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A Serious Games and Game Elements Based Approach for Patient Telerehabilitation Contexts

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Abstract

There are several factors involved in telerehabilitation therapy, such as the patient's engagement in the activity. In this context, the therapist's active participation is compromised and, on the other hand, the exercises performed are often repetitive and boring, decreasing the patient's engagement and motivation, directly impacting the results of the sessions. Considering this, this paper aims to present an approach based on an exergame (a serious game that aims to encourage physical exercise) with a distributed architecture. It was developed to assist in conducting telerehabilitation sessions that involve a cycle ergometer as a device – a bedside bicycle used in rehabilitation sessions for patients with motor disorders. In order to validate the effectiveness of this approach, the construction of an exergame prototype was undertaken, followed by two validation steps done by 16 physiotherapists from the Clinical Hospital of the Universidade Federal de Goiás - UFG (based on the Delphi Method). About $88,8\%$ of the specialists, after two rounds of evaluation, considered that the exergame was appropriate for telerehabilitation sessions.

Keywords: *Serious Games, Rehabilitation, Telerehabilitation, Game Elements, Engagement*

1 Introduction

Challenge, escape from reality, altered sense of time, significant emotional impact, and great desire to continue playing: these are some qualities that draw attention to the gaming universe, because of their potential to engage and involve the players in the proposed activity (Chen, 2007; Chou et al., 2014).

Games bring many possibilities for applications, due to their characteristics and playfulness. In rehabilitation contexts, approaches that are based on games are used because they can awaken the patient's engagement and motivation, revealing an entertainment dimension to activities that would be tiring and repetitive (Silva et al., 2017).

When considering scenarios where rehabilitation takes place remotely – the so-called *Telerehabilitation* (Santos and Pinheiro, 2016) – some problems already observed in conventional therapy processes are enhanced, such as the availability of treatment, the presence and active role of the physiotherapist in the activity, and also the patient's low engagement (Subtil et al., 2011; Cerf, 2020; Jack et al., 2010; Gonçalves, 2019). Game-based approaches and the use of some of their specific elements and features have shown benefits and good acceptance (Silva et al., 2017) to alleviate these difficulties (Souza et al., 2021b).

In this way, this paper aims to present the process of developing an exergame (serious game to motivate the performance of physical exercises) named CicloExergame, which was built in a distributed architecture involving real-time concepts and can become a possibility to support the realization of telerehabilitation sessions that use the cycle ergometer (Souza et al., 2020). This device is a bedside bicycle, through which the patient can exercise his upper and lower limbs (Needham et al., 2009). It is used in cases of muscle dysfunction caused by physical inactivity (in postoperative or recovery scenarios at an Intensive Care Unit - as is the case of post-COVID-19 patients), by the occurrence of a stroke, or cardiorespiratory problems.

CicloExergame was developed so that the patient and the physiotherapist, even remotely (both in different places), can interact in order to allow the completion of the physiotherapy session. It presents a character that moves from the patient's pedal strokes on the cycle ergometer. In the *endless runner* format, it brings objects that the player must collect, as well as obstacles that he must dodge. The goal is to collect as many objects as possible in the time set by the physiotherapist and stay pedaling at the stipulated speed.

This paper describes the steps and processes involved in the creation of the game, developed using Unreal Engine 4, an engine widely used in game development (Gregory, 2014; da Silva Peixoto, 2019; Glazer and Sanjay, 2015). The processes of 3D modeling and animation of the elements, the architectural construction of the game, and the challenges in the implementation process are detailed. In addition, the game went through two rounds of evaluation with physiotherapists, using the Delphi Method (Coutinho, 2013; Scarparo et al., 2012; Wendisch, 2010; de Azevedo Cardoso et al., 2005; Wright and Giovinazzo, 2000), recognized and widely used in the health area. In general, the game was positively evaluated and the results point to a consensus on its effectiveness.

On this project's horizon, effectiveness and its verification are understood on three levels that, in turn, complement each other. The first level is related to a qualitative study with physiotherapy professionals, aiming to validate the game's concepts and features. Next, an experiment with volunteers is carried out, aiming to bring perspectives about the use of CicloExergame in terms of engagement and gameplay. Finally, the last level includes a clinical study involving patients and physiotherapists, to evaluate the developed solution in a real scenario. This paper focuses on the description of the construction process and the evaluation of the effectiveness' first level.

The text of this paper consists of an extended and reviewed version of a paper published at the Brazilian Symposium on Games and Digital Entertainment (SBGames) 2021 (Souza et al., 2021c). Among the main enhancements, there is a more detailed explanation of the Delphi Method and the description and presentation of the second round's results of the evaluation with specialists carried out using this method.

This paper is organized into six other sections in addition to this introduction. Section 2 presents some concepts involved in the construction of the game and Section 3 the related works. Section 4 provides an overview of how the exergame works and Section 5, in turn, presents the game development process in Unreal Engine 4. From this, Section 6 provides information about the game evaluation process, through the Delphi Method. Finally, Section 7 presents the final notes and indicates future horizons based on the findings made throughout the process.

2 Games, Engagement and Serious Games

There is a huge discussion about what would be an adequate concept for a game. Among many definitions and concepts, we chose those that prioritize the elements considered to be the most important of the presented project. From a broad horizon, it is possible to infer that games are types of activities characterized by having a playfulness capable of involving the player, and providing emotional impact (Kapp, 2012).

Huizinga describes the resources involved in a game as a kind of "magic circle", which is based, in his words, on a "temporary abolition of the ordinary world":

> The exceptional and special position of play is most tellingly illustrated by the fact that it loves to surround itself with an air of secrecy. [...] What the "others" do "outside" is no concern of ours at the moment. Inside the circle of the game the laws and customs of ordinary life no longer count. We are different and do things differently (Huizinga, 2020).

The psychological concept that defines the state of a person that is immersed in the game's reality is called "the flow state", characterized by an altered sense of time and loss of self-awareness (Chen, 2007). The player feels engaged to perform actions and enable meaningful personal experiences. Therefore, we define engagement as the deep involvement of the player who is in a "flow" state, that is, immersed in the game universe (Csikszentmihalyi, 2020; Chou et al., 2014).

A game must have certain characteristics, the main ones being: the presence of players, objective, well-defined rules and procedures, a conflict that involves the players' actions together with the resources available to perform these actions, as well as general limitations and results of the players' actions (Fullerton, 2008).

The resources employed in game development used to achieve these characteristics are called game elements (de Oliveira, 2018). They can be classified into game dynamics, game mechanics, and game components (Werbach and Hunter, 2012).

The elements of game dynamics are determined by the emotions stimulated in the players, by the narrative that gives purpose to the player's actions, by the progression of actions into the game, by the interactions between players, by the restrictions that delimit the game or even by the simulation of advancement within the game's narrative (Werbach and Hunter, 2012; Costa and Marchiori, 2015).

