude the system's usability, a minimum of thirty observations and a range of ten to one hundred system users are needed to test the system. There is a need to do more tests and continue with the research cycle because only eight patients tested the conversational agent.

5.3 Future Work

Given the current limitations, future work must be done to continue along the path to achieving a more solid system that solves the current needs.

Integrating the use of sensors into the mix for extracting the patient's behaviour throughout the exercise programs will provide data to make Pandora adjust its asserts and speech. Additionally, that data can help Pandora in detecting the patient's motivation status to adjust its motivational endeavours toward the patient.

Introducing Pandora into a gamification design approach would result in a more engaging system in which the patient would be much more inclined to continue doing the exercise programs frequently.

The development of a system to assert the motivational state of the patient with the use of heuristics would greatly improve the effectiveness of the motivational endeavours on keeping the patients committed to continuing to exercise themselves to halt the Parkinson's disease evolution, which demonstrated to be one of the great challenges of this research.

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Appendix A: Planeamento de Testes - App Mobile – ChatBot

Planeamento de testes- App Mobile – ChatBot

Performance Técnica - Protocolo

Pré-requisito:

1. Entrar em Exercícios
2. Entrar em Programas
3. Escolher o Programa de exercícios de Força

Protocolo:

1. Clicar no botão de som na introdução do programa
    a. Passar para o próximo ecrã
2. Clicar no botão de som
    a. Selecionar a perceção de esforço e passar para o próximo ecrã
3. Clicar no botão de som
    a. Aguardar a leitura dos sinais vitais e passar para o próximo ecrã
4. Clicar no botão de som na introdução do exercício
5. Clicar no botão de parar som na introdução do exercício
    a. Passar para o próximo ecrã
6. A cada exercício
    a. Abrir o agente de conversação
    b. Pedir ajuda sobre o exercício (fazer outra duvida e repetir o passo a. e b. até fazer todas as perguntas)
        i. Quantas vezes repito o exercício?
        ii. Quantas séries?
        iii. Quais as instruções?
        iv. Qual a fase?
    c. Continuar exercício
7. Num exercício à escolha
    a. Abrir o agente de conversação
    b. Efetuar uma das seguintes:
        i. Saltar exercício
        ii. Continuar programa
8. Num exercício à escolha
    a. Abrir o agente de conversação
    b. Informar que não se sente bem
    c. Escolher a paragem do programa

Appendix B: Folha de Registo - Performance Técnica

Métricas - Programa de Treino de Força	Nº Obtido	Nº Total	Avg
Nº de nomes de exercícios corretamente identificados			#DIV/0!
Nº de fases do programa corretamente identificados			#DIV/0!
Nº de repetições corretamente identificados			#DIV/0!
Nº de séries corretamente identificadas			#DIV/0!
Nº de instruções de exercícios corretamente identificados			#DIV/0!
Nº de casos de motivação corretamente identificados			#DIV/0!
Nº de respostas coerentes			#DIV/0!
Nº de conversas encadeadas corretamente			#DIV/0!
Nº de casos de falha do bem-estar corretamente recuperadas			#DIV/0!
Nº de inputs não conhecidos devidamente detetados			#DIV/0!
Métrica geral	0	0	#DIV/0!

Preencher de acordo com o programa de Treino de Força (6 exercícios)
Preencher o NºObtido e o NºTotal

N° casos de motivação: notificações no início, fim do programa 1 minuto após entrar na app
- Preencher através das tabelas à direita, somando no final
- Para este preenchimento, aceder às **definições** e a cada uma das variáveis individualmente
  - **Paciente tem sido ativo**. Sim | Não
  - **Motivação anterior**: Unmotivated | Normal | Motivated
  - **Motivação atual**: Unmotivated | Normal | Motivated

N° de respostas coerentes: se a resposta foi acertada tendo em conta o contexto no momento.

