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A Conversational Agent for Empowering People with Parkinson's Disease in Exercising Through Motivation and Support

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Abstract: Parkinson's disease (PD) is a neurodegenerative disorder characterized by motor and non-motor symptoms. The MoveONParkinson project aims to enhance exercise engagement among people with Parkinson's Disease (PwPD) in the Portuguese context through the ONParkinson digital platform, which provides mobile and web interfaces. While the broader MoveONParkinson project has been previously described from a health-focused perspective, this study specifically focuses on the development and integration of an AI-driven conversational agent (CA) for the Portuguese language, called PANDORA, within the mobile interface of the solution to assist and motivate PwPD in their exercise routines. PANDORA (Parkinson Assistant in Natural Dialogue and Oriented by Rules and Assessments), designed based on Self-Determination Theory (SDT), addresses the psychological needs of autonomy, competence, and relatedness. A preliminary study involving 20 PwPD, 10 caregivers, and 5 healthcare professionals informed the design requirements for PANDORA. The development process involved four main phases: (1) Design of the Chatbot's Motivation Model, (2) Design and implementation of the conversational agent, (3) Technical Performance Evaluation, and (4) User Experience Evaluation. Technical Performance Evaluation, conducted with three physiotherapists, assessed domain coverage, coherence response capacity, and dialog management capacity, achieving 100% accuracy in domain coverage and coherence response capacity and 89% in dialog management capacity. The User Experience Study involved eight PwPD users recruited from Portuguese healthcare units performing predefined tasks, with user satisfaction scores ranging from 4.2 to 4.9 on a five-point Likert scale. The findings indicate that integrating a conversational agent with motivational cues tends to increase patient engagement. However, further studies are required to determine PANDORA's impact on exercise engagement in PwPD.

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1. Introduction and Background

Parkinson's Disease (PD) is a chronic neurodegenerative disorder characterized by the progressive loss of dopaminergic neurons, leading to both motor and non-motor symptoms [1]. Motor symptoms, such as tremors, rigidity, and bradykinesia, significantly impair the mobility and quality of life of those affected, while non-motor symptoms, including cognitive impairment, mood disturbances, and sleep disorders, further complicate disease management. Physical therapy and regular exercise play a crucial role in managing PD by maintaining mobility, improving balance, and enhancing the overall quality of life [1–4]. Adherence to therapy is crucial for the success of any medical treatment. However, despite the proven benefits of physical activity, adherence to exercise regimens among people with Parkinson's disease (PwPD) remains a major challenge [5,6]. Multiple barriers, including physical limitations, lack of motivation, and insufficient ongoing support, contribute to inconsistent engagement in prescribed therapeutic exercises.

Recent advancements in digital health solutions, particularly mobile health (mHealth) platforms, have shown promise in addressing these barriers [7–9]. By providing patients with remote, personalized support, mHealth solutions aim to promote sustained engagement in therapeutic activities beyond the clinical setting.

One such initiative, the MoveONParkinson project, was designed to enhance long-term exercise engagement among PwPD through the comprehensive digital platform ONParkinson, which includes both mobile and web interfaces for a broad, rich, personalized interaction [10]. The mobile interface (the mHealth app) is the primary interface for users (PwPD and their caregivers) to access exercise programs. The web platform provides healthcare professionals (HCPs) with access to clinical records and individual care plans, enabling them to create new exercises and programs, monitor their patients' performance, and provide feedback. By optimizing therapy outside of the clinical context, the platform aims to provide remote support for HCPs as a complement to the mHealth app.

In addition to enhancing and evaluating the interfaces and functionalities of the exercise module, the MoveONParkinson project sought to integrate advanced features into the platform. These enhancements included targeted gamification elements using technologies like Virtual Reality to increase engagement [11], the integration of biometric data-reading devices for more accurate and efficient remote monitoring, and the development of a conversational agent (CA) to support PwPD in maintaining their exercise routines. CAs are software systems designed to simulate human-like conversations, often leveraging artificial intelligence to provide personalized interactions in various domains, including healthcare [12]. These agents are also commonly referred to as chatbots in casual and technical contexts, especially when deployed on mobile or web platforms. For consistency, this paper uses the terms conversational agent and chatbot interchangeably.

The use of CAs in healthcare is rapidly expanding, enabling more natural, human-like interactions. CAs serve roles in diagnostics, education/training, and monitoring/data collection [12–14], while also providing emotional support and motivational coaching, particularly valuable in chronic disease management and mental health [15,16]. Recent studies illustrate their potential in intervention for managing chronic illness: Al-Hilli et al. [17] showed AI chatbots for genetic counseling matched the effectiveness of traditional methods, while Bibault et al. [18] found chatbots rated more favorably than physicians for providing information to breast cancer patients, despite needing improved adverse event communication. Echeazarra et al. [19] demonstrated that TensioBot enhanced knowledge of blood pressure self-monitoring. For chronic pain, Hauser-Ulrich et al.'s [20] selMA chatbot increased positive intentions toward behavior change but did not yield statistically significant improvements in disability outcomes. Hunt et al. [21] demonstrated that Zemedy, a chatbot for irritable bowel syndrome, effectively improved symptoms, quality of life, and psychological outcomes. These findings underscore the versatility and effectiveness of CAs in managing chronic diseases, offering personalized, scalable, and impactful care while highlighting the importance of addressing challenges such as user engagement, ethical considerations, and seamless integration into healthcare systems.