About the game mechanics elements, there is the collection of resources (items or objects); the presence of feedback, showing the reactions and responses of the player's progress; "chance" elements that respond to player actions with surprises; cooperation and competition mechanisms; the challenges, which are defined objectives that impact directly on the activity's difficulty; reward the player for his achievements; and finally, the victory, when the player reaches the end, after having satisfactorily completed the challenges (Werbach and Hunter, 2012; Costa and Marchiori, 2015).

Finally, among the elements of game components, the following can be mentioned: the presence of an avatar, achievements, badges and medals, missions (specific activities), division of the game into levels, scoring and ranking, the possibility of playing in teams (several players cooperating to achieve the same objectives) or in combat (players competing against each other), and also the possibility of interacting with friends within the game (Werbach and Hunter, 2012; Costa and Marchiori, 2015).

The combination of dynamics, mechanics and components builds the game experience, together with all its characteristics and difficulty levels.

Based on this, it is possible to present the concept of serious games, which is a category of games that are built with purposes that go beyond entertainment, even if they also present all the characteristics inherent to games (Aldrich, 2005; Fleury et al., 2014).

Serious games are able to create a positive context for training and other types of experiences (e Silva et al., 2018), helping to carry out activities, physical exercises, or simulations of practical situations in a playful, engaging, and attractive way. This promotes the development of many skills, as well as the learning and knowledge assimilation that comes from the practicing processes (Zyda, 2005). In this context, are called exergames the serious games that aim to encourage the player to perform physical exercises, bringing with them the advantages and details already mentioned. It is, therefore, a terminology and not another concept (Battisti, 2020).

3 Related Work

Several projects have addressed the issue of using exergames as engagement and motivation promoters in the rehabilitation or telerehabilitation process. The works presented below were selected from the Systematic Review of Literature carried out in this project (Souza et al., 2021b). Considering the 93 studies selected during the review, this section presents those that provide the most precise basis for the presented approach.

Firstly, Work A (Battisti, 2020; Battisti et al., 2019) is the project of which our research is a direct continuation. This is a work involving the creation of a game to make rehabilitation less tedious for patients who have muscular dystrophies due to long hospital stays and need to have many and sometimes long cycle ergometer sessions. The game presents a character that moves according to the patient's pedal strokes. The physiotherapist is physically next to the patient during the activity, monitoring vital data and general performance on the game screen. At the end of the session, a graph shows the oscillation of heart rate and blood oxygenation over the session's amount of time.

The following project (Rodrigues et al., 2019) (Work B) presents a virtual reality-based game, in which the user is taken to a city where a series of activities are proposed aiming at performing exercises, such as shopping in a city fair or buying CDs at a store. The tool is focused on problems related to occupational therapy in elderly people who spend a lot of time immobilized or with little mobility. The game does not cover telerehabilitation contexts but brings the discussion about the scenario of rehabilitation in domestic environments. The authors intend to awaken the engagement in the activities through the establishment of goals and objectives to be fulfilled. So that the difficulty does not discourage the user, some tips are given in the initial steps. The patient interacts with the application with the Oculus Rift[1] and from a "pedalboard", a kind of cycle ergometer.

Changing the context for the rehabilitation process of motor problems in stroke survivors, Work C (Ren et al., 2020) proposes the use of a method to improve rehabilitation patient's engagement based on *Human-in-the-loop* optimization (HITL). An exergame is presented to demonstrate the method, using an exercise bike and electroencephalography (EEG) sensors. Engagement is promoted through the difficulty levels of the training exercises, which can be continuously optimized to best match the subject's current motor ability and physiological state. Although the patient uses an exercise bike to control the virtual avatar, the character's speed is calculated from the EEG sensor. The objective is to pedal and stay on the reference speed curve, which can be modified depending on the activity selected.

Also on motor problems, the next work (Afyouni et al., 2019) (Work D) presents a versatile alternative for different types of motor rehabilitation. It proposes the construction of a game-based system that is customizable and adaptive. The idea is to allow the patient to do the exercises with the help of virtual assistants (called *"rehab bots"*), shown in the game scenes to guide the patient during the performance of the gesture sets. The patient interacts with the game through gestures recognized by a Kinect sensor. The physiotherapist has an interface that, in addition to consulting the patient's activity history, can also allow to create or customize exercises. Also, in this project, the degree of engagement is related to the difficulty of the required gestures, which are automatically calculated and adjusted by the game.

Finally, Work E (Wang et al., 2020) proposes an exergame for the rehabilitation of patients with motor disorders caused by strokes. In the game, the patient must pedal trying to follow and stay next to another avatar that appears on the screen. The player's speed is calculated from his pedaling and his attention to the exercise. Although the patient uses an exercise bike to interact with the game, the patient data on pedaling and speed is collected from a goniometer sensor[2] attached to the patient's knee. An electroencephalogram (EEG) device captures data about the patient's attention to exercise. The patient's motivation is also promoted through adjustments in the difficulty of the activity performed: the avatar that the character must follow is adjusted based on the obtained levels of attention and pedaling.

About the proposal of the present work, it is important to compare it with the related projects. Table 1 provides an overview of the works presented in comparison with each other and with the proposed approach. Regarding work A, which is the project that brings the greatest similarities, we have that the problem addressed was extended, given a new architectural design of the solution and a new research hypothesis that is based on this design: the exergame is now distributed (*multiplayer*) and the actors (patient and physiotherapist) are in two different places. On the other hand, the addition of other game elements (such as obstacles and collectible objects, in addition to the creation of goals and objectives to be achieved) aims to increase patients' engagement in the activity.

Compared with the other works, the proposed approach shows some similarities, even among some contrasts. Similar to works B, C, and E, the cycle ergometer is the device used for interaction between the patient and the game. However, while these works use high-cost auxiliary systems, such as the EEG device, this project brings up an approach that aims to complement the data coming from the cycle ergometer with low-cost sensors that are easy to use by the patient: the heartbeat and blood oxygenation, which is easily fitted to any of his fingers. By presenting a proposal with fewer devices, ease of use and practicality are sought.

Concerning engagement, the proposal of this project presents, similarly to the other works, game elements such as goals and objectives, as well as the possibility of configuring the exercise's difficulty level. This setting can be done before the start of the session and can be modified at any time by the physiotherapist. However, unlike everyone else, the interaction with the physiotherapist takes place more actively: the physiotherapist can see, talk, configure and "participate" in the activity with the patient if he wishes to do so. Therefore, unlike the others, this relationship between the two actors can take the form of direct and active interaction, increasing the patient's engagement and motivation to perform the activity.

