Serious Game for Motion Disorders Rehabilitation of Parkinson's Disease Patients

Ana Catarina Macedo, Rui Prada and Pedro A. Santos
Instituto Superior Técnico, Universidade de Lisboa and INESC-ID, Lisboa
{catarina.macedo, rui.prada, pedro.santos}@tecnico.ulisboa.pt

Joaquim J. Ferreira
Laboratory of Clinical Pharmacology and Therapeutics, Faculty of Medicine, University of Lisbon
Campus Neurológico Sénior, Torres Vedras
jferreira@medicina.ulisboa.pt

Josefa Domingos
Campus Neurológico Sénior, Torres Vedras
domingosjosefa@gmail.com

Abstract

Serious games have an entirely different purpose than just entertainment: they are meant to educate, make plans, help in the decision making progress or enable ill and elderly people recover from their illness and disabilities. These games' goal is to help solve problems through interactive and fun activities. They should have a beneficial effect on the players, having them make a noticeable progress throughout the entire treatment.

Our aim was to develop a serious game for Parkinson's disease patients. We explore the use of serious games and technologies to aid patients, by improving their lifestyle, delaying or reducing drug use, while still maintaining or improving function.

Our project is a game developed with Unity and using Kinect, where players have to perform a series of meaningful tasks (challenges) that aim to have the benefits previously referred, while being monitored by the therapists and doctors, who also control the parameters on which the game runs, tailored to each specific player. The main goals were achieved, with proven satisfaction and great feedback both from the patients and doctors.

Keywords

Parkinson's disease, motor disabilities, serious games, games for health, games for elderly

1. INTRODUCTION

Parkinson's disease is a neuro-degenerative disorder characterized by the clinic triad of bradykinesia, rigidity and tremor [1]. It can result in significant disability and morbidity for the millions of patients affected. Parkinson's disease primarily affects individuals aged 60 and older, limiting their functional mobility and, at times, their ability to sustain independent living [2]. It has been estimated that, across Western Europe's five and the world's ten most populous nations, there were between 4.1 and 4.6 million people over 50 years of age with Parkinson's in 2005. This total is expected to double to between 8.7 and 9.3 million by 2030 [3]. Parkinson's is the second most common neurodegenerative disorder, after Alzheimer's disease. Overall cost estimates for Parkinson's disease vary from country to country, but the largest component of direct cost is typically inpatient care and nursing home costs, while prescription drugs are the smallest contributor [4]. Indirect costs arising from productivity loss and career burden tend to be high. The total cost in the UK has been estimated to be between £449 million and £3.3 billion annually, depending on the cost model and prevalence rate used [4].

People with Parkinson's disease can live full and active lives, and an important part of this is leisure time and clinical treatments that involve physical activity, movements training and speech practice [5]. Parkinson's disease can make some activities difficult, but often the only restriction is the sole interest of the individual [5]. A person with Parkinson's disease should make an effort to keep up their social contact, continuing to interact with others and taking pride in themselves and their appearance. Someone who is open and honest about Parkinson's disease has no reason to feel anxious when out in public or when in the company of family and friends [6].

In addition to improving the overall quality of life, leisure activities like playing a videogame can also reduce stress and anxiety, revive personality, promote independence, exercise the body and brain, encourage a new or existing interest and provide an opportunity to enjoy an activity together with a caregiver, friend or loved one. It is very important to us that people who struggle with Parkinson's disease and other movement diseases every day, increase their sense of self-worth and independence, by achieving small tasks and improving a little every day, while staying at the comfort of their home and being around their loved ones. This is where games and videogames can help them immensely. We picked-up this opportunity and developed a serious game to support the treatments of people with Parkinson's disease.

2. RELATED WORK

This section describes a few interactive systems, such as games, that address a similar problem.

2.1 Rehabilitation Gaming System

The Rehabilitation Gaming System is a new and highly innovative Virtual Reality tool for the rehabilitation of deficits that occur after brain lesions. Currently, the Rehabilitation Gaming System has been successfully applied to the rehabilitation of the upper extremities after a stroke. The brain has a property called neuroplasticity, which is the brain capacity of changing and adapting itself due to changes in behaviour, environment or neural processes, as well as changes resulting from bodily injury, such as strokes [7]. This can be used to activate secondary motor areas such as the mirror neurons system (the ability to learn by imitation) [8].