By integrating CAs into mobile apps, patients can receive reminders, motivational messages, and educational content related to their treatment plans in real time. This real-time communication helps patients adhere to their therapy regimens and increases accessibility, particularly for rural or remote areas with limited access to medical professionals [14]. AI-powered CAs offer significant benefits for patient self-management by providing smarter features such as personalized interventions, lifestyle recommendations, and support for treatment engagement [22]. Cloud-based solutions such as IBM watsonx Assistant, Amazon Lex, Google Cloud Dialogflow, and Azure AI Bot facilitate chatbot implementation. However, the selection of chatbot services must consider language capabilities, as natural language processing techniques are employed to interpret requests, and not all services support all languages.

Moreover, motivational models provide a framework for understanding how people are motivated and what drives their behavior [23]. According to López-Jaquero et al. [24], motivation is a key factor because it influences people's ability to use, learn, and make decisions, among other things. Recently, several studies have shown that motivation plays an important role in patient engagement in rehabilitation and is a predictor of functional outcomes. While the role of motivation in driving behavior change is well-established, the application of motivational models and strategies in neurorehabilitation research has only recently begun to be systematically explored and described [25,26]. Neglecting the design of motivational models, including how motivation is employed when designing mHealth systems, can lead to a design that discourages users from using it. By integrating motivational models into the CA design, developers can tailor messages and interactions to the specific needs and preferences of users, increasing their motivation to engage with the agent and move forward with recommended behaviors.

This paper details the design and development of PANDORA (Parkinson Assistant in Natural Dialogue and Oriented by Rules and Assessments), an AI-driven CA integrated into the ONParkinson mobile app, which seeks to motivate and support PwPD in their exercise routines. PANDORA is based on the principles of Self-Determination Theory (SDT) [27], a well-established motivational framework that emphasizes three core psychological needs—autonomy, competence, and relatedness—as essential drivers of sustained behavior change. By addressing these needs, PANDORA aims to empower users to take an active role in managing their health, fostering a sense of control and connection that is often lacking in traditional therapeutic approaches.

This study outlines the development process of PANDORA, including its technical performance evaluation and user experience assessment, and explores its potential to improve exercise adherence in PwPD. The findings presented here aim to contribute to the growing field of AI-driven mHealth applications, particularly those focused on enhancing therapeutic engagement and self-management in chronic conditions like Parkinson's disease.

2. Methods

As introduced above, this research work is embedded in a large research project—the MoveONParkinson project—that follows a participatory design methodology [28,29]. This approach actively involves those impacted by the outcome in the design process, which is particularly important when designing for special groups, as noted by Heijsters et al. [30]. By adopting a participatory mindset, designers can shift their focus from their own experience and expertise to the needs of those with special needs or limitations, as highlighted by Albouys-Perrois et al. [31]. To ensure the success of the design process, a multidisciplinary research team was established in collaboration with the Portuguese Association for PwPD (APDPk) and Saudis (a clinic for rehabilitation). This participatory approach ensured that the final product meets the specific needs and requirements of the users, resulting in a more effective and impactful solution.

Regarding the integration of a CA to assist PwPD in completing exercises, an initial study was conducted as part of the MoveONParkinson research project. This study explored the barriers and motivators to home exercise in the Portuguese context, identifying factors that influence individuals' willingness or reluctance to exercise at home [32]. Feedback was gathered from participants through recorded semi-structured interviews and questionnaires. A literature review was conducted on the integration of CAs for elderly individuals and PwPD in order to identify best design practices. The decision to extend the search to elderly individuals was due to the limited research specifically focused on the design of CAs for PwPD, as well as the existence of shared characteristics between these two groups of users.

The feedback gathered from PwPD, caregivers, and health professionals during the interviews, along with insights from the literature review, served as a foundation to identify the needs and requirements of users. The works of Stara et al. [33] and Rampioni et al. [34] served as key references in designing the CA interactions, identifying potential concerns specific to interactions with PwPD that need to be addressed for successful implementation.

The development of PANDORA to support PwPD in exercise comprised four main phases, as illustrated in Figure 1. The first phase, "Design of the Chatbot's Motivation Model", involved developing the theoretical framework that guided the CA's motivational strategies. The second phase, "Design and Implementation of the Chatbot", entailed creating its architecture and integrating it into the platform, incorporating the motivation model designed in the first phase. The third phase, "Technical Performance Evaluation", focused on assessing the CA's functionality, reliability, and technical performance through rigorous testing. Finally, the fourth phase was the "User Experience Evaluation", where user interaction with the CA was assessed regarding ease of use and overall satisfaction, gathering feedback for further improvements.

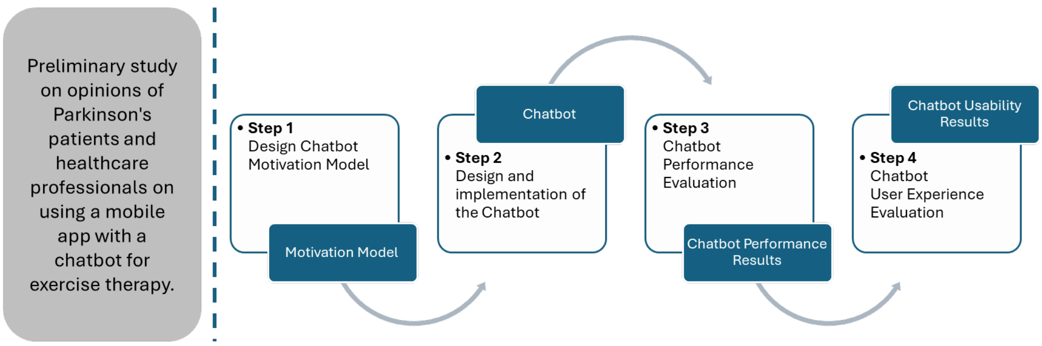

Figure 1. Four-phase research approach underlying the development and evaluation of the PANDORA system.

