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Physioland: a motivational complement of physical therapy for patients with neurological diseases

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Abstract
The number of patients with mobility constraints is increasing as a result of neurological diseases. From the substantiation of the lost functions recoveries, it was possible to determine that the nervous system is able to reorganize itself expressing its property called neuroplasticity. Physical therapy is the well-known way to encourage and promote this ability. However, repetitive traditional physical therapy exercises may become boring and patients eventually abandon their physiotherapeutic programs. The development of new environments that motivate patients to continue with their treatments may be a suitable alternative or complementary tool. Serious games seems to be the ideal tool to provide them. Thus, the purpose of this paper is to present Physioland, a serious game already developed which can be a motivational complement for the physical therapy of patients with neurological diseases. Physioland is a non-invasive system that uses Image Processing Techniques and Artificial Intelligence to monitor patients and adapts some exercises of traditional physical therapy to electronic game situations. To determine whether Physioland would be motivating and challenging enough to increase a patient's desire to perform the exercises and continue/complete the rehabilitation process the game was tested in a clinical environment using two samples: one with twelve health professionals in the area of physiotherapy and the other with eleven patients with neurological diseases. The research team carried out a questionnaire-based survey. This questionnaire is an adaptation of another one already validated in the literature—the Technology Acceptance Model (TAM). For the analysis of the data obtained with the Likert scale, percentages were calculated. The answers to the open questions were subject to a content analysis. The results showed that the developed game, Physioland, proved to be highly motivating for patients at the physiotherapy clinic where it was tested. If the results are similar in other clinics, Physioland, can be used as a good and effective complement to traditional physical therapy for patients with neurological diseases.

Keywords Mobility problems · Neurological diseases · Neuronal plasticity · Physical therapy · Serious games · Physioland · Patient motivation

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1 Introduction

Neurological diseases are a significant public health problem worldwide since more and more people are being affected. According to the most recent estimates from the Global Burden of Disease Study, which predicts, by November 2022, a world population of eight billion people, where one in three people in the world suffers from a neurological disorder, which can vary from the simplest to the most complex. According to the same study, neurological disorders are currently the leading cause of disability, with stroke the largest contributor, with a percentage of 42.2% [10].

For the majority the sequelae left by these diseases is observed by changes and kinesis functional disorders which require regular practice of physical therapy in order to achieve the highest possible degree of physical autonomy. However, the repetitive nature of the physiotherapeutic exercises that this kind of treatments involve makes them boring and patients can more easily become unmotivated and leave therapy. The solution to the problem of discouragement and abandonment of treatments by patients is to find new ways of practicing physical therapy that encourage and lead them to accept their problems and fight for a better quality of life. Advances in technology have led to the development of serious games that can be the desired alternative with the opportunity of reducing the undesirable effects.

In the recent years there has been a significant increase in the number of serious games developed for physical therapy. Some studies related to serious games show very positive results regarding the recovery of motor functions while others have not yet been sufficiently tested to lead to definitive conclusions [9, 24, 27]. However, according to these studies they all managed to create pleasant environments where patients felt good and found meaning for their treatments and hope for their lives. The environments created helped the patients to gain the necessary motivation not to give up on their rehabilitation programs since they opened new avenues that empowered them, enabling them to reduce the impact of their limitations. There is currently a diversity of serious games aimed at physiotherapy, and many more will continue to be developed but the player himself needs new narratives, new graphics, new mechanics to get motivated over time. The idea of playing the same game every day will demotivate the patient, in the same way that the same exercises also demotivates him. Following this line of thought, the purpose of this paper is to present Physioland, a serious game which can be a motivational complement for the physical therapy of patients with neurological diseases.

Physioland, with a simple narrative, framed in a medieval period, joins the existing games, as an alternative to promote the motivation of the practice of traditional physical therapy to patients with neurological diseases. Through Image Processing Techniques and Artificial Intelligence, it is possible to understand if the patient is correctly performing a conventional physiotherapy exercise and adapts these movements to electronic game situations as a source of motivation. It differs from any game for XBox or Kinect, because it was designed specifically for physical therapy purposes, not being an adaptation of existing games. In addition, it has a different narrative and different mechanics and player experience. It is non-invasive game and does not require any kind of pre-calibration, which ends up giving the player a better experience. The good usability and experience combined with the smooth functioning of the entire system are also an added value. So, the research question considered in this study is: "Will Physioland be a serious game that effectively motivates the practice of physiotherapy for patients with neurological diseases?".

2 Neuroplasticity and physical therapy, serious games and motivation

The occurrence of injuries in neurons is revealed through neurological disease since such injuries are reflected in the neural networks of which the damaged neurons are part compromising the information transport [30]. In patients with neurological diseases such as stroke, Friedrich's ataxia, Parkinson's disease or multiple sclerosis, the injured regions of the Nervous System are related to motor circuits, so their mobility is affected.

Although in most cases recovery is almost impossible, frequent recoveries of lost functions after injury in neurons have been observed. This results from neuronal reorganization which is a consequence of a characteristic of the Nervous System known as neuroplasticity. In response to repeated stimuli, neuroplasticity facilitates the recovery of a lost function, helping patients to develop, maintain or restore maximum movement and functional capacity throughout life. It is up to physical therapy to select combinations of therapeutic procedures to trigger sensory stimuli capable of stimulating neuroplasticity [16, 31, 32, 34].