While training with the Rehabilitation Gaming System, the patient is playing individualized games where movement execution is combined with the observation of correlated actions performed by a virtual body displayed in a first person perspective on the monitor. It also is a multilevel adaptive tool, providing a task oriented game training with individualized graded complexity. The system optimizes the user's training by analysing all the quantitative and qualitative aspects of the user's performance during the tasks. This allows for a detailed assessment of the deficits of the patient and their recovery dynamics.

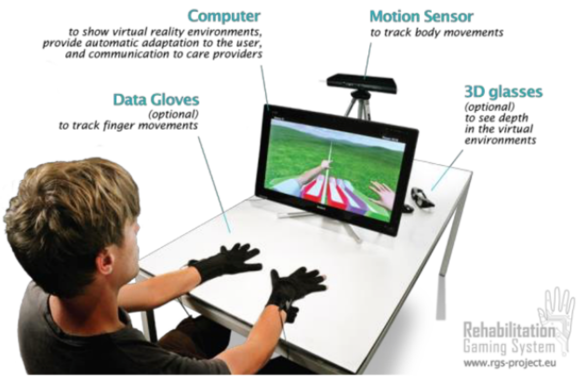

Figure 1: The Rehabilitation Gaming System

The Rehabilitation Gaming System is currently being evaluated in clinical studies and the initial results with 14 patients show a positive impact in their progress and recovery. It's also deployed in a number of hospitals with positive outcomes on rehabilitation. Strong points about this system are that it is designed to be portable and could be used at home, making home rehabilitation possible. The system also provides personalized cognitive and functional rehabilitation as well as giving the patients their status, progress, prognosis and individualized rehabilitation protocols. This is a good starting point for our own work as it is very similar in some points, like the rationale behind the scenarios. We decreased the hardware needed (only Kinect) and consequently the costs of the solution. But the principle of enabling patients to do their rehabilitation at home is shared.

2.2 Virtual Reality for Patients with Parkinson's disease

One of the primary symptoms of Parkinson's disease is the difficulty in the initiation and continuance of motions, especially during ambulation. Although the symptoms can be reduced or even mitigated by some drugs (like L-dopa) and medicines, these can become less and less effective over time, and they can also produce unwanted and harmful side effects (like choreiform and athetoid movements). The field of virtual reality has experienced an immense growth in recent years, which caused an appearance of practical applications that use this technology for many fields, particularly for medicine [9].

A new and alternative method was explored, developed and tested by a group of researchers (led by Weghorst and Riess) [10] [11]. Patients with Parkinson's disease who can't walk on open and plain ground are, paradoxically, able to step over objects with ease [12]. So the researchers wanted to test if Virtual Reality technology could provide a way to take advantage of this phenomenon and facilitate the patients' walk by placing virtual objects overlaid on their path [13]. The hardware used to test this method was a simple laser pointer and a display device with a visor and small lens mounted in front of one eye, reflecting a LCD (Virtual Vision Sport head-mounted display). For this technique to be successful, it was needed to meet various requirements. The virtual objects had to have some degree of realism: not exactly photorealism, but interactive realism as well, for example, adjustment to different walking speeds and changes of perspective with head tilts. A key factor in the success of this technique was the movement speed of the virtual cues [14], which had to be linked with the patient's gait speed; this way, these virtual cues are spaced at stride length.

The best results were obtained when the researchers combined the real world view with the virtual environment view [10] [11]. They partially occluded the visual field and projected continuous virtual objects, which in their tests were horizontal bars that were scrolling downward in the patient's visual field. This gave the patients the illusion of objects that were stable relative to the ground, so they could step over them. There was some evolution noticed on the patients. They had an increase in their stride length, which varied from patient to patient. Also, after a couple hours of practicing using the laser pointer as a cue, they were able to initiate and sustain gait without any cue. This effect was maintained, although weakly, for 2-3 months in some of the patients that tested this technology.