2.1. Design of the Chatbot's Motivation Model

The findings from the previous study conducted with 12 PwPD (mean age 70.4 years ± 8.65; 7 male) suggest that self-efficacy, autonomy, competence, and support from others are key factors in motivating PwPD to engage in regular physical activity [32]. These factors align closely with the core principles of SDT, a well-known motivational model that has already been used to improve therapy engagement [24,35,36]. SDT emphasizes three essential psychological needs [27]: autonomy, competence, and relatedness, which are critical for fostering long-term behavioral change. It makes it a strong theoretical foundation for developing a CA. Participants emphasized the importance of being involved in decision-making about their exercise routines, including defining exercise goals and selecting modalities that fit their needs and preferences. This viewpoint relates to the autonomy key principle of SDT, highlighting the importance of offering users a sense of control over their exercise choices to enhance intrinsic motivation [27]. Furthermore, the study found that participants with higher self-efficacy engaged in physical activity more regularly and felt more capable of exercising at home, highlighting the importance of fostering competence, which is the confidence in one's ability to successfully achieve desired outcomes [27]. Additionally, social support, including from health professionals, caregivers, and peers, was highlighted by participants as a key motivator, which relies on the relatedness principle of SDT.

Evidence from previous systematic reviews [37–39] and recommendations from clinical guidelines [3] about the importance of implementing behavior-change approaches supported the research team's decision-making. By leveraging SDT in the CA's design, the app can offer personalized goal-setting, social support, autonomy in exercise choices, and feedback mechanisms that enhance users' sense of competence and intrinsic motivation, ultimately promoting sustained exercise engagement.

2.2. Design and Implementation of the Chatbot

This phase comprises the CA development and its integration into the ONParkinson mobile application. During this phase, a suitable technology was selected for implementing the agent, and an overall architecture was designed, including information flow, knowledge base, and motivation system. These components determine message generation based on the user's motivation and exercise execution states. As the agent is intended to support exercise performance, additional web services were required to access user data and exercise programs. For the implementation, Google's services were utilized, including Dialogflow [40], text-to-speech (TTS), and speech-to-text (STT) services. Google's TTS and STT services were chosen for their high accuracy in the Portuguese language, supported by advanced machine learning (ML) models, and their ability to process speech in real time, which is crucial for applications requiring immediate feedback [41].

User feedback from People with Parkinson (PwPD) and Physical Therapists (PTs), collected during the MoveONParkinson platform's development, played a critical role in shaping the mobile application. PwPD recommended including images alongside exercise descriptions to improve clarity and comprehension, especially for users with cognitive impairments. Similarly, PTs emphasized the importance of providing detailed and easily understood exercise descriptions to address potential cognitive challenges faced by PwPD. They also suggested using a relaxed tone of voice for audio descriptions, prioritizing a calm, clear delivery with unhurried pacing to avoid confusion or distress. Additionally, PTs highlighted the need for measurable data to demonstrate progress towards exercise goals, proposing features that track metrics such as daily steps or distance covered to enhance motivation through visual representations of achievement.

Special attention was also given to designing the user interface (UI) to interact with the CA. According to Chen and Chan [42], designing simple, intuitive, and user-friendly interfaces is critical, particularly for older adults, who often experience lower self-efficacy and higher levels of technology anxiety. These principles, combined with the insights from PwPD and PTs, guided the interface design to ensure accessibility and usability for this demographic. For example, integrating visual aids and progress-tracking features into the UI not only supports clarity and engagement but also addresses the specific needs and challenges highlighted by users.

2.3. Technical Performance Evaluation

The technical performance study involved a series of tests to evaluate different dimensions of the CA's performance. These dimensions include domain coverage, coherence response capacity, and dialog management capacity, as outlined in [12,43–45].

Domain Coverage is an aggregated indicator that is used to assess the CA's ability to understand and respond appropriately to user queries or requests across one or more subject areas. In this particular case, the primary subject area being evaluated is exercise programs. A set of queries relating to exercise programs was conducted to determine whether the implemented agent provides accurate responses (see Table 1). The correct responses for each query are counted, and the accuracy metric is calculated accordingly. The Domain Coverage indicator is defined as the average of the obtained accuracy values of each simple measure.

Coherence Response Capacity is an indicator used to assess the ability of a CA to provide responses that are relevant and comprehensible. It evaluates the CA's capacity to engage in logical and meaningful conversations with users by generating consistent, relevant, and coherent responses within the context of the ongoing dialogue. In this context, the tester evaluates the consistency and relevance of the responses generated by the chatbot in response to each query. The Coherence Response Capacity indicator is defined as the accuracy value of the measure of consistent responses.

Dialog Management Capacity assesses the CA's expertise in managing the conversation, including: (1) maintaining the flow of conversation, (2) managing well-being fallback responses, and (3) reacting to non-understandable messages. Maintaining the conversation flow is measured by establishing dialogues (each with at least three interactions) and evaluating whether the conversation chain is maintained. The accuracy rate is calculated according to the number of tested conversations and the number of well-connected conversations. Four conversation scenarios have been established to validate the two other metrics, including (i) a happy scenario with three independent questions, (ii) a scenario with one chaining question, (iii) a scenario with two known questions and one unknown question, and (iv) a scenario with non-understandable questions. The well-being fallback indicator is also expressed as an accuracy measure. It is calculated from the number of situations where the user expresses that they do not feel well, and the agent correctly identifies that situation. Similarly, the accuracy rate of the CA in identifying non-understandable input is also measured. Finally, the Dialog Management Capacity indicator is defined as the average of the accuracy values obtained for each of these three measures.