N° de conversas encadeadas: pergunta-resposta-pergunta-resposta no mesmo seguimento sem quebras

N° de casos de falha do bem estar: identifica corretamente "Não me sinto bem"

N° de inputs não conhecidos: número de perguntas não reconhecidas sobre assuntos não relacionados

Início do Programa

Motivação anterior	Nº Obtido	Nº Total
Unmotivated		
Normal		
Motivated		
Total	0	0

Final do Programa

Motivação atual	Nº Obtido	Nº Total
Unmotivated		
Normal		
Motivated		
Total	0	0

Appendix C: Planeamento dos testes - Handguide

PREPARAÇÃO PARA OS TESTES

Pessoal Necessário: **1-2** (sem contar com o/a utente). **É necessário conhecimento e familiarização prévia** com a Aplicação Móvel + Agente de Conversação, de modo a entender o funcionamento e propósito de ambas as partes.

Condutor/a do Teste – Tem de haver pelo menos uma pessoa para conduzir os testes. Terá também de realizar o trabalho de Observador/a, caso não haja uma segunda pessoa disponível. É importante que o/a Condutor/a do Teste tenha conhecimento sobre e seja capaz de lidar com Pessoas com Parkinson (utente).

Observador/a - Se possível, haverá mais uma outra pessoa para servir de observador/a e auxiliar quem conduzir os testes. Este/a observador/a deverá também ir preenchendo ao longo do teste um questionário, próprio para si, com as suas observações.

Material Necessário:

- **Um smartphone** com a Aplicação Móvel + Agente de Conversação instalada;
  - Usar um tamanho de fonte entre ***Large*** – ***Extra Large***
- **Pelo menos um portátil (ou outro dispositivo)** para poder preencher os questionários online.

Tempo Estimado para a Realização do Teste:

- Utente sem caracterização prévia ≈ 40 minutos
- Utente com caracterização prévia ≈ 30 minutos

Texto Introdutório à Aplicação Móvel + Agente de Conversação:

O projeto ONParkinson surgiu de uma parceria entre a Escola Superior de Saúde e Escola Superior de Tecnologia do Instituto Politécnico de Setúbal, e visa desenvolver projetos sem fins lucrativos focados na terapia da Doença de Parkinson.

Este projeto visa aproveitar o crescimento e vantagens das Tecnologias da Informação e Comunicação, e aplicá-las na área da saúde em benefício de todos.

Para tal, o foco é proporcionar a tríade “Paciente - Cuidador - Profissional de Saúde” com ferramentas que a apoie na gestão da Doença de Parkinson de uma forma mais eficaz

Esta Aplicação Móvel + Agente de Conversação é uma parte deste projeto e tem como objetivo ser uma ferramenta acessível para Pessoas com Parkinson e os seus Cuidadores e que potencie a prática do exercício físico à distância.

ANTES DE MOSTRAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO AO UTENTE

1. Preencher e submeter o questionário "**Caracterização Socio-demográfica – Utente"**, caso não tenha sido previamente feita a caracterização do/a utente. Anotar o número do utente para uso nos restantes questionários.

2. Aceder ao "**Questionário do Observador**" e ir preenchendo conforme a situação.

3. Aceder ao "**Questionário Aplicação Móvel + Agente de Conversação**".

    a. Preencher **até chegar** à "2ª Ronda de perguntas", **exclusive**.

MOSTRAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO AO UTENTE

1. Introduzir a Aplicação Móvel + Agente de Conversação.

2. O utente tem capacidade para interagir com a Aplicação Móvel + Agente de Conversação?

    a. Se Sim:

        i. O/A Condutor/a do Teste deverá **disponibilizar o smartphone** ao utente para este/a poder interagir com a Aplicação Móvel + Agente de Conversação.

        ii. O/A Condutor/a do Teste deverá guiar o/a utente numa simulação **SIMPLIFICADA DO PROTOCOLO DE TESTES** descrito mais abaixo, de modo que o/a utente tenha um contacto introdutório com a Aplicação Móvel + Agente de Conversação.

        iii. O/A Condutor/a do Teste deverá explicar ao utente como funciona a interação com a Aplicação Móvel + Agente de Conversação.

    b. Se Não:

        i. O/A Condutor/a do Teste deverá **ele/a próprio/a** realizar uma simulação **SIMPLIFICADA DO PROTOCOLO DE TESTES** descrito mais abaixo, de modo que o/a utente tenha um contacto introdutório com a Aplicação Móvel + Agente de Conversação.

        ii. O/A Condutor/a do Teste deverá explicar ao utente como funciona a interação com a Aplicação Móvel + Agente de Conversação.