This study and tests were actually very important for an early concept of our own project, when we still thought about integrating challenges for the lower body. This idea was postponed for future work, but it was still a good way to find out which exercises would be more impactful on patients with Parkinson's disease.

2.3 Kinect-based Game to improve Cognitive Performance in Elderly

This work focuses on the effects that a Kinect-based exercise game can have on improving executive cognitive performance in elderly. The decrease of dual-task ability is a known fall-risk factor (which is by itself a symptom of Parkinson's disease). The researchers' team developed a new concept called Dual-Task Tai Chi (DTTC) using a Kinect device for motion-capture [15]. The DTTC test requires users to solve a number placement problem (Sudoku) by controlling a virtual stick figure on the screen using full-body motion. This motion is translated (in real time) into movements for the stick figure on the screen. The cognitive task is to fill 3 empty boxes chosen at random with digits ranging from 1 to 4. Basically, the user needs to do the following actions: select a digit using the right hand and left foot; point to the box using his left hand; and finally, move his right hand to the left hand to fill the indicated box with the selected digit.

The results revealed that DTTC training is effective at improving executive cognitive functions in particular [16]. This training was useful for improving balance ability and mobility among elderly people [16]. Authors also believe that DTTC training has the capability of improving both physical and cognitive functions.

In our work we got some inspiration from this project, since it correlates motion-based and cognitive-based exercises, and also uses the Kinect sensor for the upper body, exploring the same kind of movements as we did.

2.4 WiiPD

WiiPD is an approach to home-based objective assessment of Parkinson's disease (or other similar chronic conditions, such as post-stroke rehabilitation). WiiPD goal is to make use of the many different capabilities of the Nintendo Wii Remote in combination with data gathering methods to provide an engaging and rich user experience that can capture a wide range of motor and non-motor metrics. WiiPD researchers propose a low-cost and consumer-ready technology approach to gather detailed information about a patient's condition over extended periods of time. This approach has the potential for application in clinical decision support and disease management, with the possibility of providing doctors with suggestions for medication and/or therapy adjustments [17].

The most relevant tasks implemented in WiiPD were (Name | Description | Symptoms):

- Target Shooting: Move the cursor and click on n targets sequentially displayed in random location (Tremor, Bradykinesia);
- Target Holding: Same as Shooting, but the player must hold the cursor over each target for n seconds before the next target will appear (Tremor, Postural Tremor, Bradykinesia);
- Target Following: Follow a moving target with the cursor for n seconds. The target will follow a random path with increasing speed (Tremor, Bradykinesia);
- Target Sorting: Cognitive task in which users must click and drag a selection of blue and red targets to correct designated on-screen area (Cognitive function, Tremor, Bradykinesia).

It is proposed by the authors that the metrics analysed by WiiPD are capable of reflecting the severity of various Parkinson's disease motor symptoms. Movement accuracy and movement efficiency are metrics detailing fine motor movement and have the potential to reflect the severity of tremors and dyskinesias. Metrics which details gross motor movements, like completion time, reaction time, movement speed, error time and fatigue time may highlight the severity of bradykinesia and akinesia. We implemented some of these same metrics in our game, to evaluate the performance and evolution of each patient.

3. THE GAME

3.1 Overview

We propose a serious game that helps complement rehabilitation strategies used for Parkinson's disease patients. The game's guidelines follow many of the principles that were presented on the Related Work section of this paper.

The main idea is to use the Kinect with a PC for motion tracking, while the player/patient is presented with a series of challenges and mini-games in their TV/monitor. This setup is cost efficient, since it only requires off-the-shelf components that are currently available on the market.

This allows patients to greatly improve their lifestyle, since they will be able to do exercise activities integrated in their rehabilitation program from the comfort of their home and in the company of their loved ones (family and/or friends). This can complement their current rehab therapy and reduce the amount of trips they need to make to the clinics/hospitals, representing also a decrease in the costs associated with the treatment. Also, with this system, we also intended to study the possibility of allowing family members to take part in the therapy, by helping the patient to play the game and providing support in an interactive, engaging and fun way.