Domain experts, who are physiotherapists, perform the tests since most of the evaluations require knowledge of the domain. Each physiotherapist records the test results in a spreadsheet for later analysis.

Table 1. Technical Performance Evaluation plan.

Characteristic	Metric (Number 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

2.4. User Experience Evaluation

The user experience evaluation aimed to explore some aspects of the mobile application's usability, which integrated the new CA towards support of PwPD. The study was conducted in a controlled environment, following a well-defined test guide with scripted interactions provided to both the test conductor and the observer. This guide ensured consistency and standardized data collection throughout all sessions.

The evaluation began with an introduction to the mobile application, during which participants were guided on how to use the app and encouraged to explore its features. Participants then entered a structured scripting phase, where the test conductor remained uninvolved, intervening only in cases of confusion or difficulty. After completing the scripted tasks, participants were asked to finish the remaining sections of the feedback survey.

A designated observer closely monitored participants' interactions with the chatbot throughout the testing process, noting both verbal and nonverbal cues. These observations were recorded in a separate survey designed to compare participants' feedback responses with their observable behaviors.

Following the testing phase, participants completed a user satisfaction questionnaire comprising 12 closed-ended questions (statements) rated on a five-point Likert scale. The survey aimed to assess the experience of using the mobile app with the integrated CA, across the following dimensions, following the uMARS questionnaire proposed by Stoyanov et al. [46]: (i) Functionality (performance, ease of use, navigation, and gestural design), (ii) Aesthetics (visual appeal, graphics, and layout), (iii) Information Quality (accuracy, credibility, quantity, and relevance of the information), and (iv) Subjective Quality (motivation for repeated use, overall satisfaction, and likelihood of recommendation). It was decided not to use the full uMARS questionnaire at this study stage, as its length could cause fatigue in PwPD participants, many of whom tire quickly.

Participants were selected according to specific criteria based on the following [7–9]:

- **Inclusion criteria** .
  - People who are at least eighteen years old and have been diagnosed with PD.
  - PwPD who understand the purpose of the study, who can commit to the required tasks and can fill out a consent form.
- **Exclusion criteria**.
  - PwPD with severe vision or hearing impairments.
  - PwPD with other neurological, respiratory, or orthopedic conditions significantly impairing their ability to complete tasks safely.
  - PwPD with severe neuropsychiatric symptoms, such as major depression.
  - PwPD with severe cognitive or physical impairment (Level 5 on the Hoehn and Yahr Scale (H and Y) [47]) interfering with study participation.

- PwPD with clinical instability in the past six months, such as a recent stroke or acute myocardial infarction, or other health conditions of similar severity.
- PwPD with instability in PD medication or deep brain stimulation within the last three months.

Additionally, participants completed a socio-demographic background questionnaire, including physical activity and exercise levels, details on technology use in daily living, and clinical data. PD staging was reported according to the H and Y.

3. Results

This section presents the results of the development of the CA solution, its integration into the ONParkinson application, and its evaluation. The CA system designed to support and motivate PwPD in their exercise routines was named PANDORA.

3.1. PANDORA Motivation Model

As described in Section 2, this model is primarily based on SDT, which asserts that human motivation and behavior are influenced by three fundamental psychological needs: autonomy, competence, and relatedness. Figure 2 represents the PANDORA Motivation Model, illustrating how each need is achieved by the CA.