<u>DEPOIS DE MOSTRAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO AO UTENTE</u>

1. No "**Questionário Aplicação Móvel + Agente de Conversação**".
    a. Preencher **até chegar** à "3ª Ronda de perguntas", **exclusive**.

<u>TESTAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO COM O UTENTE</u>

1. O utente tem capacidade para interagir com a Aplicação Móvel + Agente de Conversação?
    a. Se Sim:
        i. O/A Condutor/a do Teste deverá **disponibilizar o smartphone** ao utente para este/a realizar o **PROTOCOLO DE TESTES**.
        ii. O/A Condutor/a do Teste deverá guiar o/a utente durante a realização do **PROTOCOLO DE TESTES** descrito abaixo, passo a passo.
    b. Se Não:
        i. O/A Condutor/a do Teste deverá **disponibilizar o smartphone** ao utente para este/a realizar uma versão **SIMPLIFICADA DO PROTOCOLO DE TESTES**.
        ii. O/A Condutor/a do Teste deverá guiar o/a utente durante a realização **SIMPLIFICADA** do **PROTOCOLO DE TESTES** descrito abaixo, passo a passo.

<u>DEPOIS DO UTENTE TESTAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO / FINAL</u>

1. Terminar de preencher o "**Questionário do Observador**" e submeter.
2. Terminar de preencher o "**Questionário Aplicação Móvel + Agente de Conversação**" e submeter.
    a. Ter a atenção de mostrar os ecrãs alternativos e responder às questões relacionadas antes de submeter.
        i. Definições > Ligar o *Debug Mode* e **gravar** > Clicar no *botão Debug Mode Menu* > Leitura de Sinais Vitais – Alt [1..3]

PROTOCOLO DE TESTES

Pré-requisitos:

1. Abrir a aplicação móvel "**ON-Parkinson**"
2. Entrar em Exercícios
3. Entrar em Programas
4. Escolher o programa de exercícios "**Força**"

Protocolo:

1. Clicar no botão de som na introdução do programa
   a. Passar para o próximo ecrã
2. Clicar no botão de som na perceção de esforço
   a. Selecionar a perceção de esforço e passar para o próximo ecrã
3. Clicar no botão de som nos sinais vitais
   a. Aguardar a leitura dos sinais vitais e passar para o próximo ecrã
4. Clicar no botão de som na introdução do exercício
5. Clicar no botão de parar som na introdução do exercício
   a. Passar para o próximo ecrã
6. No primeiro exercício (ecrã com o vídeo):
   a. Interagir com a "individualização e ajuste da prescrição de exercício" (+ e -)
   b. Carregar no botão de ajuda (símbolo de ?)
   c. Tocar "Preciso de ajuda sobre o exercício"
   d. Carregar no botão do microfone
   e. Falar "Quantas vezes repito o exercício?" e enviar
   f. Tocar na opção "Outra duvida"
   g. Tocar "Preciso de ajuda sobre o exercício"
   h. Escrever "Quantas séries?" e enviar
   i. Tocar na opção "Outra duvida"
   j. Tocar "Preciso de ajuda sobre o exercício"
   k. Carregar no botão do microfone
   l. Falar "Qual a fase?" e enviar
   m. Escrever "Continuar exercício" e enviar
7. No seguinte exercício (ecrã com o vídeo):
   a. Carregar no botão de ajuda (símbolo de ?)
   b. Tocar na opção "Preciso de ajuda sobre o exercício"
   c. Tocar na opção "Quais as instruções?"

d. Tocar na opção “Outra dúvida”
e. Tocar na opção “Saltar exercício”

8. Prosseguir normalmente
9. No segundo exercício da fase de treino:
    a. Carregar no botão de ajuda (símbolo de ?)
    b. Tocar na opção “Não me sinto bem”
    c. Escrever “Sim” e enviar
    d. Tocar na opção “SIM”
10. TERMINA O PROGRAMA