3.2 Game Design

Given our observations and discussions with therapists we find important to avoid negative feedback in the game, because this could hinder the motivation of the patient. Therefore, instead of losing points or receiving a negative message such as "Game Over" or "You Lost", we found that it is best to have positive feedback messages, even in case of failure (e.g., "You were really close... Try again!"). Also, when the player misses an objective or loses the game, the points are not lost. In that case, no points are awarded, but its previously achieved points are saved. This type of non-negative rewarding system reduces the stress and the frustration on the player, making him interested and engaged for a longer period.

In terms of design, our goal was to keep it simple, relatable to reality and with the most contrast between colours and between objects as possible. It is important to mention that, in the present stage of development, graphical design does not possess a great relevance in the game, since we are focusing on the methodology itself, the types of games that should be included and the effects that are introduced in therapy by this type of interactive treatment. Our main set is depicted in figure 2.

We also aimed at understanding which type of data could be collected and inferred through the application of serious games, such as our own, to therapy. Therefore, it was crucial to contextual inquires not only to the patients, but also the therapy personnel, caretakers and family members.

This assessment is very important to discover which data should (and can) be obtained from the gameplay, the information that should be kept in the patients history, find how to use this data to improve the patients' health condition, etc. At the present moment, we are monitoring and saving the patient's options, gameplay time, score and processed information about the type of movements (which include speed, acceleration and movement direction for each joint).

Figure 2: The main game setting

It was very important to keep in mind some theoretical assumptions and concerns of Parkinson's disease and its treatments. In our game we want patients to develop and improve function and we must know exactly what we can do to help patients in the best way possible. According to therapists it is important to work two different aspects: motor and cognitive. For motor exercises it was crucial to promote these movement characteristics: amplitude, complexity, speed and relevance. Grasping, reaching and flexing are good movement examples. For cognitive exercises we focused on these functions: work memory, visual exploration and divided attention.

The game developed addressed these concerns in the gameplay it promotes.

3.3 Game Modes

With the ideas obtained from the feedback provided by the therapists, we developed 4 main levels that were approved by the therapists after we presented them. In the second prototype we started allowing player to move along the X axis, because for the patients in an early stage of Parkinson's disease, this would increase the difficulty of the gameplay as they would have to move sideways to catch the objects. This was a setting that therapists could manipulate. Hence, four modes were developed: Normal, Numbers, Colours and Hands.

In the Normal level the goal is to catch as many balls as possible in the set time. Yellow balls will fall from the top of the screen and the player needs to move sideways and raise their hands and arms to catch them.

In the Numbers level there are four objects with the numbers from 1 to 4 falling from the top of the screen simultaneously, more slowly than the normal game. The goal here is for the player to catch all the four objects sequentially, from 1 to 4: the player only scores if for each sequence of objects that spawns, he gets all the four of them in ascending order.

In the Colours level there are balls with three different colours: yellow, blue and green. The goal in this level is that the player only catches the balls that are of the colour indicated on the screen, using a text that only shows for 3 seconds in order to work the memory of the player. Every time the player catches five balls of the right colour, the game randomly chooses another (or the same) colour that the player needs to catch.

The Hands level has the same set up as the Normal level: there are yellow balls falling from the top of the screen. Only in this level there is a new restriction, which is the hand with which the player can catch the ball. There is a text splashed on the screen for 3 seconds telling the player with which hand he should catch the balls. The designated hand changes after 5 balls being caught with the right hand.

3.4 Mapping real movements with game interactions

Our main concern since the very beginning, was to use the available technology to provide the best possible methods for real-life therapy. Therefore, after several meetings with the aforementioned specialists, we decided to perform a mapping that is mostly focused on the upper part of the body. This is due to two main reasons. The first reason is based on a technology limitation. Since the space available for walking both in a typical room and in the Kinect's range is limited, we decided to focus mostly on the upper torso and limbs, limiting the possibility of walking and strafing. Added to this is the fact that the studied methods of therapy are also mainly focused on the recovery of motor skills of the hands, arms and upper torso, which are more likely to be affected by Parkinson's symptoms.