However, patients with motor dysfunctions are faced with repetitive exercises, which end up bothering them, discouraging them and, sometimes, making them give up on their physiotherapeutic programmes and treatments. Motivation is the keyword for them to persist in their programmes for as long as they need to, without getting discouraged [18, 19, 21]. The solution to triggering the motivation of neurological patients is probably to provide them with a playful environment that manages to involve them in a meaningful experience. This can be achieved through the use of serious games which integrate motivating factors for patients, such as feedback, stimulus control, stimulus and response modification [6, 15, 17, 24].

3 State of the art – serious games used in physical therapy and rehabilitation

Currently, serious games have become a tool with great potential to optimize the quality of life of people with mobility problems. Proof of this is the proliferation of serious games used in the areas of physiotherapy and rehabilitation, some of which are shown in the Table 1.

Although there are already a considerable number of serious games for physical therapy and rehabilitation, the works that have been reported in Table 1 show how important these games are when used to optimize and to improve the quality of life for patients with mobility problems. But in general, the serious games used are generic games that have been adapted to different situations. The solution we present in this paper consists of a game specifically based on exercises that traditional physiotherapy uses and which is exclusively intended for the treatment of patients with neurological diseases. It has a different narrative and different mechanics and player experience.

4 The Physioland game

4.1 Monitoring of physical therapy exercises

In order to promote the motivation and the monitoring of physiotherapeutic exercises of patients with mobility problems due to neurological disease, the research team proposed to develop a simple and non-invasive serious game exclusively based on Image Processing Techniques and Artificial Intelligence.

Table 1 Some serious games used in physiotherapy

Game Name Year	Target audience	Ages	Type	Environment	Hardware
PHYSIOLAND	Patients with neurologic diseases	All	Platform	3D Environment	Microsoft Kinect
— 2019 [5]	Parkinson's disease patients	All	Platform	3D Environment; Virtual Reality	Bio-sensors; Microsoft Kinect; Oculus Rift
— 2019 [12]	Stroke survivors	All	Platform	2D Environment	EMG Sensor
—- 2019 [11]	Stroke survivors	All	Platform	3D Environment; Virtual Reality	Oculus RIFT
— 2019 [4]	Post surgeries; Degenerative diseases victims	All	Platform	3D Environment; Virtual Reality	Oculus Rift; Microsoft Kinect; Leap motion controller
— 2019 [13]	Parkinson's disease patients	All	Sports	3D Environment	Microsoft Kinect
HarpyGame 2019 [8]	Stroke survivors	All	Platform	3D Environment	Joysticks
— 2020 [29]	Neurological diseases patients	All	Platform	3D Environment; Virtual Reality	Unity 3D; Microsoft Kinect
— 2020 [7]	Multiple sclerosis patients	All	Platform	3D Environment; Virtual Reality	Leap Motion Controller;
mimPong 2020 [25]	Hemiparetic stroke survivors	18 years old or more	Sports	2D Environment	Arduino with various sensors
— 2021 [26]	Stroke survivors	All	Platform	3D Environment; Virtual Reality	Wearable Sensor; Arduino with various sensors
MERLIN 2021 [28]	Chronic stroke patients (unilateral upper limb paresis)	All	Platform	2D Environment;	ArmAssist; Camera; Various sensors
— 2021 [3]	Children with neurological disorders	Children	Platform	3D Environment; Virtual Reality	Leap Motion Controller
— 2021 [33]	Stroke survivors	All	Sports; Platform	3D Environment; Virtual Reality	Intel Depth Sensor Camera

Table 1 (continued)

Game Name Year	Target audience	Ages	Type	Environment	Hardware
Stomp Joy 2021 [35]	Stroke survivors	All	Platform	3D Environment; Virtual Reality	Depth Sensor Camera
StepAR 2022 [1]	Multiple sclerosis patients	All	Platform	Augmented Reality based	Microsoft Kinect
— 2022 [14]	Stroke survivors, Musculoskeletal pain patients	All	Platform	Video Mapping based	Microsoft Kinect

The research team worked together with several specialists in the field of physiotherapy (physiatrists, physiotherapists and physiotherapy technicians), who gave relevant instructions that were combined with the system development and allowing a broader support in order to assure a proper research methodology. Firstly, there was a need to know the traditional physiotherapy exercises that patients perform in their treatment programs, that is, those exercises which are technically designed for a professional to rehabilitate a patient. Six exercises where defined whose dynamics differ from one to the other:upper limbs, lower limbs, free movement exercises and controlled movement exercises. In all cases, they can be performed standing (with or without support) or sitting.

The exercises performed by the patients are monitored only by a camera with a low-cost depth sensor (Miscrosoft Kinect). The system does not require pre-calibration or any other sensors, making it completely non-invasive. Through image acquisition, using various techniques (artificial intelligence, computer vision, trigonometry principles) it is possible to detect the different segments and joints of the human body and check whether the movements performed by the patients are being performed correctly.

The participation of the research team members in several physical therapy sessions conducted by physical rehabilitation professionals allowed to perceive that the detection of the correct performance of each exercise is made according to four main characteristics: angles defined by different body segments, alignment, compensation and speed [20].

Through artificial intelligence techniques—in this case deep learning—it was possible to train the system (different people, with different shapes, standing, sitting or supported positions) to detect if a certain physiotherapeutic exercise was being correctly executed or not. One of the big challenges was not to compromise the performance of the system, since the game had to be played in real time.

4.2 Integrated solution

Physioland is based on an integrated solution of five main pillars: the game, the main component of the system (standalone application), which itself has its own database; the remote database, the central component that supports all the information storage of the system; the backoffice, a centralised application for the management of the game, web-based; the API (application programming interface), which is the bridge between the game and the database and between the backoffice and the database; the solution users (patients—players, physiotherapists, physiatrists and administrators) who have different roles and privileges throughout the system architecture.