[1] https://www.oculus.com/rift/

[2] The goniometer or angular sensor is a kind of sensor made up of two components joined by a cable. One component is attached before the joint and the other immediately after. They can measure the joint's opening angle.

Table 1. Related works and the proposed approach.

	Work A	Work B	Work C	Work D	Work E	Proposed Project
Interaction Method	Cycle ergometer and sensors (heart rate + oximeter)	Oculus Rift Cicle ergometer	Cycle Ergometer EEG	Kinect	Ergometer Bike goniometer + EEG	Cycle ergometer, joystick and sensors (heart rate + oximeter)
Equipment Cost	Low	High (> BRL 3000,00)	High (> BRL 3000,00)	Low	High (> BRL 3000,00)	Low
Proposal for Engagement	The very construction of the game is seen as a promoter of engagement.	Goals and objectives	Continuously optimized difficulty levels	Continuously optimized difficulty levels	Continuously optimized difficulty levels	Dynamic difficulty setting, objectives, goals and in-game interaction with the Physiotherapist
Active presence of the Physiotherapist	Yes, in person.	No	No	No	No	Yes, virtually.
Physiotherapist sets up the activity before it starts	Yes	No	Yes	Yes	No	Yes
Is there interaction between the patient and the Physiotherapist?	Yes, in person.	No	No	No	No	Yes, virtually.

4 CicloExergame - Overview

As a whole, CicloExergame[3] aims to enable, through a distributed architecture, the execution of telerehabilitation sessions with the cycle ergometer, which is transformed into a low-cost joystick by attaching sensors for capturing vital data (heartbeat and blood oxygenation) and patient pedaling (magnetic switch inside the cycle ergometer) (Fig. 1) (Souza et al., 2021a). An Arduino board integrates the sensors, serializes a JSON tuple with the information that comes from them, and sends this tuple via serial port to the exergame.

Figure 1. The cycle ergometer that was adapted for the project.

The two actors involved in the game are the Patient and the Physiotherapist. The Physiotherapist configures the parameters for carrying out the activity (minimum and maximum acceptable values for the level of heart rate and blood oxygen saturation, duration of the activity, and expected speed of pedaling, among others). In addition, he monitors the physiological data collected from the patient during the session and he can, if desired, follow the game interactively, getting an avatar and “playing” with the patient, through keyboard commands (instead of pedaling with the cycle ergometer), aiming to promote a form of interaction that increases the engagement. At the end of the activity, it is possible to view a graph with the heart rate and oxygen saturation data collected throughout the session by the sensors, as well as view the history of the sessions.

[3]This software was registered by INPI (Instituto Nacional da Propriedade Industrial - Brazil) with number BR512022001849-7.

The patient, in turn, is able to perform the activity within the parameters set by the Physiotherapist. He plays through his pedals, which regulate the character’s speed, and also through secondary commands that can be performed with a *joystick* (numeric keyboard with markings that allow identifying the commands more easily - Fig. 2) or with the conventional keyboard (character shifts to the right and left or rotations). He also visualizes his physiological data on the screen and, at the end of each session, he has access to the generated report.

Figure 2. Numeric keypad used to control the game.

The game, whose construction is based on the model *endless runner*[4], presents to the patient an avatar with a bicycle controlled by his pedal strokes on the cycle ergometer and by an auxiliary joystick that allows more movements. His vital data and other information are shown on the screen (Fig. 3). The objective is to collect as many coins as possible that appear along the track, avoiding obstacles, within the time stipulated by the physiotherapist. The activity is previously configured by the health professional, who informs the parameters expected for the patient’s performance, being able to modify them throughout the activity. Data is displayed in real-time on the healthcare professional’s interface, using real-time systems technologies (provided by the multiplayer

[4]A video that presents the operation of CicloExergame can be seen at: https://youtu.be/nd3HzcEvhcc.

environment from Unreal Engine 4). In addition, the solution includes interaction with a platform for verbal communication between the two actors, through video call resources.

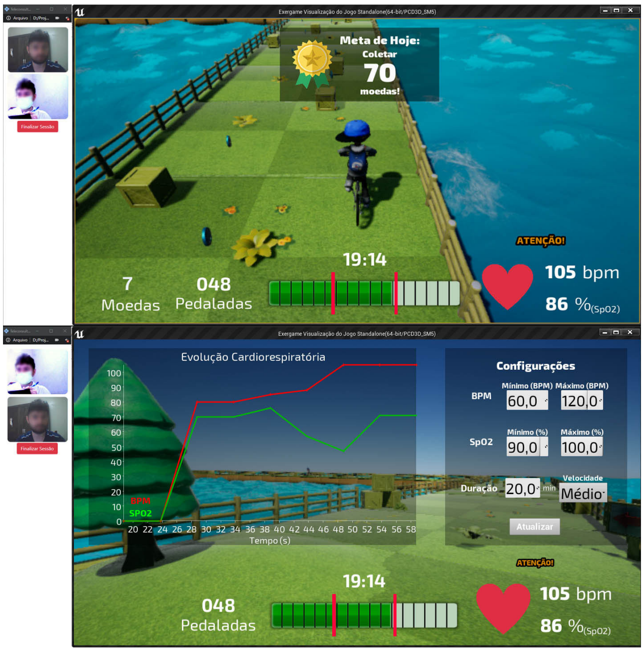

Figure 3. Game screenshots (in Portuguese): patient (above) and physiotherapist (below).

In terms of interaction between patient and physiotherapist, the exergame is designed to allow the physiotherapist, in addition to monitoring sensor data in real-time, to generate follow-up reports and configure the activity dynamically (at runtime), and can interact in the game environment with the patient, participating with him in the activity (Fig. 4). If the healthcare professional so wishes, he can have his own avatar and "pedal" alongside his patient, using the keyboard controls (he can control his own speed, in addition to lateral displacements and rotations). Thus, the two actors can "run" side by side. Among other things, this allows the physiotherapist to control the performance of the activity in other ways that can be more "friendly" and informal, in addition to simply setting limits. For example, if he wants the patient to slow down, he can move his avatar more slowly, asking the patient to accompany him. This participation further increases the patient's bond and motivation with the activity and with the treatment (Subtil et al., 2011).

Figure 4. Physiotherapist's screen in "Player" mode (in Portuguese).

During the activity, the data from the sensors is constantly displayed on the screen, and an alert is issued if they deviate from the initially stipulated range. At the end of the session, the final performance graph is shown on the screen for both the patient and the physiotherapist, from which the health professional can clinically evaluate the patient, observing the evolution of heart rate and oximetry during the time of activity. These data are stored and presented to the physiotherapist also in the form of a general follow-up report (history), thus showing the general development of the patient during the sessions.