3.5 Implementation

In terms of hardware, Kinect was our primary choice since the beginning, when we thought about developing the game. It is a motion sensing input device that enables the users to interact with the computer without the need of any additional hardware, using gestures and spoken commands. Microsoft has a software development kit (SDK) released and supported, which allowed us to build our game in a language that we were very comfortable with, C#.

For software, after some tries building a native application, we decided that we would build the game using

Unity (from Unity Technologies). Besides helping with the development time needed for bringing the game to life, since we had previous experience with the developing games with Unity, it would also allow us to make the game multiplatform: we could build for Windows, OSX, Linux and even the web. This was a major worry for us: we wanted to make sure that anyone and everyone could have the game installed in their personal computers at home and would be able to play it with the fewest setup and lowest cost possible.

ZigFu development kit (ZDK) was found to be the easiest way to make a true cross-platform and motion-controlled game with Kinect in Unity. All we needed to do was import the ZDK package into our project in Unity, and it would take care of all the needed bindings, as well as coming with some fully functional sample scenes and some 3D models of humans that we could use in our own game, with skeletons already set up and mapped for the Kinect joints.

4. DEMONSTRATION

4.1 First Prototype

For the first prototype we analysed all the feedback and suggestions that we received from initial mock-ups used in the initial contacts with patients and therapists and tried to come up with a solution that we could deploy in a short amount of time. We made this decision since we wanted to test our ideas with real patients as soon as we could, to see if we were heading in the right direction. We also wanted to see the impact that the game would have and to make sure that the patients would be able to play it with their condition.

We decided that as a first prototype we would develop a single level, very similar with the Level 4 of the paper mock-up. We set up the scene in Unity, with the virtual character in the middle of the screen that would be controlled by the player through the Kinect. There were balls falling from the top of the screen and in a given time, the patient would have to catch has many balls as he could (there were no forbidden objects). At first and since we were trying to be as safe as possible, we did not allow the character to move on the X axis. Even if the player moved sideways (by default and as we already explained, we did not allow the player to move forwards or backwards) the virtual character would stay in place and not follow the movement. We made the balls fall within arm's reach so players would not get frustrated by not being able to catch the ball just because it was impossible for being too far away. Every time the player catches a ball, a sound is played, we increment the visible score on the screen by 1 point and the ball disappears. On the screen a timer is also displayed, with the aim to make patients more engaged and add a stress factor to the game, which the therapists mentioned would be important for them to manage. The session time was 1 minute by default.

Our first prototyped worked as we envisioned and described it. This is when we could test our solution for the first time with real patients who volunteered to help us. We went to the Centro Neurológico Sénior and, accompanied by Dr. Josefa Domingos, we set up the whole system for patients to test (1 PC running Unity + ZigFu; 1 Kinect facing the patient; 1 Projector facing the wall). These first tests were extremely useful for our ongoing development. We could test if the solution was viable, meaning that we were able to validate that the patients could play the game with no difficulties and with a positive attitude. We had the opportunity to test the first prototype with two different patients, in two different stages of Parkinson's disease. The first one was still in a very early stage and had almost no visible motion or cognitive problems: we could notice some light tremors and a small difficulty in the speech. The patient agreed on us filming her during the two tests she made.

Figure 3: Testing the first prototype – Patient 1

The game worked really well and during the afterwards conversation we had with the patient, she said she was feeling happy to participate in the pilot and the game showed potential. She also said that she would like to have the game available in the clinic and at home. One thing that she noted though, was that the game was too easy for her: she felt like she wasn't challenged by it and didn't feel any effect after the exercise. We also asked about some specifics of the game:

- Would she prefer that the 3D character was tailored for her, having the same gender and physical characteristics?
  - She answered an immediate "no" because she would feel ashamed of having her body projected on a screen; the gender choice was indifferent;
- Would she prefer to play with someone else?
  - She answered that yes, she would rather be playing the game along with someone else because it would be more fun and it was very stressful to be playing by herself.
- Would she rather consider/call our project a game or a treatment?
  - She answered that if we said it was a treatment she would eventually play it more, because she would take it more seriously knowing that she was improving her skills and working on delaying the Parkinson's disease symptoms.