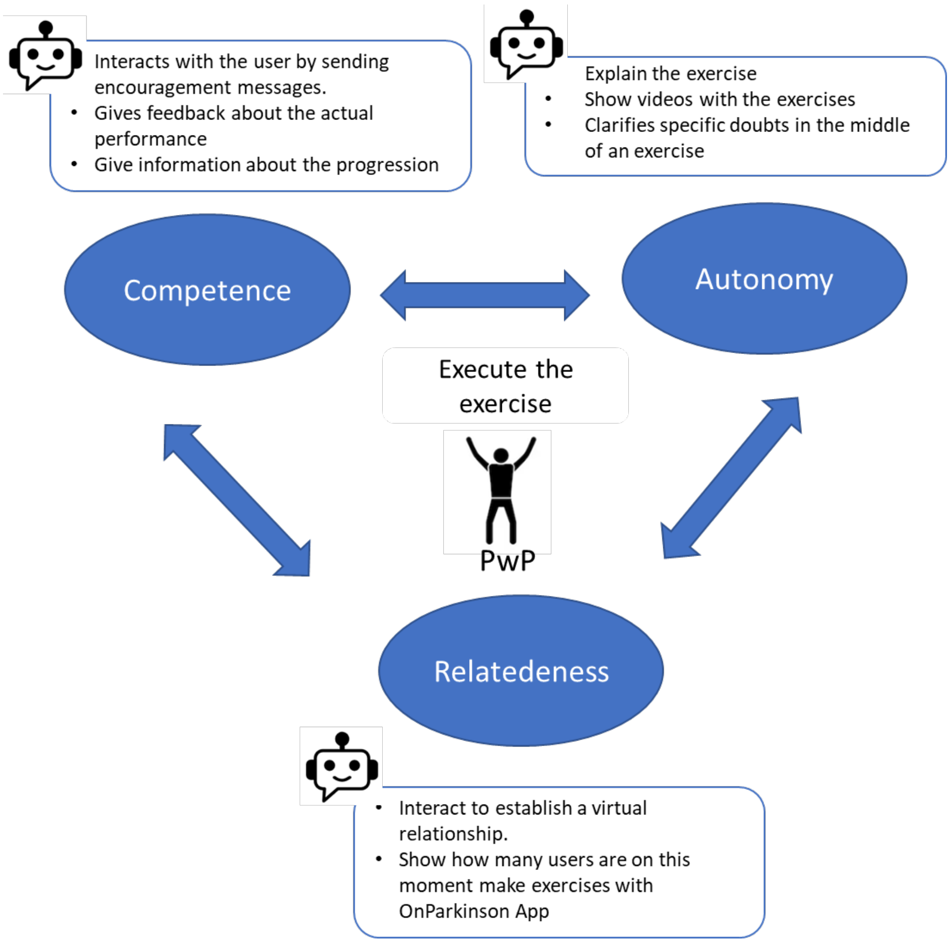

Figure 2. Diagram of the PANDORA Motivation Model aimed at supporting and motivating individuals with Parkinson's disease to maintain regular physical activity.

Autonomy is the psychological need for individuals to feel in control of their own lives and decisions. In order to improve the user's sense of autonomy, PANDORA implements two main aspects: (1) the user is given the initiative to start the conversation with the chatbot to ask for help, and (2) the chatbot explains the exercises in detail, enabling the user to perform them without the assistance of a health professional.

Competence refers to the need for individuals to feel capable of achieving their goals. In this context, this may be addressed by providing positive feedback and encouragement for completed exercises, as well as offering appropriate challenges and progression as users improve.

Relatedness refers to the human need for social connection and a sense of belonging. In this case, this need is addressed by providing social support and encouragement to users, either through direct interactions with the chatbot or by demonstrating that other PwPD are using the ONParkinson platform to engage in exercises. The success of a CA in motivating a user greatly depends on the quality of its verbal interaction, whether written or spoken [48]. The literature review identified several key features to enhance user motivation which are integrated into the proposed motivational model of the CA. These features include:

- Informing users of the goals they need to achieve [49].
- Sending a personalized message daily [49].
- Displaying a graph of results over time [50].
- Using positive emojis in messages to increase the sender's perceived warmth [51].
- Incorporating both male and female genders for a customized agent to increase bonding and acceptance [50].
- Providing empathic responses according to the user's state of mind [49].

3.2. PANDORA Chatbot

In order to implement a CA that complies with the PANDORA Motivation Model presented in Section 3.1, the following key requirements were identified:

1. Allowing users to interact by entering text or using voice commands.
2. Providing responses that users can read or listen to.
3. Guiding PwPD through their exercises.
4. Using the European Portuguese language.
5. Using simple language, with short sentences and common terms.

PANDORA is specified using the set of parameters proposed by Laranjo et al. [12], as summarized in Table 2, to facilitate a more straightforward comparison with other healthcare CAs.

Table 2. PANDORA chatbot specifications.

Parameter	Specification
Type of Technology	Service delivered via an Android mobile application
Dialogue Management	Agent-based
Dialogue Initiative	User leads the conversation
Input Modality	Written and spoken (Portuguese language)
Output Modality	Written and spoken (Portuguese language)
Task-Oriented	No (the system is not directed to the short-term achievement of a specific end-goal)
Health Domain	Neurology (Parkinson's Disease)
Purpose	Support, Education and Motivation
Languages Supported	European Portuguese

Figure 3 illustrates the conceptual architecture of PANDORA. The user interacts with PANDORA using the ONParkinson mHealth app. First, the user's message is transmitted from the ONParkinson mobile app to the ONParkinson server. From there, it is forwarded to the Dialogflow platform, where the Natural Language Processing (NLU) Unit and the Dialogue Manage process the user input.

The Dialogue Manager triggers the generation of a response, which often includes custom tags used to identify specific information required in the text or actions not accessible through Dialogflow. The ONParkinson server receives the response and forwards it to the ONParkinson mobile app.

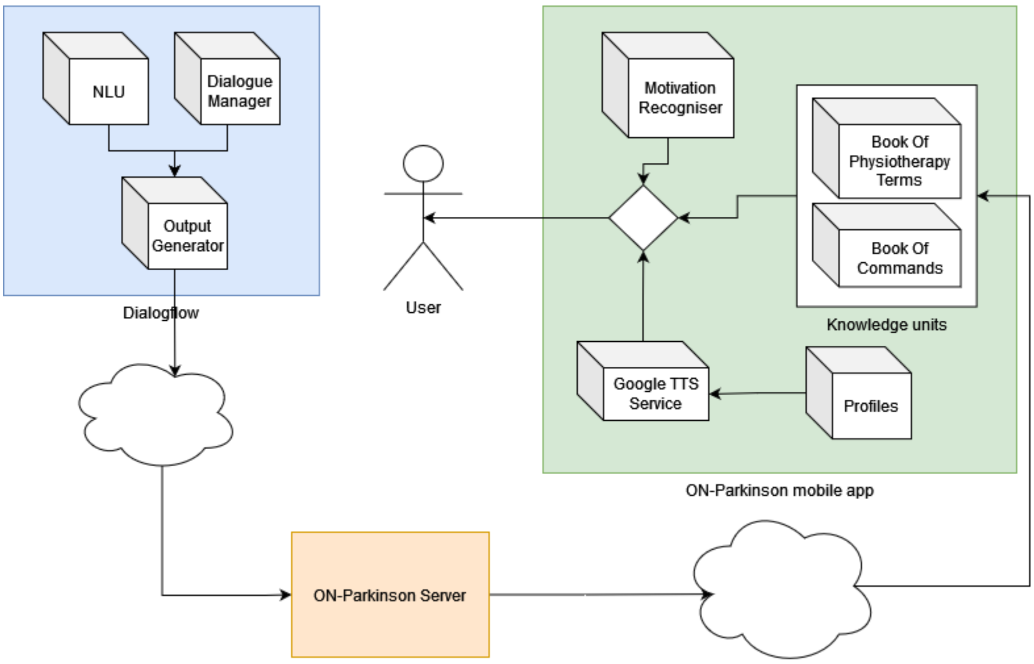

Figure 3. Conceptual architecture of the PANDORA system, depicting its core components and their interactions.