The use case diagram shown in Fig. 1 describes the functionality proposed for the integrated solution and where the interactions between the actors and the system can be observed.

One of the main cores of the integrated solution is the remote database that supports the storage of all inherent information, namely information about health units, staff, patients and other relevant information. The Entity-Relatioship (E-R) diagram is shown in Fig. 2. In the free mode, the patient caretaker can adjust all settings to perform at a specific level. In this case the results are not sent to the remote database, they are only stored locally.

The normalization of the class diagram database presented in Fig. 2 was performed in order to organize the data to reduce redundancy and improve data integrity. This process considered to identify the functional dependencies between the attributes in each table, to define the primary key for each table, to eliminate partial dependencies by creating new tables that have a one-to-many relationship with the original table, to eliminate transitive

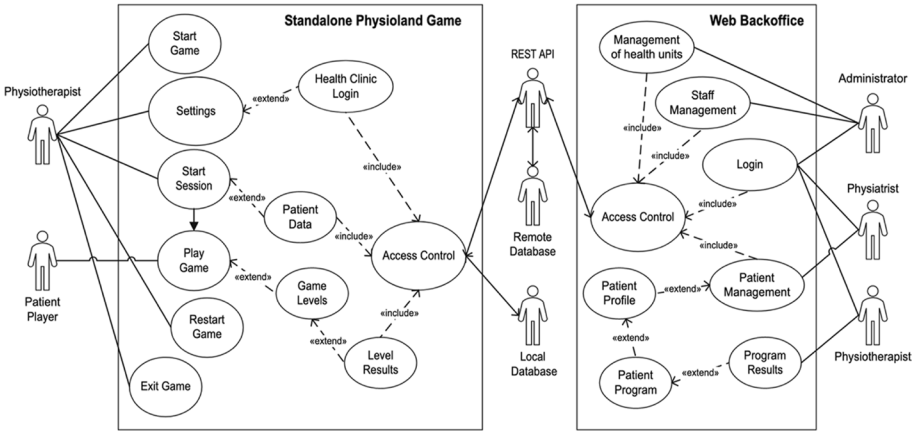

Fig. 1 Use Case Diagram of Physioland Integrated Solution

dependencies by creating new tables that have a one-to-many relationship with the original table, to check for insertion, deletion, and update anomalies in order to ensure that the tables are normalized.

4.3 Physioland – the game

Physioland game is based on a medieval concept being this concept one of the points that differentiates it from other games. Since the style is the same for all ages, it is always difficult to please everyone. However, this style had already been successfully used for the

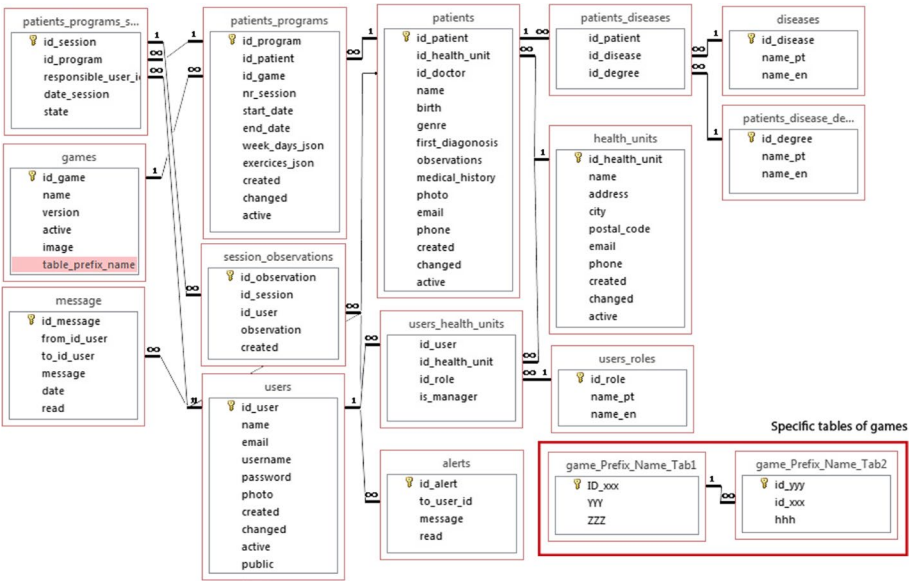

Fig. 2 E-R Diagram of the Remote Database [22]

same purpose in a prototype called PhysioVinci, having revealed to be generically interesting for different age groups [2]. Physioland game recreates a 3D environment developed with the Unity 3D game engine using the programming languages C# and Javascript. It was tried to endow the game with a narrative that neurological patients could easily understand. Characters and other 3D elements were obtained from available banks of images, in order to develop the graphic component of the game. The research team also made use of easy implementation software that facilitated the design of 3D elements and the animation of characters.

The game is generally made up of game modes, configurations and levels. It should be remembered, first of all, that the player should always be accompanied by a physical rehabilitation professional who is responsible for providing him/her with the challenges provided by the game.

After the Physioland loading screen (Fig. 3 (a)), the main menu (Fig. 3 (b)) appears with the options: normal mode, free mode and settings. In the settings, the user can set the sound volumes, both for music and effects, the language to be used in the game, deactivate or activate the alerts, when the exercises are being badly executed, as well as check the existence of new updates (Fig. 3 (c)). The login is compulsory to play in normal mode. In practice, the function of this login is to authenticate the clinic and not a user itself. Any health professional of a given clinic can use his/her credentials to login, being automatically assumed the clinic of that professional.