5 CicloExergame - Development Details

For the CicloExergame's implementation, we chose to use the Unreal Engine 4[5], because it is a widespread game engine that presents some of the tools and resources that stand out in the market (Gregory, 2014), including resources for the multiplayer architectures used in this project, given that the physiotherapist and the patient are in different environments. Unreal performs well, considering the demands of this project, and brings tools that allow a less time-consuming development and good quality results, as well as several optimization tools so that communication between clients and servers can be fluid (da Silva Peixoto, 2019; Gregory, 2014; Glazer and Sanjay, 2015).

5.1 Architecture and Data Transmission

The game was developed in a distributed architecture, interpreted by the game engine (Unreal Engine) as multiplayer, with each actor (patient or physiotherapist) being a player, although performing different functions. For this, Unreal implements a client-server architecture. The server can be run linked to one of the players or it can be executed in a dedicated way (Epic Games, 2020). The project aims to run the server linked to the Patient's player. The communication, illustrated in the diagram in Fig. 5, happens through the storage of variables sets (called Game States) and their request between the clients and the server.

Therefore, the data from the sensors that are stored in variables within the player Patient are taken to the server and made available to the Physiotherapist, when he requests access. On the other hand, the exergame configuration data, provided by the Physiotherapist, is also sent to the server and the Patient, in turn, requests them before the start of the activity or when these settings are changed by the Physiotherapist.

The activity configuration is an example of how this process occurs within the game engine. It is performed by both the Patient and the Physiotherapist, although they configure different functionalities. The Patient needs to indicate the serial port in which the cycle ergometer is connected, and the Physiotherapist, in turn, configures the activity parameters, such as expected speed, duration, and expected minimum and maximum values for heart rate and blood oxygen saturation. Each of them changes the Game State variables on the server that are associated with the settings made, and when the activity is started, each one request from the server the settings

[5]https://www.unrealengine.com/en-US/

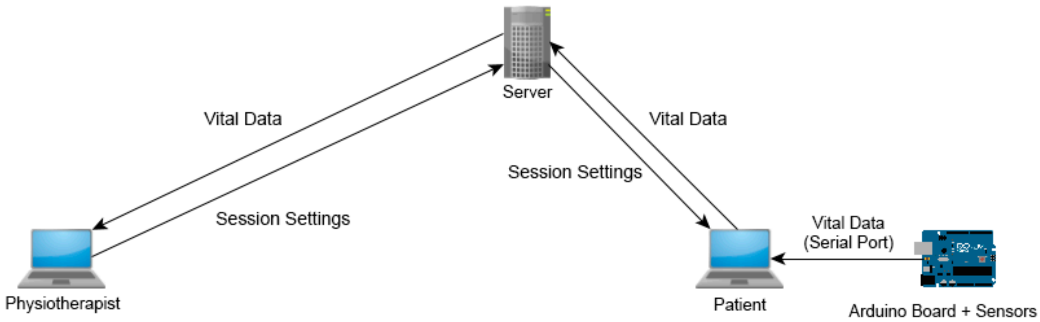

Figure 5. Data Transmission Diagram.

made by the other.

Still, on this step, other settings are allowed that aim to provide a greater degree of customization to the activity, making the session "tailor-made" to the needs of each patient. In this sense, the Physiotherapist can configure the presence or absence of obstacles (which the patient must avoid) or coins (objects that the patient must collect). He can also choose how he prefers to participate in the experience, either as a spectator (without directly interacting with the game, focusing on the patient's data) or as a player, that is, participating in the activity alongside the patient.

He can change some of the settings made at the beginning at any time if he decides that it is necessary. He can change the minimum and maximum values of heart rate and blood oxygenation, in addition to the duration of activity and the expected speed. This last configuration, in addition to allowing greater customization of the activity, also contributes to increasing or decreasing the difficulty of the game, thus enhancing patient engagement. In this case, the Game State variables of the server are modified again and the Patient, when verifying that there have been modifications (through a control variable on the server), updates the values.

As before, during the activity, the sensor data from the JSON tuple that keeps being sent by the Arduino (via serial port) are deserialized and stored in variables inside the player Patient. After that, they are taken to the server and will be available to the player Physiotherapist, who will request access. On the other hand, the exergame configuration data, provided by the Physiotherapist, is also sent to the server and the Patient, in turn, will request before the activity starts or when these settings are changed. This is the basic data transmission dynamic on CicloExergame.

5.2 3D Modeling, Game Elements and Interaction

Some of the 3D models were developed with the help of Autodesk 3D Studio Max[6] software, where the steps of 3D modeling, texturing, skeleton assimilation (*rigging*) and animation were performed. Some scenario items and even the main character (Fig. 6) were modeled within this process. Other models were obtained externally from UE Marketplace[7].

For the construction of the character's movement, two sequences of animations were produced: low and high-speed pedaling. Thus, it is possible to merge these two movements, using the *animation blueprint* and *animation blendspace* resources (in Unreal Engine), which allow associating the value of the character's speed variable (in the range from 0.0 to 1.0) with the execution of the animations. In this way, the character "pedals" with the speed corresponding to the exercise on the cycle ergometer. In addition to running the animation, the character's velocity variable (calculated from the patient's pedaling speed captured by the magnetic switch) is responsible for moving the character forward.

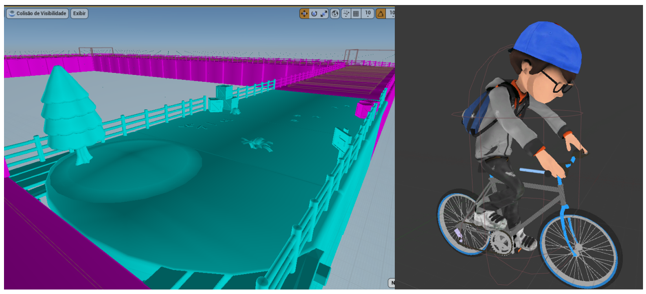

Figure 6. Scenario and character developed for the exergame.

In addition to the frontal movement (patient pedaling with the cycle ergometer), the game brings other possibilities for controls and movements. The patient can perform lateral displacement movements and rotations, using the A-D (lateral displacements - left and right) and Q-E (rotations - left and right) keys. These controls can also be performed using a numeric keypad or *Bluetooth joystick*. The physiotherapist, when choosing the option to "play together" with the patient, can control, in addition to all these commands, the speed of his avatar with the W-S keys (increase and decrease the speed). Thus, the character moves as the patient interacts with the physical device and controls.

Concerning the patient's ergonomics, together with the cycle ergometer adapted with the sensors and also with the extra control (numeric keypad or Bluetooth joystick), the project was organized to allow the sessions to be carried out in two main positions (those that are, in fact, most used in traditional therapy): with the patient sitting or lying down. An ergonomics model for these two possibilities can be seen in Fig. 7.

When physically interacting with this equipment, the patient causes the interaction between the character and the scenario, and that includes the objects that are arranged along the track.