Before reaching the user, the message undergoes treatment and refinement in PANDORA's Knowledge units. These Knowledge units can perform automatic actions based on detected patterns. Upon arrival at the ONParkinson mobile app, the Knowledge units analyze and process the message, providing PANDORA with contextual knowledge such as the user's exercise program or current exercise. The knowledge base is divided into two units: the Book of Physiotherapy Terms and the Book of Commands.

The Book of Physiotherapy Terms is responsible for analyzing the message text of the user to detect customized tags and match them with a conversion dictionary. The conversion dictionary maps the custom tags to attribute names. For example, the tag "<number repetitions>" is mapped to the attribute "numberOfRepetitions". The Book of Physiotherapy Terms replaces the tag with the corresponding attribute value in the message text. On the other hand, the Book of Commands analyzes the user message text to detect custom action tags. Similarly to the book of physiotherapy terms, the book of commands maps action tags to attribute names. However, rather than replacing these tags within the message text, the Book of Commands removes them and generates a set of actions for the application to execute later.

Additionally, PANDORA incorporates four distinct Portuguese language voice profiles obtained through Google Text-to-Speech services, consisting of two male and two female voices.

We illustrate how PANDORA works and aligns with the proposed motivation model through three user interaction examples (see Figure 4a,b as examples of PANDORA integration in the mHealth app):

- **Skipping Exercise**: The PwPD user asks PANDORA chatbot to skip the current exercise and continue with the program. By allowing the user to request to skip a specific exercise, the chatbot empowers the user to make decisions about their exercise routine. This feature respects the user's autonomy, gives them control over their fitness program, and acknowledges that they know the limitations of their bodies and needs.
- **Asking for Help**: During a strength exercise program, the PwPD user can request assistance by clicking the help button. Users can dictate, type their questions, or select predefined options. The PANDORA agent provides guidance and allows the user to continue or ask more questions. The ability to seek assistance from PANDORA's conversational agent during the exercise program enhances the user's competency. PwPD may encounter challenges while exercising, and the ability to ask for help ensures that they can perform the exercises correctly and safely. The agent boosts the user's competence and confidence in performing the exercises effectively by providing helpful information and guidance.
- **Well-being Fallback**: If the user feels unwell during the exercise program, they can inform the PANDORA agent, which expresses its concern and recommends stopping. The user's decision is shared with their physiotherapist, prioritizing well-being and safety while preserving autonomy. This feature emphasizes user autonomy and prioritizes the user's well-being. If the user does not feel well during the exercise program, they can decide to stop and inform the chatbot. PANDORA's concern and recommendation to stop shows that the system values the user's health and safety. However, the final decision to stop or continue is made by the user. The physiotherapist associated with the PwPD user is informed of the event and the decision taken, thus preserving the user's autonomy in managing their well-being while at the same time valuing their health and safety.

These interactions demonstrate how PANDORA contributes to PwPD user autonomy and competence by empowering users to control their exercise routines, providing necessary guidance to enhance competence, and prioritizing user well-being and safety.

(**a**)

Figure 4. *Cont.*

(**b**)

Figure 4. User interfaces of the ONParkinson mobile application, showcasing its integration with the PANDORA chatbot. (**a**) The left screenshot shows the "Programs" (*Programas*) screen with options: "Daily Life Activities" (*Atividades Vida Diária*), "Balance" (*Equilíbrio*), "Strength" (*Força*), and "Aerobic" (*Aeróbio*). The right screenshot shows a "Strength" (*Força*) tutorial for a squat without a chair (*Agachamento sem sentar na cadeira*). Users can adjust repetitions (*Repetições*) and sets (*Séries*), navigate exercises with arrows, or ask the chatbot for help using "?". (**b**) The left screenshot shows the chatbot interaction for requesting exercise assistance, with the chatbot asking, "How can I help?" (*Em que posso ajudar?*). Four options are available: "I need help with the exercise" (*Preciso de ajuda sobre o exercício*), "I don't feel well" (*Não me sinto bem*), "Skip exercise" (*Saltar exercício*), and "Continue program" (*Continuar programa*). The right screenshot shows the chatbot responding to "I don't feel well" (*Não me sinto bem*) by suggesting stopping the exercise program to prevent harm, with options "Yes" (*Sim*) and "No" (*Não*).

3.3. PANDORA's Technical Performance Evaluation

Three physiotherapists (mean age: 34.0 ± 15.7; mean experience years: 6.3 ± 5.1) participated in the performance tests. They followed a script of activities to be performed using the ONParkinson mHealth app, which included performing a therapeutic exercise program with six exercises, interacting with the PANDORA Chatbot, and registering the measures taken in a spreadsheet according to the protocol introduced in Section 2.3. After collecting the results, the accuracy was calculated for each metric and each overall characteristic, as shown in Tables 3 and 4.