The game can be run in normal mode or free mode, the former being the most versatile and complete. When a health professional chooses this mode (clinic login is required in the settings and internet connection), the list of health professionals of the clinic that is logged in appears to him/her. After selecting the health professional, the list of patients of the chosen professional is displayed to him/her, and when one of these is selected, he/she can see

Fig. 3 Physioland screenshots: (**a**) Physioland loading screen; (**b**) Main menu; (**c**) Settings

the summary table of the same. Next, the levels are loaded, with the respective settings of that patient. At the beginning of each level, a screen is displayed with information about it, together with an animation showing how the exercise should be carried out. At the end of each level, a summary is shown with the score obtained. After the sequential execution of all the levels aimed at the player, he/she is redirected to a screen at the end of the game and then the option is shown to return to the main menu or to exit the game. In this game mode, all information about the player's results is sent to the remote database.

Free mode is best suited for patients who are not yet registered in the database, or when there is no internet connection. In this mode, it is possible to customise the levels to be played and their settings. The levels are loaded and the process is similar to normal mode. In this case, the best score of each level is the maximum score obtained by all players together. This data is stored in the local database.

Figure 4 represents the flowchart of the Physioland game.

4.4 Physioland levels

As already mentioned, the Physioland is based on a simple narrative, which refers to a story that takes place in a village, in medieval times. A man (main character) lives there and has to win six challenges (levels of play) to ensure his livelihood, as well as for his wife and son.

The center of a medieval village is the scene for the game's first level, which motivated the patients to give the name "village" to this challenge (Fig. 5). The exercise performed here is composed of two opposing movements: the abduction, in the upward direction, and the adduction in the downward direction. This exercise should be performed with the arm extended, that is the arm-forearm angle should be equal to 180º. In turn, the angle formed by the upper limb and the midline of the body should vary between 0° and 180°. The joints must be aligned in the frontal plane which is the execution plan of this exercise. So that there is no compensation, the joints must be aligned horizontally and vertically.

The scenario chosen for the second level shows a tower, at the top of which is the main character. The name of this level is "sunset" (Fig. 6). Here it is performed the exercise of the flexion/extension of the glenohumeral joint that must be performed by the patient in the sagittal plane. The angles monitored are exactly the same as in the previous exercise. The compensation check follows the same procedure of the previous exercise, but the alignment must be checked in the frontal and sagittal planes.

"Boat" was the name that the patients had chosen for the third level of the game (Fig. 7). At this exercice the patient performs the flexion/extension exercise of the radioumeral joint. Throughout the exercise the angle obtained by the arm and the midline of the body should remain equal to 90°. The arm-forearm angle should vary between 30° and 180°, decreasingly in flexion, and increasing in extension. The procedure for monitoring angles, checking alignments, and compensations, is the same that is used in the first level.

Patients assigned the name "cascade" to the fourth level of the game (Fig. 8). At this level, the patient performs the physiotherapeutic exercise of the abduction/adduction of the hip joint. It is the only challenge of the Physioland that allows to exercise the lower limbs. The lower limb that is performing the exercise should remain stretched, that is the thigh-leg angle should be equal to 180º during the whole execution of the movement. The