[6]https://www.autodesk.com/products/3ds-max/overview
[7]https://www.unrealengine.com/marketplace/en-US/store

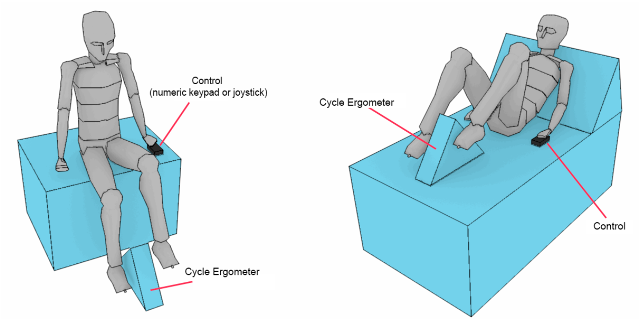

Figure 7. Ergonomic positions for the interaction with the exergame.

Considering the creation of the game's scenario, it has been thought of as a kind of road arranged in the form of a path in a cycle, where the player moves and the activity unfolds. Two fences were placed to prevent the character from falling overboard. Invisible collider elements (*box triggers*) were also placed next to the fence to prevent the character from falling in any way. The vegetation, the sea, and the wind in the foliage are elements that arouse emotions and sensations related to calm and anxiety reduction - according to the colors' semantics and were chosen to reduce the tension related to the therapy difficulties. The main tones of the game's color palette are shown below and their psychological and symbolic meaning from Andrade and Evangelista, 2018:

- Green: relates to youth, vigor, freshness, hope, and calm;
- Blue: relates to loyalty, fidelity, idealism, and dream.

As the track is arranged in a cycle and, consequently, has curves in its path, the character's movement was also designed to make the gameplay more fluid: the rotations in the curves of the track are made automatically using a box trigger: when the character collides with this object, it modifies the avatar's rotation. Thus, with a box at each end of the curve (Fig. 8), the curves are performed without any command.

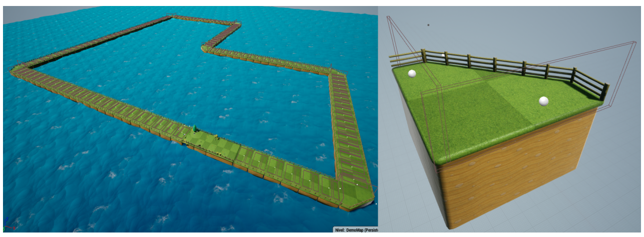

Figure 8. Cyclic road and curves' system.

Besides, the character also interacts with two other categories of elements: collectible objects and obstacles (Fig. 9). They are components that correspond to the objectives and goals of the game (Souza et al., 2021b). The obstacles, arranged in the scenario, were configured in their collision options as "*BlockAll*", that is, they are objects that offer resistance to the character's passage. When the character collides with one of them, he needs to make a detour, moving sideways to continue the path.

Relating to the collectible objects (which are coins and even bonus objects that reward each completed lap), they have colliders that, when colliding with the character (action of collecting the object), destroy the collectible object and increase the value of the variable responsible for storing the player's score. In addition, at the beginning of the game, it is shown to the player the collecting coins session goal. When the goal is reached, a congratulatory message is displayed, accompanied by audible feedback.

Figure 9. Obstacles and collectable objects (in Portuguese).

An important issue for the exergame development was the generation of all of these elements (obstacles and collectible objects), as many nuances are involved in the relationship between the competitiveness/playfulness of the game and the therapy itself. It is necessary to consider that, in certain scenarios, the existence of obstacles, for example, can impact or disturb the session's progress. Therefore, it was decided to offer the possibility to activate or deactivate the generation of these elements in the physiotherapist's initial configuration panel. Thus, he can choose the best option and personalize the activity, based on the situation of each patient.

In terms of development, considering the exergame's nature, which is distributed/multiplayer, some impasses have arisen. The simple random generation of these elements resulted in obtaining different positions of obstacles and collectible objects for the two players since this generation happened locally to each player. On the other hand, a non-random generation resulted in the same scenario in every session, bringing monotony to the game and impacting playfulness. The solution was to randomly generate the positions on the server and distribute them to the two clients, who store these values locally in a vector, causing the same scenario to be generated locally by both players. The vectors are iterate circularly, which makes the obstacle generation scalable by the time of activity.

Still in this field, considering the circular layout of the scenario, a strategy was devised so that the configuration of these elements varies with each lap. After the character passes through a certain part of the scenario (one of the grassy platforms that make up the road), a delay counter with a duration of five seconds is triggered and, after this time, the elements are generated again on the platform, from a new position of the random vector that was generated at the beginning of the game. Thus, every time the character passes through a certain platform, he encounters obstacles in different places and new objects to collect.

6 Evaluation Process and Results

In order to evaluate the developed exergame, we chose to use the Delphi Method (Bloor et al., 2015), coming from the health area and carried out with specialists in the object of study. For this, the project was submitted and approved by the Ethical Committee on Research with human beings (CEP) of the Universidade Federal de Goiás - UFG[8], ensuring that the tests respect the integrity of those involved, presenting no risk to the health of the participants. With this approval, the application of the method was followed.

6.1 Delphi Method

The Delphi Method is defined as a "systematized method of judging information, used to obtain expert consensus on a given topic, through validations articulated in phases or cycles" (Scarparo et al., 2012). It is a technique that comes from the health area and has been used since the 1950s. It is based on obtaining consensus among specialists in the area of interest - called "judges" - about the object in question, using questionnaires applied in steps, followed by the analysis of the results obtained. The three pillars of the method are the anonymity of the judges (to avoid the formation of an artificial consensus), the statistical distribution of opinions, and finally their evaluation (Munaretto et al., 2013; Wendisch, 2010; de Azevedo Cardoso et al., 2005; Wright and Giovinazzo, 2000).

Regarding the sequence of steps to carry out an evaluation using the Delphi Method, Fig. 10 presents an activity diagram that outlines the process.