Table 3 shows the accuracy results for the metrics that assess the CA's technical performance. For metrics such as exercise names, exercise stages, repetitions, sets, exercise descriptions, motivation asserts, coherent responses, conversations chained, and well-being fallback, the bot achieved a perfect accuracy of 100%. This indicates that PANDORA accurately provided the expected information and responded appropriately in these areas.

However, the metric for detected non-understandable input shows an accuracy of 66%. This means that out of 116 non-understandable inputs, PANDORA correctly recognized and flagged 77, while 39 were not recognized as non-understandable. This metric suggests there is room for improvement in PANDORA's ability to handle ambiguous or unclear user input.

Table 3. Technical Performance: measures.

Metrics	**Obtained (n)**	**Expected (n)**	**Accuracy (%)**
Exercise names correctly identified	24	24	100
Exercise stages correctly identified	24	24	100
Repetitions correctly identified	24	24	100
Sets correctly identified	24	24	100
Exercise descriptions correctly identified	24	24	100
Motivation asserts correctly performed	72	72	100
Coherent responses	122	122	100
Conversations chained correctly	124	124	100
Well-being fallback correctly recovered	108	108	100
Non-understandable inputs correctly detected	77	116	66

Table 4. Technical Performance Indicators: results.

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

Table 4 presents the values obtained for the aggregated indicators, calculated as explained in Section 2.3. Domain Coverage achieved a perfect accuracy of 100%, indicating that PANDORA effectively covered the entire domain of the therapeutic exercise program. Coherence Response Capacity also achieved a perfect accuracy of 100%, indicating that the CA consistently responded coherently throughout the interactions. However, Dialogue Management Capacity shows an accuracy of 89%, indicating there is room for improvement in the CA's ability to effectively manage the flow of the dialog.

3.4. PANDORA's User Experience Evaluation

We recruited eight PwPD from APDPk and the Saúdis clinic. In the first validation stage, we conducted a one-day session in a controlled environment, following a predefined script to identify significant issues. During this session, participants tested the ONParkinson app and provided feedback through a user satisfaction questionnaire. In order to ensure anonymity, we referred to participants as Pn, where n denotes their assigned participant number.

As shown in Table 5, the participants varied in age, sex, profession, years since diagnosis, and engagement in physiotherapy. The mean age of the participants was 67.6 ± 9.7 years, and the mean number of years since diagnosis was 10.6 ± 6.6 years. In addition to their physiotherapy routines, participants reported various other physical activities and levels of comfort with technology. P1 frequently used an Android smartphone and computer to access the Internet, while P2 relied on a basic cell phone, limited to calls and texting.

P3 supplemented physiotherapy with static cycling and rowing once a week and enjoyed using his Android smartphone for taking photos and videos. P4, although not engaged in physiotherapy, stayed physically active through handball, soccer, table tennis, and swimming three times a week. He also used his Android smartphone and computer to browse the Internet and social networks and play games.

P5 added regular walking to her routine and comfortably used her Android smartphone and computer for browsing the Internet and recording media. P6 experienced difficulty with his smartphone's touch sensitivity due to Parkinson's, but continued to use his smartphone, tablet, and computer for various tasks. Outside of physiotherapy, he engaged in fishing, table tennis, and cycling five times a week.

P7 incorporated walking twice a week into his schedule and used his iOS smartphone for browsing the Internet and capturing photos. P8 focused solely on physiotherapy and did not participate in additional physical activities, but used her iOS smartphone and computer for communication and online browsing.

Table 5. Summary of participants' characterization.

P	Age	Sex	Profession	Professional Status	PD Duration	H&Y Stage	Education	Physio. Frequency (Weekly)
P1	75	M	Administrator	Retired	9	3	11 years	2
P2	71	M	Mechanic	Retired	17	2	5 years	3
P3	82	M	Agricultural Researcher	Retired	4	2	University	2
P4	49	M	Tax Technician	Retired	16	2	12 years	None
P5	68	F	Hairdresser	Retired	12	3	9 years	3
P6	59	M	Medical Info Sales Rep	Retired	21	2	10 years	3
P7	74	M	NR	Retired	5	1	11 years	3
P8	63	F	Teacher	Employed	<1	1	Doctorate	2

The results of the five-point Likert items and the corresponding average for each item in the user satisfaction questionnaire are shown in Table 6. The average for each participant across all metrics is also presented in the last row.

A minimum of thirty observations is often required to perform significant statistics [52]. Moreover, according to the World Health Organization [53], between ten and one hundred system users need to test a system to assess its usability effectively. Therefore, evaluating PANDORA's usability effectively is impossible because only eight users have tested it. A larger sample size could better capture variability in user experience, particularly among PwPD at different stages of disease progression, with varying levels of comfort with technology, and with differing physical capabilities. Therefore, the metrics were mostly analyzed participant by participant in order to validate the user experience.

Overall, patients rated the system highly, with scores ranging from 4.2 to 4.9. Given the advanced age of most of the patients and their limited level of schooling, lower scores were expected for some of the metrics, namely ease of use, perception of usefulness, and interaction satisfaction. Although the advanced age and low level of formal education may negatively affect technology acceptance, the fact that most of them own a smartphone and are comfortable accessing the Internet may be a factor that positively affects technology acceptance and therefore positively impacts ease of use, perception of usefulness, and interaction satisfaction.

Despite the small sample size of eight participants, this study presents promising preliminary findings on the effectiveness and usability of the PANDORA conversational agent. The high satisfaction ratings provided by participants suggest that PANDORA successfully addresses core needs for support and guidance in exercise routines for PwPD. These positive results align with previous studies on CAs in healthcare, where tailored support has shown effectiveness in enhancing patient engagement.