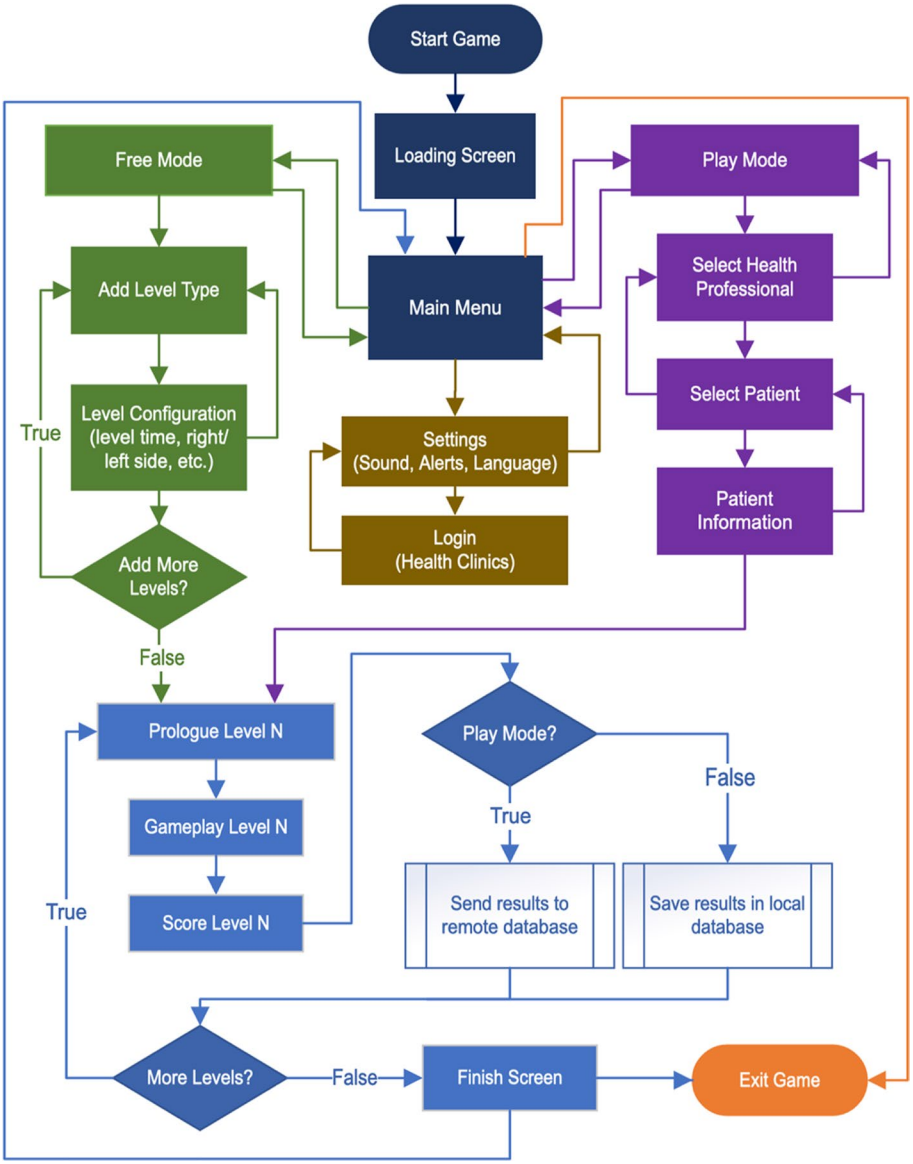

Fig. 4 Physioland flowchart

thigh-midline angle of the body should be approximately between 0° and 30°—alignment and compensation monitoring follows the same procedures of the previous levels.

"Bridge" was the name given by patients to the fifth challenge (Fig. 9). It is an exercise performed in oblique planes to the frontal and sagittal planes (there is no fixed plane of execution), in which the patient has to reach a target that the physiotherapist places, in a random way, either to the right or to the left, forcing him/her to move forward and up or down the arm on the opposite side where the target appears. Due to the great flexibility

Fig. 5 Screenshot and storyboard of the first level of Physioland game [23]

of movements that this exercise allows only the compensation is monitored in a similar way as in the other exercises. There are also no predefined values of the angles defined by the involved joints.

Patients suggested the name "Fishing" for the sixth and last level of Physioland (Fig. 10). In this level collecting coins is only possible by preventing them from falling into the water. So, the patient has to perform the pulley exercise—so called because it uses a system of these pieces. It is a combination of abduction/adduction of the glenohumeral joint and flexion/extension of the radioumeral joint, therefore performed in the frontal plane.

The techniques used for their monitoring are a mixture of those that have been used specifically for each of the components, with regard to the determination of angles, verification of alignments and compensations. The difficulty degrees of easy, medium, difficult, and very difficult were defined in this sixth level, based on the speed with which the coins fall.

On the right side of the game screen there is a vertical scale, which varies in color, between green, yellow, orange and red and gives information on the acceleration of the patient's movement through an arrow on the left of the graph which moves up or down, depending on the direction of the movement. This information allows the player to see how he/she is controlling the speed of the exercise.

Fig. 6 Screenshot and storyboard of the second level of Physioland game [23]

Fig. 7 Screenshot and storyboard of the third level of Physioland game [23]

5 Methodology

An experiment in clinical environment was prepared to test Physioland in an attempt to understand if the developed game could solve the problem of patient motivation for the practice of physical therapy. In this experiment, patients themselves and professionals from different domains such as physiotherapy specialists and game designers worked together with the authors/research team.

As already indicated in the Introduction section, the research question considered in this study was: "Will Physioland be a serious game that effectively motivates the practice of physiotherapy for patients with neurological diseases?".

To gather information allowing to fulfill the research question, the data collection instrument used was a questionnaire, as it was considered the most appropriated approach for the target audience: patients with neurological diseases. It was applied to both health professionals and patients.

5.1 Questionnaire description

The questionnaire used is an adaptation of another already validated in the literature – the Technology Acceptance Model (TAM). Several reasons contributed for it to be the model

Fig. 8 Screenshot and storyboard of the fourth level of Physioland game [23]

Fig. 9 Screenshot and storyboard of the fifth level of Physioland game [23]

chosen among the existing ones: it is a specific model for information systems; it is considered one of the most influential and most widely used to describe the acceptance of a given technology; it has a strong theoretical base, in addition to broad empirical support through validations, applications and replications; having already been tested with different samples and in different situations, it proved to be valid and reliable.

It is divided into three parts. The first part allows to gather data for the characterization of the health professionals/patients. The second part, regarding usability and satisfaction, comprises a total of twenty-one items, distributed in three groups: A, B. C. In this part, similar to TAM, the seven-point Likert scale was used, which sought to place the opinion of each respondent on a bipolar scale (two opposite poles: "disagree" (D) and "agree" (A), left and right, respectively), with the levels of affirmation "strongly" (Str), "quite" (Qt) and "slightly" (Sly), from each pole, and having a "neutral" (Neut) level of affirmation at the center. The participant was asked to indicate the option that best suited their level of agreement. Group A consists of seven items to obtain information associated with the ease of use of Physioland. Group B also has seven items related to the appearance and performance of the game. Group C includes the remaining seven items related to use satisfaction. The third part of the questionnaire regarding the appreciation of Physioland, has seven open questions, used to allow respondents to freely express themselves about certain aspects and functionalities of the developed game.

Fig. 10 Screenshot and storyboard of the sixth level of Physioland game [23]

5.2 Samples characterization

The type of sampling used was non-probabilistic convenience sampling. In fact, most health professionals from the physiotherapy clinic where the experiment took place, and patients from the same clinic with mild or moderate neurological diseases, with compatible schedules, made themselves available to participate in the tests. In this way, two samples were constituted (the only possible ones), one for each type of participant, which are characterized below.