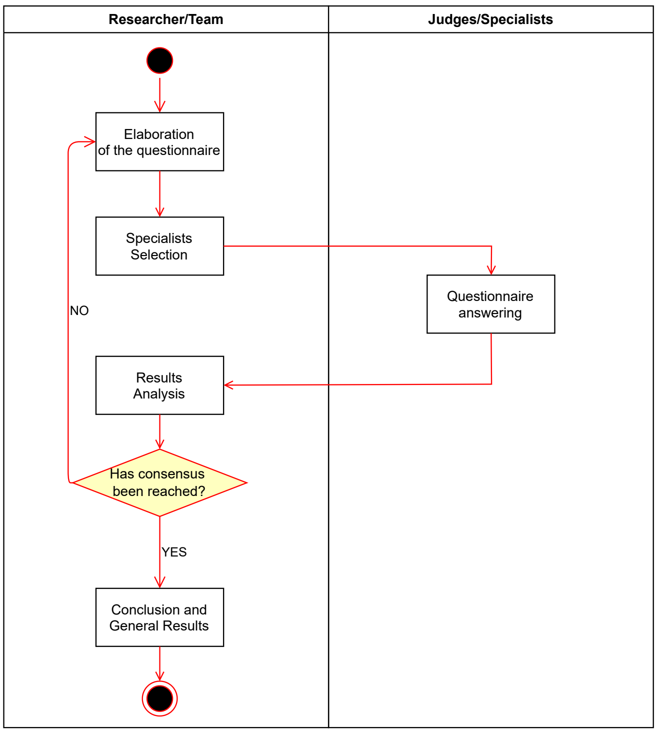

Figure 10. Delphi Method Activity Diagram.

[8]CEP/UFG approval can be consulted on Plataforma Brasil (plataformabrasil.saude.gov.br) under CAAE code 35651120.6.0000.5083 and number 5025873.

The sequence of steps of the Delphi Method is well defined. First, the research team prepares a questionnaire that makes it possible to visualize the opinions of experts about the object, using open-ended questions or questions that present a scale of values, such as the Likert Scale, widely used in Delphi questionnaires, whose values variate according to the agreement of the respondent with the proposed sentence in the utterance, which may vary from "Strongly agree", through neutral opinion to total disagreement (Alexandre and Coluci, 2011; Scarparo et al., 2012; Coutinho, 2013).

Next, the experts who will participate in the questionnaire are selected, taking into account that they need to be trained to issue opinions on the investigated topic (Scarparo et al., 2012).

The next step is to send the questionnaire to be answered by the specialists. Based on the answers, an analysis is made based on the pillars presented, to determine whether consensus has been reached. For this, consensus metrics are defined that serve the research objectives, being consistent with the number of participants (Coutinho, 2013). Based on the analysis, the team judges whether or not consensus has been reached, establishing at which points it will be necessary to build a new round with a new questionnaire. The interactions continue until consensus is reached on all necessary points, presenting the conclusions and general results. Regarding the discrepancies of opinion among respondents, Dias proposes that:

> If the consensus group position is not reached in two rounds, those individuals whose opinions deviate considerably from the majority (i.e, those outside the interquartile space) should be asked to argue their opinions. Points of disagreement should be explored, not ignored. Once evaluated, the information is aggregated and presented to each participant – in statistical terms – to obtain new results. This process continues until a satisfactory degree of convergence of responses is reached (de Cássia Barros Dias, 2007).

It may also happen that the answers are polarized in two or three positions, without indicating an approach to a consensus (Wright and Giovinazzo, 2000). This fact is relevant for analyzing the problem in question and must be taken into account. If the situation does not change during the steps, it is possible to declare "stability" in the answers and the discussion of this point ends (de Cássia Barros Dias, 2007).

Also according to Dias, most of the research produces a maximum amount of four rounds, and a number greater than this, although it can be carried out, is not recommended due to time constraints and the fact that the literature points out (based on experiences carried out and documented) for the non-existence of significant changes of opinion after this issue (de Cássia Barros Dias, 2007).

Upon reaching consensus (or stability) at all points, the results are compiled and an analysis is performed and reported. The conclusions and general results gain space in this final moment.

The main advantages of the method are the possibility of performing an asynchronous evaluation, in addition to guaranteeing the reliability and robustness of the results obtained, due to the consensus of experts. As for disadvantages, one can cite: the risk of obtaining an artificial consensus and dependence on the participation of experts, with participants' withdrawal being a risk to the research (Scarparo et al., 2012; Coutinho, 2013).

Considering the possibilities, guarantees, and limitations, the Delphi Method was chosen for the project evaluation because it brings in itself the possibility of obtaining consensus about the evaluation of the developed exergame.

6.2 Evaluation - First Round

For the accomplishment of the first round of the evaluation by the Delphi Method, the questionnaire was elaborated, giving the main points and important concepts of the constructed exergame. The respondent, after having informed his specialty and time of work in the area, read a brief explanatory document about the project, followed by a demonstrative video, which presented scenes of CicloExergame being used in practice.

The questions were asked using the Likert Scale, together with optional open-ended questions, giving space for the experts' criticism or suggestions (Table 2).

The selection of specialists was carried out with the help of a key person: the head of the Physiotherapy Residency Ward at the Clinical Hospital of the Universidade Federal de Goiás - UFG. A total of 16 judges were selected, 10 experienced physiotherapists and 6 physiotherapists in residence. The working time of these specialists is distributed as follows: 3 have been working for less than one year; 5 work from 1 to 5 years; 4 work from 5 to 15 years; and 2 have been working for over 16 years. The judges have experience in hospital and/or cardiorespiratory physiotherapy, and residency in intensive care, emergency, and urgent care.

The research team defined that "consensus" would be declared if the question reached more than 80% degree of agreement between the judges. As a result, the questionnaire was sent to the specialists, with an interval of 15 days to complete the responses.

6.3 First Round - Results

Based on the experts' answers, it is possible to verify the degree of agreement with the exergame points raised by the questionnaire. The graph in Fig. 11 shows the distribution of multiple-choice responses (Likert Scale).

Based on the results obtained, the following statements can be made:

With more than 81.3% of strong agreement on Question 1, experts agree with the promotion of engagement generated by the game. Likewise, the 75% of strong agreement in Question 2, added to the 25% of agreement, points to the validation of the idea that the exergame is an enabling instrument for physiotherapy sessions.

In Question 3, a degree of agreement was reached that corresponds to 12% of the answers, with one judge (6.3%) taking a neutral position. However, as 43% of the specialists strongly agreed and 37.5% also agreed with the assertion, the consensus on the sufficiency of CicloExergame in carrying out telerehabilitation sessions is affirmed (with 81.3%).

In Questions 4 and 5, the consensus is manifested by the strong agreement of 31.3% and 56.3% of the judges (respectively) and agreement of 68.8% in Questions 4 and 37.5% in Question 5. This externalizes the agreement of the experts regarding the satisfaction of the initial settings and activity customization options, and the follow-up of the patient via performance graphs.

In the other multiple-choice questions, there is a unanimous agreement of all the participating experts, ranging from 50% of agreement and 50% of strong agreement in Question 6 to a high index of strong agreement (81.3%) in Questions 8 and 11. Through these data, it is observed that the judges showed a consensus of agreement on these points, thus validating all the assertions presented in the multiple-choice questions of the questionnaire.

Despite the smaller number of answers in the open-ended questions, it is possible to extract, concerning the functionalities (Question 13), the possibility of presenting game pause resources, the suggestion of adapting the activity to be carried out also with the upper limbs, in addition to the inclusion of sensors and techniques that could monitor the feeling of tiredness and fatigue in the lower limbs.