PROTOCOLO DE TESTES SIMPLIFICADO

Pré-requisitos:

1. Abrir a aplicação móvel "**ON-Parkinson**"
2. Entrar em Exercícios
3. Entrar em Programas
4. Escolher o programa de exercícios "**Força**"

Protocolo:

1. Clicar no botão de som na introdução do programa
    a. Passar para o próximo ecrã
2. Clicar no botão de som na perceção de esforço
    a. Selecionar a perceção de esforço e passar para o próximo ecrã
3. Clicar no botão de som nos sinais vitais
    a. Aguardar a leitura dos sinais vitais e passar para o próximo ecrã
4. Clicar no botão de som na introdução do exercício
    a. Passar para o próximo ecrã, mesmo se estiver a falar
5. No primeiro exercício (ecrã com o vídeo):
    a. Interagir com a "individualização e ajuste da prescrição de exercício" (+ e -)
    b. Carregar no botão de ajuda (símbolo de ?)
    c. Tocar "Preciso de ajuda sobre o exercício"
    d. Carregar no botão do microfone
    e. Falar "Quantas vezes repito o exercício?" e enviar
    f. Escrever "Continuar exercício" e enviar
6. No próximo exercício (ecrã com o vídeo):
    a. Carregar no botão de ajuda (símbolo de ?)
    b. Tocar na opção "Não me sinto bem"
    c. Escrever "Sim" e enviar
    d. Tocar na opção "SIM"
7. TERMINA O PROGRAMA

ANEXO 1 – ESCALA

Qual o seu grau de concordância com cada uma das questões:

1	2	3	4	5
Discordo Totalmente	Discordo	Indiferente / Não Sei	Concordo	Concordo Totalmente

Appendix D: Caracterização Socio-demográfica - Utente

Identificação

*Obrigatório

1. Nome da Instituição

____

2. Número do Participante

____

1. Dados Pessoais

3. Nome *

____

4. Sexo *

Marcar apenas uma oval.

- ( ) Masculino
- ( ) Feminino
- ( ) Não responde

5. Idade *

____

6. Profissão *

____

7. Reformado? *

Marcar apenas uma oval.

- Sim
- Não

8. Estado Civil *

Marcar apenas uma oval.

- Solteiro(a)
- Casado(a)
- Viúvo(a)
- Companheiro(a)

9. Nível de escolaridade *

____

10. Com quem reside? *

Marcar apenas uma oval.

- Esposo(a)
- Sozinho(a)
- Família
- Outro

11. Se reside com alguém que não é familiar , indique qual a relação

____

12. Se reside com um familiar, indique que familiar

____

2. Doença de Parkinson

13. Há quanto tempo foi diagnosticado com DP (em anos)? *

____

14. Qual o estadio H&Y em que se encontra? *

Marcar apenas uma oval.

- ( ) 1
- ( ) 1.5
- ( ) 2
- ( ) 2.5
- ( ) 3
- ( ) 4
- ( ) 5

15. Medicação atual *

____
____
____
____
____

16. Outros problemas de saúde? *

Marcar apenas uma oval.

- ( ) Sim
- ( ) Não

17. Se sim, indique quais

3. Fisioterapia

18. Realiza Fisioterapia atualmente? *

Marcar apenas uma oval.

- Sim
- Não

19. Se sim, quantas vezes por semana?

Marcar apenas uma oval.

- 1
- 2
- 3
- 4
- 5
- 6
- 7

20. Se sim, há quanto tempo?

21. Se sim, pratica exercício terapêutico na Fisioterapia?

Marcar apenas uma oval.

- Sim
- Não

22. Fora da Fisioterapia, em casa ou na rua, pratica atividade física? *

Marcar apenas uma oval.

- Sim
- Não

23. Se sim, qual a frequência semanal (x/semana)?

Marcar apenas uma oval.

- 1
- 2
- 3
- 4
- 5
- 6
- 7

24. Se sim, há quanto tempo?

____

25. Se sim, qual o tipo de atividade física que pratica?

____

4. Tecnologias

26. Possui algum destes tipos de tecnologias?

Marcar tudo o que for aplicável.