The health professionals sample consists of twelve participants, seven of them male. Six of them are between the age of 25 and 34, five are between the age of 35 and 44, and there is only one that by little is not in this last age group. Two of them are physical technicians, five are physical therapists and the other five practice the profession of physiatrists.

The sample patients has a total of eleven participants, all victims of neurological diseases, distributed as follows: two participants with an age from 15 to 24 years old, two participants from 25 to 34 years old and two from 45 to 64 years old and other five aged no less than 65 years. Seven are female. With regard to the diseases that affected them, six were victims of stroke, three were diagnosed with Strumphell-Lorrain disease, one had meningitis, and the prematurity of another caused spastic diplegia. The sequelae left by these diseases and which take them to the physical rehabilitation center are hemiparesis (six), paraparesis (three), hemidystonia (one), cerebellar syndrome (one), diplegia (one) and hemi-hyposthesia (one). It should be noted that some patients have more than one disability.

5.3 Experimental procedure

In the development of the serious game it was necessary to know the physiotherapeutic plans prescribed for these type of patients. So, firstly, managers of some physical therapy clinics were contacted in order to schedule meetings with health professionals in this area. These meetings allowed the research team to understand better which physiotherapeutic exercises are transversal to a greater number of neurological diseases After an in-depth analysis of how the different physiotherapeutic exercises are performed, six of them were chosen that are susceptible to be monitored through image processing techniques and adapted to electronic game situations.

After the development of the serious game Physioland, tests were carried out in a clinical environment, both by health professionals and patients, which allowed the game to be validated.

The tests with the health professionals took place during a week, taking into account their availability. Individually, they were elucidated about the general concept and objectives of Physioland. They were asked to put themselves in an initial position and saw a video with one of the exercises that they should perform; then they were explained the procedure to follow to fulfill the goal of the level of the game that uses that exercise. We proceeded in the same way with the remaining levels. After the experimentation of the game, they were presented the questionnaire used as a data collection instrument.

With respect to the patients, they were given the possibility of using the game in two weekly sessions, with a unitary duration of approximately thirty minutes, ranging from twelve to fifteen the total sessions attended by each one. When each patient performed any level for the first time, he/she was instructed to understand the exercise and received information about its dynamics. Since the game chronometer is setup, so that the duration of each exercise is five minutes or two and a half minutes, each patient had the possibility to perform several exercises of their physiotherapeutic plan in each session, which were modified from session for session, as instructed by the health professional. When the

experiment came to an end it was sought to know their opinions about Physioland through the questionnaire that was given to them.

As for the analysis of the results, regarding the first part of the questionnaire, only counts were made for the characterization of the samples. Considering the second part (Likert scale), the variables under study (ease of use, appearance and performance of Physioland, and use satisfaction) are not directly observable (latent variables), and each one of them must be obtained through the items of the respective groups. Taking into account the reduced size of the samples, the only possible analysis consisted in calculating, for each item, the percentages of the respondents' opinions recorded in each of the levels of affirmation. Therefore, for each of the latent variables, the average of the percentages obtained in each of the levels of affirmation of the items of the respective group was calculated. With regard to the open-ended questions, a content analysis was carried out, marking the opinions that were considered relevant, to constitute a categorization system, then inserting the information collected in the respective category of the defined system, noting the number of occurrences of each one of them.

6 Results – analysis and discussion

Before presenting the results, it should be noted that the following abbreviations and their meanings will be used in the graphs below: Str D –strongly disagree; Qt D – quite disagree; Sly D – slightly disagree; Neut – neutral; Sly A – slightly agree; Qt A – quite agree; Str A –strongly agree.

6.1 Ease of use

For the ease of use of Physioland the results obtained can be seen in Fig. 11.

All participants, patients or health professionals, responded positively to the seven items present in group A, regardless of the sample, age or gender: they found easy to implement the instructions given to use the system; everyone agreed the procedure for starting the game is intuitive; everyone thought it was easy: take a stand; interpret the exercises;

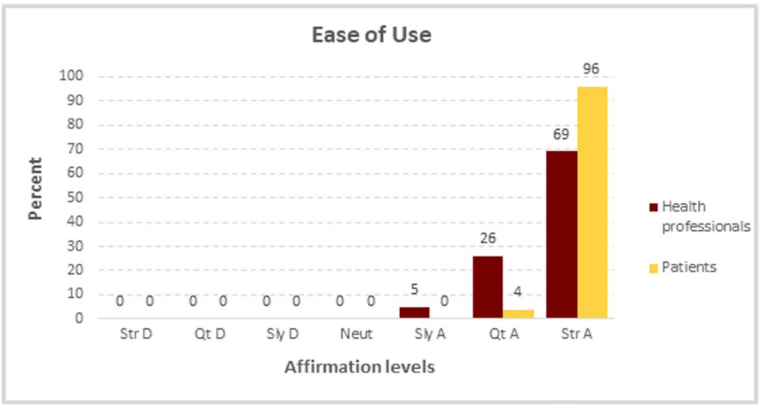

Fig. 11 Percentages related to Physioland ease of use

execute them; interact with the game; learn to work with it. In the graph (Fig. 11) only the bars of the latent variable "ease of use" appear, which are the averages of the percentages obtained for the different items, in each of the affirmation levels. These percentage bars appear only on the right part of the considered scale, which means that all participants marked their opinions at the affirmation levels close to the positive pole. In short, for all elements of both samples, Physioland's ease of use is a reality.

6.2 Appearance and performance

The graph in Fig. 12 summarizes the results obtained for Physioland appearance and performance.