As limitations and restrictions (Question 14), the experts pointed out hygiene, the possibility of sharing the cycle ergometer between patients, and internet connection, in addition to restrictions in certain contexts, such as in cases of severe heart diseases, where the physical presence of the health professional is essential.

The judges also recommended the use of CicloExergame for several health problems (Question 15): 3 (three) judges pointed out problems involving motor rehabilitation/telerehabilitation; 5 (five) emphasized motor problems together with neurological ones, such as Cerebrovascular Accidents; 7 (seven) reinforced respiratory problems; 6 (six) emphasized heart problems; 2 (two) mentioned rehabilitation after periods of a long stay in intensive care units; 2 (two) reinforced the possibility of use in post-COVID-19 rehabilitation cases, and 2 (two) indicated the use in elderly patients.

In general, CicloExergame was evaluated as effective by experts. The points raised in the assertions were an object of consensus and the open-ended questions raised elements that can lead to improvements in the project.

6.4 Evaluation - Second Round

To carry out the second evaluation round, the same parameters as in the previous round were considered, concerning the objectives, needs, and parameters (consensus definition). In general, the suggestions and problems raised by the judges in the first round of responses and also the evolution of the project stages brought new demands.

Therefore, a new questionnaire was prepared, to be applied to the same judges, in order to clarify the following points: patient ergonomics when using the cycle ergometer in conjunction with the game, the possibility of using it also for treatment with the upper limbs, in addition to the degree of exergame's adequacy in the context of telerehabilitation sessions, given that there was some divergence about to this is-

Table 2. Questions created for the evaluation.

Multiple-Choice Questions (Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree)	
1. Applying the presented exergame during rehabilitation or telerehabilitation sessions with a cycle ergometer engages the patient in the activity.	**2.** The exergame makes it possible to carry out the session with the active participation of the physiotherapist, even if remotely.
3. The developed exergame sufficiently allows telerehabilitation sessions to be carried out.	**4.** The initial settings options available to the physiotherapist are satisfactory and allow a proper customization of the activity.
5. The possibility to follow the patient's performance in real time through the performance graph is satisfactory.	**6.** The possibility for the physiotherapist to customize the activity (expected minimum and maximum values of heart rate and SPO2, duration and expected speed), after starting the session, through the settings panel, is satisfactory.
7. The possibility of adding an avatar so that the physiotherapist is "next to the patient" promotes engagement.	**8.** The possibility of using an additional control for the patient to command the character's movements along with the cycle ergometer makes the patient feel more engaged in the game.
9. The auxiliary video call system is useful for communication between the patient and the physiotherapist.	**10.** The display of data on the patient's screen (number of pedal strokes, speed, heart rate and SPO2) helps in carrying out the activity.
11. The display of data on the physiotherapist's screen (number of pedal strokes, speed, heart rate and SPO2) helps monitoring the activity.	**12.** In general, the presented exergame fulfills the objectives it proposes and is a satisfactory solution.
Open-Ended Questions	
13. Do you notice any functionality that could be added to the game? Any additional contribution for the project?	**14.** Do you see any limitations or restrictions regarding the use of the game in rehabilitation or telerehabilitation sessions?
15. For which health problems would you recommend using this game in a rehabilitation or telerehabilitation case/scenario?	**16.** Any additional comments or remarks?

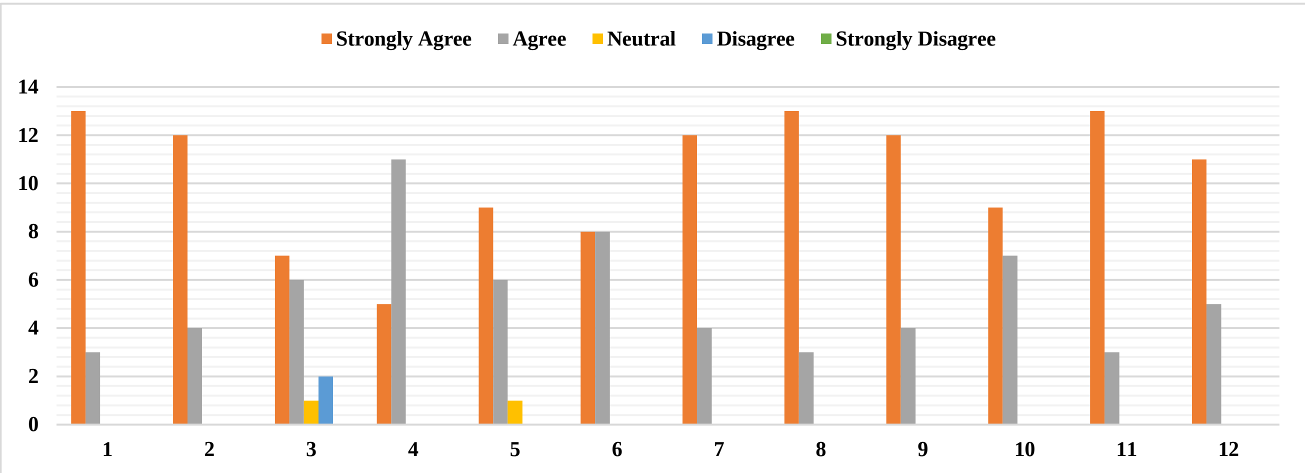

Figure 11. Distribution of answers to the multiple-choice questions of the first round.

sue. Faced with the suspicion that the disagreement might have occurred because of a semantic issue related to the use of the word "sufficient" in the question that generated disagreement (which may suggest the exclusion/replacement of the health professional), this term was changed to "satisfactory", which expresses in a less ambiguous way what was intended from the beginning.

From these new definitions, the questionnaire (Table 3) was again sent to the same judges as before. Of the 16 professionals contacted the first time, two had their contract canceled with the institution and were, therefore, unable to respond to the second round. A new deadline of 15 days was granted for the response. After this time, the team analyzed the results.

6.5 Second Round - Results

Based on the results of the first round, the second round was responsible for addressing the issues that generated some divergence between the judges, especially regarding the sufficiency of CicloExergame for the performance of the sessions, in addition to the suggestions of the experts. Of the 14 judges contacted, a total of 9 responded to the invitation and answered the questionnaire. This represents an abstention/dropout of approximately 35.7%, which is within the standards expected by the Delphi Method, which provides for drop-outs of up to 50% between rounds (de Cássia Barros Dias, 2007).

What follows, therefore, is an analysis of the answers given by the judges, along the same lines as the previous analysis. The graph in Fig. 12 shows how the multiple-choice responses (Likert Scale) are distributed. From this overview, it is possible to analyze the results of each specific question (again, the percentages are in approximate values).