Table 6. User Experience Results.

Metrics/Users	P1	P2	P3	P4	P5	P6	P7	P8	Average
Speech Recognition Satisfaction	4	4	4	5	4	5	5	3	4.3
Speech Generation Satisfaction	5	4	4	5	5	5	4	3	4.4
Message Buttons Satisfaction	5	4	4	5	5	4	3	5	4.4
Aesthetics	5	5	5	5	5	5	5	5	5.0
Information Quality	5	4	4	5	5	4	1	5	4.1
Subjective Quality	5	4	4	5	5	5	4	4	4.5
Ease of Use	5	4	5	5	5	5	5	5	4.9
Perception of Usefulness	5	5	4	4	4	5	5	4	4.5
Interaction Satisfaction	5	4	4	5	5	5	5	5	4.8
Satisfaction with Answers Given	5	4	4	5	5	5	5	5	4.8
User Average	**4.9**	**4.2**	**4.2**	**4.9**	**4.8**	**4.8**	**4.2**	**4.4**	**4.6**

Testing within a controlled environment allowed for initial observations of PANDORA's user interface and motivational features. Results indicate the agent's potential as a functional exercise aid and a motivational companion. Even with a limited number of participants, the findings highlight PANDORA's capacity to foster autonomy, competence, and a sense of connection—factors essential for sustained behavior change, especially in chronic conditions like Parkinson's disease.

The study also underscores the agent's potential for further customization. Adding more adjustable features, such as personalized feedback speed and voice recognition sensitivity, could make the app even more accessible, meeting the unique needs of PwPD as their condition progresses. The high satisfaction scores suggest that with ongoing refinements, PANDORA could provide a robust, accessible tool that adapts to evolving user needs.

In summary, while additional research with larger samples and real-world testing is necessary, these initial findings support PANDORA's promise as an impactful mHealth tool. Its potential to empower PwPD through motivational support and user-friendly design offers an encouraging foundation for enhancing patient engagement in therapeutic exercises and overall quality of life.

4. Conclusions

Interactions with PANDORA's conversational agent foster patient autonomy by providing choices and support while enhancing competence through guidance and assistance. This empowers patients to make informed decisions and manage their exercise programs effectively, ensuring their well-being remains a top priority.

The Technical Performance Assessment results demonstrate that the CA performed well in delivering accurate exercise-related information, maintaining coherent responses, and achieving comprehensive domain coverage. However, areas for improvement include handling non-understandable inputs and enhancing dialogue management capabilities, which are critical for providing a more robust and reliable conversational experience. These findings highlight opportunities for refining and optimizing the agent's performance.

Future research should prioritize enhancing PANDORA's natural language understanding (NLU) by training the Dialogflow engine on a more diverse and comprehensive dataset, including examples of non-understandable elements to improve input recognition. Leveraging Large Language Models (LLMs), known for their advanced capabilities in handling language variations such as misspellings, grammatical errors, and colloquialisms, could significantly enhance PANDORA's ability to interpret user inputs accurately. Moreover, incorporating contextual understanding through the consideration of the user's interaction history and current task could further refine the agent's ability to handle ambiguous or unclear inputs effectively. These advancements, combined with LLM integration, hold the potential to elevate PANDORA's dialogue management and overall user experience.

Moreover, incorporating sensors to measure steps, guide users through exercises, and provide virtual rewards for completing exercises or achieving goals can help keep patients motivated to perform therapeutic exercises and continue their treatment. Sensors enable the CA to adapt its behavior to fit the context, providing alerts and assistance when patients encounter difficulties while performing tasks. This context-aware support enhances patient engagement and motivation. Additionally, using a virtual avatar to embody PANDORA increases user acceptance [54].

Additionally, according to [55], virtual rewards increase motivation. Using behavioral reinforcement with virtual rewards while supporting positive behavioral reinforcement plays an important role in motivation. In addition, mindfulness helps maintain the patient's psychological well-being, increasing their motivation to continue therapy.

PANDORA was developed for the Portuguese language but designed to be language-independent, integrating motivational theory for adaptability across linguistic and cultural contexts. Powered by Google Cloud's Dialogflow, which supports over 40 languages, the system offers technical ease for language localization. However, effective adaptation requires addressing cultural nuances, such as communication styles, interaction preferences, and motivational techniques, alongside careful translation to ensure cultural relevance. Despite these challenges, PANDORA's robust framework and Dialogflow's extensive language support provide a solid foundation for efficient customization across diverse settings.

Beyond promoting exercise adherence, PANDORA has the potential to provide emotional support, reduce isolation, and enhance the overall quality of life for People with Parkinson's Disease (PwPD). As a scalable and low-cost solution, it can complement traditional healthcare by offering remote support, particularly valuable for patients in underserved areas. Its design and motivational framework, grounded in Self-Determination Theory, further extend its applicability to broader healthcare contexts. By fostering autonomy, competence, and relatedness, PANDORA could be adapted to support patients managing other chronic or neurodegenerative conditions, such as Fibromyalgia, Amyotrophic Lateral Sclerosis (ALS), or stroke recovery, which similarly require sustained engagement with therapeutic routines and benefit from tailored motivational support.

Incorporating features such as biometric monitoring and personalized interventions, PANDORA could integrate seamlessly with existing healthcare platforms to enable more holistic and effective care. This adaptability positions it not only as an innovative solution for enhancing patient engagement and well-being in Parkinson's management, but also as a versatile tool for supporting multidisciplinary approaches across a range of chronic conditions.

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