In terms of appearance and performance, Physioland deserved the approval of the participants of both samples, in the seven items that constitute the group B, except in one or another less favorable point of view, with respect to the subjective aspects, as is the case of audiovisual interface (colors and music), with very small percentages. However, for the majority of participants, the developed game has an appealing appearance; fits the purpose for which it was defined; the sound is pleasant and adequate; the operation is good; the animations are interesting; physiotherapeutic movements are well adapted to game situations; does not lead the player to be distracted from the correct practice of the proposed exercises. Similar to what was mentioned for the latent variable "ease of use", in this graph (Fig. 12) the bars also correspond to the mean percentages obtained for the various items, at different levels of affirmation, that is, the percentages achieved for the latent variable "appearance and performance". Thus, it also confirms that the majority of participants, from one sample or another, agree with the Physioland "appearance and performance".

6.3 Use satisfaction

The results obtained for Physioland use satisfaction can be observed in Fig. 13.

Regarding use satisfaction, both health professionals and patients, agreed unanimously in considering Physioland as a fun, useful game with an attractive environment; a game capable of motivating a patient to continue the physiotherapy treatment replacing the

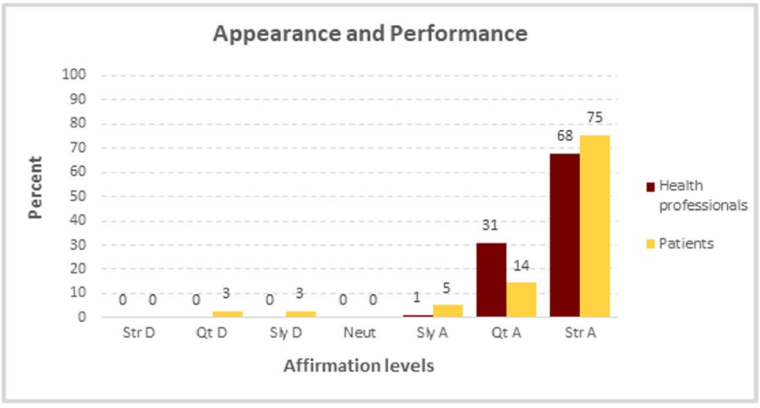

Fig. 12 Percentages related to Physioland appearance and performance

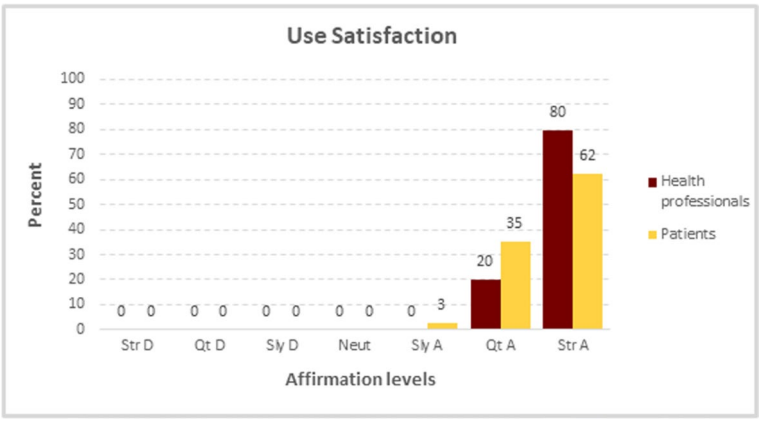

Fig. 13 Percentages related to Physioland use satisfaction

annoyance that traditional physiotherapy provokes with the enthusiasm that the challenge inspires.

6.4 Aspects and functionalities

The third part, with questions that require free and spontaneous answers about certain aspects and functionalities of the developed game, includes a question whose answers allow to know the negative aspects found by the participants, in Physioland.

All responses (health professionals and patient) were compiled and categorized. The categories that emerged from the analysis are summarized in Figs. 14 and 15.

As one can see in Figs. 14 and 15, the majority of participants, both health professionals and patients, did not find any negative aspects in Physioland. It is also believed that some aspects, such as the audiovisual interface, were considered negative, as they depend on the social environment and the personal preference of the participants who indicated them.