The first was built on account of the investigation of the cause of the small divergence in question 3 of the previous questionnaire, and it is plausible that there is a comparison of the results. The percentage of agreement increased from 81.3% (in the first step) to 88.8% (percentage increase of 7.5%), with 33.3% of strong agreement, and the rest (55.5%) also in agreement. A judge presented neutrality, a fact that

Table 3. Questions created for the second round.

Multiple-Choice Questions (Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree)	
1. The developed exergame satisfactorily allows telerehabilitation sessions to be carried out - not dispensing with the participation of the physical therapist.	**2.** The patient can use the exergame in the LYING use position. In this case, the screen is in front of him.
3. The patient can use the exergame in the SEAT use position. In this case, the screen is in front of him.	**5.** The exergame can also be used for the upper limbs, without major adaptations.
Open-Ended Questions	
4. Do you suggest any other positions in which the patient can perform the activities with the exergame?	**6.** Any additional comments or remarks?

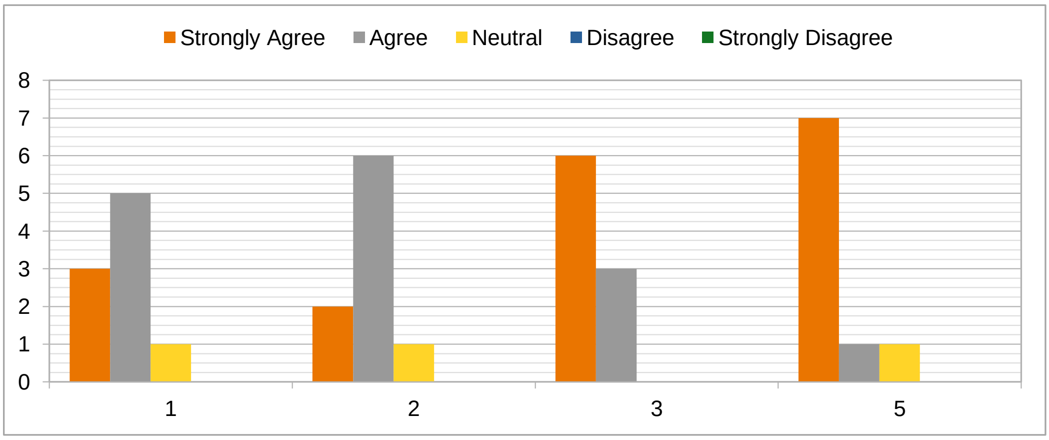

Figure 12. Distribution of answers to the second round multiple-choice questions.

also occurred previously. When analyzing the change or maintenance of the opinion of each judge between the rounds, it was possible to notice that 44.4% of the experts increased a degree of agreement (migrated from "I agree" to "I strongly agree", for example), while 33.4% maintained their opinion and two judges (22.2%) decreased their agreement by one degree. Of the two judges who presented disagreement in the first round, one migrated his position to agreement, while the other did not respond to the questionnaire. This analysis allows us to verify that, firstly, it is possible to declare consensus on this issue and, secondly, that there is a high probability that the divergence generated in the first step was a semantic issue and was not related to any aspect of exergame. Given the stability in the answers and the conclusions obtained, this point can be declared validated and closed.

In question 2, we have a strong agreement percentage of 22.2% and agreement of 66.6%, so it is possible to perceive the formation of a consensus, even though a judge has remained neutral. It appears that the game developed can be a solution for use in patients who are lying down. This is a point that attests to the versatility of the presented solution. In question 3, the sit position obtained 100% agreement, with 6 experts strongly agreeing and 3 agreeing. CicloExergame can be used in the sit position, the position for which it was originally designed. This question was passed unanimously.

As suggestions for additional positions in question 4, a judge suggested a position in which the patient, seated, reclines in a chair, which has back support, like an armchair. A second specialist proposed suspending the cycle ergometer on a table to perform exercises with the upper limbs. Also, in this case, the patient is seated in a chair, facing the device. These answers further expand the range of use possibilities for the developed game.

In question 5 we see another question that was evaluated positively by the judges. While one was neutral, the rest was distributed between strong agreement (77.7%) and agreement (11.1%). The game developed can be used in the upper limbs, according to the experts consulted. There is, also at this point, statistical convergence of responses for agreement and, therefore, there is consensus.

In this last question, only one expert made his remarks. He states that the characteristics of a game like this can cause difficulties in elderly and very debilitated patients, that is, it is not suitable for all types of patients. On the other hand, he points out that, in many cases, it is not possible to dispense with face-to-face sessions with the physiotherapist and that, in this space, too, the game is welcome to arouse greater motivation in patients. This observation again brings to view the limitations of exergame, although it also reinforces the positive aspect of promoting engagement/motivation that the game proposes.

In summary, CicloExergame was again the subject of a good evaluation by the judges, a fact that is corroborated by the consensus obtained on all questions. On the other hand, the comments and observations in the open-ended questions pointed to the versatility of the solution presented, albeit in a context of limitations inherent to its nature. With no new open points, the completion of this second round marked the end of the Delphi evaluation step.

7 Conclusion

This project presents CicloExergame, a distributed exergame that aims to make it possible to carry out telerehabilitation sessions for patients who use the cycle ergometer in their treatment. The game aims to offer a playful experience, which aims to increase the patient's engagement and mitigate the difficulties encountered by health professionals in this process, such as the possibility of configuring and monitoring the performance of the activity and interacting with the patient.

For the evaluation of the project, two rounds were done based on the Delphi Method. Counting on the opinions of 16 specialists in the first round and 9 in the second, it was possible to verify the validity of several points about the developed solution, as well as to collect suggestions for the continuity of the project. The results of the two rounds revealed a good evaluation of the solution, considered effective in the context of patient's telerehabilitation.

The next steps of the project will continue the process of the exergame effectiveness' evaluation. In this sense, carrying out a stage of tests with patients in a hospital unit (short term) or even carrying out a clinical intervention study (long term) with deeper analysis (cost-effectiveness in contrast with traditional therapy, for example, or detecting possible "side effects" of using the game) is a possibility to be explored. On the other hand, a comparative study with other available solutions (those presented as related works, for example) can evaluate the efficiency of CicloExergame in the context of games used in functional rehabilitation.

Finally, it is expected to impact the lives of patients who have difficulties related to access and engagement in therapy. In the current circumstances, the present project wants to indicate an alternative for access to care and rehabilitation sessions, increasing the patients' quality of life. On the other hand, the possibility of carrying this out using games wants to be a factor that impacts the quality of the sessions' results, being funnier and less boring or repetitive. It is expected that the impacts will be significant and the results will also be improved. Therefore, it is still expected that this solution will open ways and possibilities for the telerehabilitation scenario, still so recent in the Brazilian reality.

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