- [ ] Telemóvel (não smartphone)
- [ ] Smartphone (touchscreen)
- [ ] Tablet
- [ ] Computador

27. Se posssui smartphone e/ou tablet, qual o sistema operativo?

Marcar apenas uma oval.

- ( ) Android
- ( ) IOS

28. Se posssui smartphone e/ou tablet, tem facilidade em funcionar com o mesmo?

Marcar apenas uma oval.

- ( ) Sim
- ( ) Não

29. Se não tem facilidade em funcionar com o smartphone e/ou tablet, quais as dificuldades?

30. O que mais faz com este tipo de tecnologias?

Marcar tudo o que for aplicável.

- [ ] Entrar em contacto com as pessoas
- [ ] Telefonar
- [ ] Mandar mensagens
- [ ] Tirar fotografias / gravar vídeos
- [ ] Jogar
- [ ] Redes sociais
- [ ] Pesquisar na internet
- [ ] Outra: ______________________

31. Utiliza regularmente a Internet?

Marcar apenas uma oval.

( ) Sim
( ) Não

Appendix E: Questionário Aplicação Móvel + Agente de Conversação

Questionário Aplicação Móvel + Agente de Conversação

*Obrigatório

1. Declaração de Consentimento Informado *

   Aceito contribuir para o desenvolvimento deste projeto. Foi-me explicada a importância e finalidade da minha participação no projeto, tendo compreendido o meu papel como participante. Depois de me ter sido explicado e ter compreendido esta informação, aceito em baixo, compreendendo que tenho o direito, a qualquer momento, de recusar ou interromper a minha participação no projeto. Fui também informado que, caso necessário, poderei contactar um dos membros responsáveis para responder a qualquer dúvida que tenha relativamente à minha participação. Aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, tendo garantias da sua confidencialidade e anonimato, bem como de que serão utilizados unicamente para este fim.

   Marcar apenas uma oval.

   - Aceito
   - Não aceito

1ª Ronda de perguntas

ANTES DE MOSTRAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO AO UTENTE

2. Número do Participante *

   Realizar previamente caracterização o utente, caso não exista

   ____

3. Fora da Fisioterapia, em casa ou na rua, pratica atividade física? *

   Marcar apenas uma oval.

   - Sim *Avançar para a pergunta 4*
   - Não *Avançar para a pergunta 7*

SIM - Fora da Fisioterapia, em casa ou na rua, pratica atividade física?

4. Por iniciativa própria ou prescrito pelo profissional de saúde? *

Marcar apenas uma oval.

- Iniciativa própria
- Prescrito pelo profissional de saúde

5. Como sabe quais os exercícios que deverá fazer? E como os deverá fazer? *

6. Há alguma parte frustrante relativamente à prática de exercício físico fora das sessões de fisioterapia? *

Avançar para a pergunta 9

NÃO - Fora da Fisioterapia, em casa ou na rua, pratica atividade física?

7. Há alguma coisa que o/a iniba de praticar exercício físico fora das sessões de fisioterapia? *

8. Acha que seria útil se houvesse uma ferramenta que o/a ajudasse na prática do exercício físico fora das sessões de fisioterapia? *

____
____
____
____
____

Avançar para a pergunta 9

2ª Ronda de perguntas

DEPOIS DE MOSTRAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO AO UTENTE

9. Já utilizou alguma aplicação similar? *

____
____
____
____
____

10. Qual é a sua (primeira) impressão sobre esta aplicação? *

____
____
____
____
____

3ª Ronda de perguntas

DEPOIS DO UTENTE TESTAR A APLICAÇÃO MÓVEL + AGENTE DE CONVERSAÇÃO / FINAL

Eficácia do sistema (AGENTE DE CONVERSAÇÃO)

11. Fui capaz de pedir ajuda ao Agente de Conversação. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente						Concordo plenamente

12. O Agente de Conversação reconhece perfeitamente a minha voz. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente						Concordo plenamente

13. Entendo perfeitamente a voz do Agente de Conversação. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente						Concordo plenamente