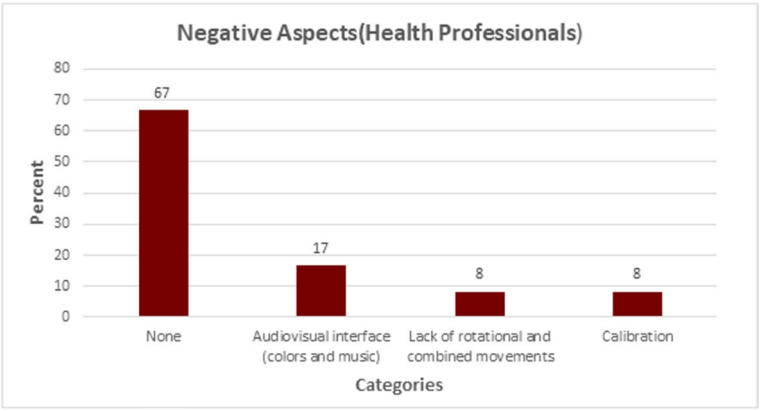

Fig. 14 Negative aspects referred by health professionals

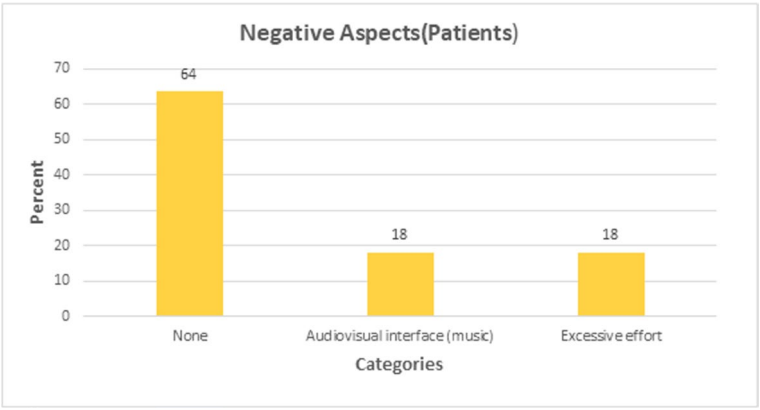

Fig. 15 Negative aspects referred by patients

The third part of the questionnaire ends with the question with which is intended that the participants make a general evaluation of Physioland. The categories found in the answers to this question can be seen in Figs. 16 and 17.

The information obtained in this third part of the questionnaire confirms the results already presented, revealing that Physioland is an innovative, interesting, challenging tool and, above all, an effective tool to increase the motivation of patients with neurological diseases to practice physiotherapy.

7 Conclusion and future work

First of all, it should be noted that, in most cases, the consequences left by neurological diseases are irreversible. Affected patients are unlikely to get better. Therefore, they will need physical therapy, perhaps, for the rest of their lives, just to maintain the quality of life

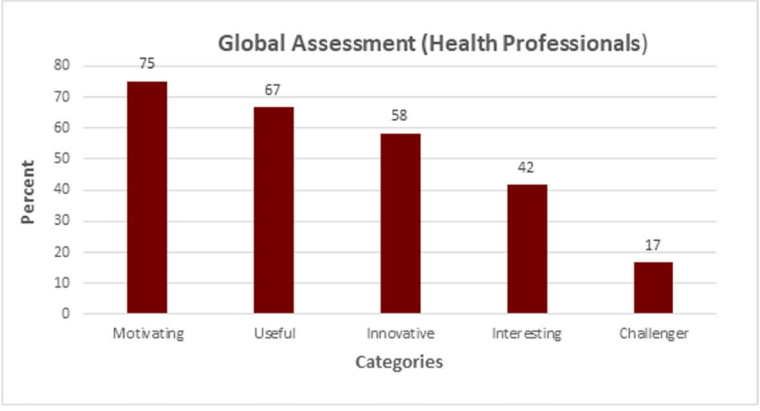

Fig. 16 Global assessment of Physioland (health professionals)

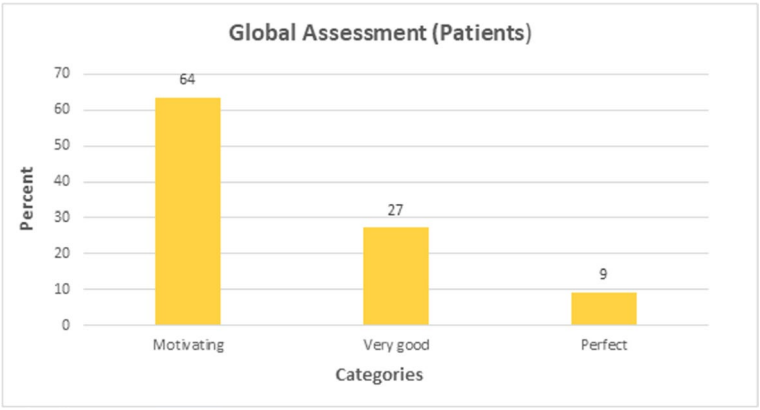

Fig. 17 Global assessment of Physioland (patients)

they still have, preventing the disease from getting worse. Therefore, the research team did not tryed to develop a game to improve the physical condition of these patients, but rather to motivate them to carry out their physiotherapeutic plans for as long as possible.

The game developed is Physioland, based on image processing techniques and artificial intelligence. The results obtained with the data collected by the questionnaire suggest that this game can be a motivational complement for the physiotherapy of patients with neurological diseases. The main aspect of Physioland taken from the results obtained from the respondents' opinions is its motivating role, which was the particularity most pointed out by the elements of both samples. Opinions on other aspects such as fun, challenge, pleasure, incentive, interest, already pointed in that direction.

Thus, the objective of developing a serious game capable of motivating neurological patients to carry out their physiotherapeutic treatments is fulfilled. In the clinic where it was tested, Physioland proved to be a serious game that was highly effective in motivating patients with neurological diseases to undergo physiotherapy. It is an original and creative game that offers challenges that replicate physiotherapeutic movements, aimed at patients with neurological diseases, which makes it a good motivational complement for performing traditional physiotherapy exercises.

The main limitation of this study is found in the small sample sizes that do not give them either significance or representativeness, but still a relevant case study. However, the research team did not intend to generalize results, but only to know the opinion of groups of participants, regarding a specific situation.

In response to the participants' suggestions, it was proposed, as future work, the integration of other exercises in the game, especially for the lower limbs, as well as the improvement of some aspects of Physioland, such as the possibility of choosing the avatar, soundtrack and appearance and, if possible, using larger samples. Further approaches may also consider the study of the game elements that can be used to motivate the physiotherapy commitment and adherence of the patients. Moreover, additional experiments with other empirically-validated tests, apart from TAM, could be considered, namely General Causality Orientations Scale (GCOS), Intrinsic Motivation Inventory (IMI), Self-Determination Scale (SDS) and ARC Self-Determination Scale (ARC SDC).

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