14. O Agente de Conversação reconhece o que escrevo. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente						Concordo plenamente

15. Entendo as respostas do Agente de Conversação. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	◯	◯	◯	◯	◯	Concordo plenamente

16. Entendo as minhas opções do que posso perguntar ao Agente de Conversação. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	◯	◯	◯	◯	◯	Concordo plenamente

17. O Agente de Conversação reconhece as perguntas nas quais toquei. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	◯	◯	◯	◯	◯	Concordo plenamente

18. O Agente de Conversação esclareceu as minhas dúvidas relativamente ao exercício. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	◯	◯	◯	◯	◯	Concordo plenamente

19. O Agente de Conversação ajudou-me a entender em que fase do programa de exercícios me encontro. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	⬭	⬭	⬭	⬭	⬭	Concordo plenamente

20. Fui capaz de continuar o programa de exercícios depois de falar com o Agente de Conversação. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	⬭	⬭	⬭	⬭	⬭	Concordo plenamente

21. O Agente de Conversação ajudou-me a saltar para o próximo exercício quando lhe pedi. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	⬭	⬭	⬭	⬭	⬭	Concordo plenamente

22. O Agente de Conversação entendeu perfeitamente quando lhe disse que não me sentia bem, aconselhando-me de imediato. *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo plenamente	⬭	⬭	⬭	⬭	⬭	Concordo plenamente

23. Sugestão de melhoria ou comentários que gostaria de fazer

Feedback Final

SE NECESSÁRIO VOLTAR A MOSTRAR A APLICAÇÃO AO UTENTE. PARA RELEMBAR ECRÃS, ETC...

24. Há alguma interação com a aplicação que seja frustrante de utilizar? *

25. Acha a informação existente na aplicação legível e compreensível? *

26. Existe algum ecrã com demasiada informação? *

27. Sente que a aplicação está adaptada para si (Pessoa com Parkinson)? Porquê ou porque não? *

28. Se pudesse mudar uma coisa sobre a aplicação de modo a melhorá-la, o que seria? *

29. Há algo que gostaria de ver acrescentado à aplicação no futuro? *

30. Acha que gostaria de utilizar esta aplicação com frequência? *

31. Acha a aplicação fácil de utilizar. *

Ecrãs Alternativos

Mostrar os ecrãs alternativos

Definições > Ligar o Debug Mode e gravar > Clicar no botão Debug Mode Menu > Leitura de Sinais Vitais – Alt [1..3]

Alt 1 - seria o ideal, com dados recolhidos automaticamente via sensores
Alt 2, 3 - as alternativas nas quais os utentes têm de manualmente inserir os valores

32. Qual o melhor modo alternativo de inserir a informação? *

Marcar apenas uma oval.

- Alt 2
- Alt 3

33. Porquê?

Appendix F: Questionário do Observador

Questionário do Observador

Assinalar a reação percetível do utente

*Obrigatório

1. Número do Participante *

   Realizar previamente caracterização o utente, caso não exista

2. Reação inicial à aplicação *

   Marcar apenas uma oval.

	1	2	3	4	5	
Muito Mau	⬭	⬭	⬭	⬭	⬭	Excelente

3. Observação

4. Entendeu como proceder *

   Marcar apenas uma oval.

	1	2	3	4	5	
Discordo Plenamente	⬭	⬭	⬭	⬭	⬭	Concordo Plenamente

5. Observação

6. Mostrou-se motivado/interessado *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo Plenamente	◯	◯	◯	◯	◯	Concordo Plenamente

7. Observação

8. Os sintomas da doença de Parkinson não dificultaram a interação *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo Plenamente	◯	◯	◯	◯	◯	Concordo Plenamente

9. Observação

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10. Concluiu a tarefa sem problemas *

Marcar apenas uma oval.

	1	2	3	4	5	
Discordo Plenamente	◯	◯	◯	◯	◯	Concordo Plenamente

11. Observação

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12. Reação final *

Marcar apenas uma oval.

	1	2	3	4	5	
Muito Mau	◯	◯	◯	◯	◯	Excelente

13. Observação

14. Observações extra

Appendix G: ParkinsonBot Process Diagram