The second patient that agreed to participate in the pilot was in a more advanced stage. He had some noticeable speech problems and was already in a wheelchair. This allowed us to test if the game worked well under more restricted conditions, and if a person in a wheelchair would be able to play the game. We had to do some tweaks to the game before the patient could play it: we had to enable the Sitting Mode we developed and also narrow down the spawn area of the falling balls so they were always within reach.

In the end of the test, the patient shared many of the same opinions as the first one: he liked the activity, although it got frustrating in some points when the objects were unreachable for him (we had a bug in the code which did not allow us to properly set the area). He would also rather see the exercise as a treatment and not a game because it felt pointless if we referred to it as a game.

Our main goal with this visit was validating the solution we found and if it worked even within the constraints of Parkinson's disease patients. We considered it a success.

These first tests and direct contact with the patients and therapists changed many things on our development. After the tests, we all discussed how we could further develop the solution in order to improve the experience and create more impact on the patients: in terms of physical activity and psychological engagement and stimulation. We all agreed that we needed to develop more diversified challenges. We would also need to find a way to tailor the experience to each of the patients. It was also very important to save the history of the game sessions and having them associated with the patient who's playing it, so the therapists and doctors could analyse the data and see how the patient would evolve through time.

4.2 Final Prototype

The first problem we needed to address was the Numbers level. The way it was developed, with all the four objects with the four numbers falling at the same time, caused some confusion on the patients and it was hard for them to get one sequence right on time, before the objects touched the ground and disappeared. The way the therapists envisioned it, was to have objects falling down constantly, with random numbers on them from 1 to 4, and the player would have to make sequences. For each object they caught in the correct order, they would score one point. In the end of game session set time, the more points the player scored, the better he had performed. This way the Numbers level was much more accessible for the players, but also got harder because they would have to remember which number they previously caught, to catch the next one in the sequence. We did not provide any indication on the numbers they already caught on the screen exactly for this purpose.

Other than this big change in the Numbers level, the rest of the three levels remained the same, although we made some tweaks and corrected some bugs and errors on the code, that occurred and that we found about during the tests. The settings remained the same. We just changed some ranges of values to be more appropriate for each of the parameters. During the tests we observed that some of the values we had available for choice were either too low or too high for the game to be playable. We added a new feature, which was very requested by the therapists and doctors, and also our supervisors, which was having a game session history. We implemented it in the form of text logs, which are created individually for each game session a patient plays, with the following structure and information:

- **Patient name:** the name of the patient who played through the game session;
- **GameType:** which of the levels the patient played (Normal, Numbers, Colors or Hands);
- **GameTime:** how long was the game session, in seconds;
- **FallingIntervalTime:** how long was the interval time between the objects' spawns;
- **ObjectVelocity:** Force applied to the falling objects;
- **ColourInterval (if applicable):** how many objects does the player have to catch in order for the required colour to change;
- **HandInterval (if applicable):** how many objects does the player have to catch in order for the required hand to change;
- **Score:** obtained score in the end of the game session.

With this game history log the therapists and doctors will be able to analyse the patient progression as they play the game. Since the logs are saved in text dumps, the therapists and doctors can save them and build some statistics on top of this data.

5. EVALUATION

There are many factors that needed to be evaluated to determine the success of a game as a valid way of treatment for Parkinson's disease patients. Some identified factors in the beginning of the development and the respective results in the end of the final prototype tests are presented in table 1.

We evaluated the impact of this work by having a controlled test group. Through the doctors and therapists from Hospital Santa Maria, we had access to older adults with diagnosed Parkinson's disease in their rehabilitation centres. This was extremely helpful and valuable, since this way we could take the game prototypes to them, have them test/use them, and modify or make adjustments according to the received feedback. In the earliest development stage, we met these patients, and also engaged in meetings with the doctors and therapists, to better know their struggles, what created enthusiasm in them, what they would like to do and how they envisioned a game like this. This made our game meet their desires and the doctors' requirements as well.

We also tested these objectives by carrying out conversations with the patients who volunteered to be testers, and with doctors and therapists. These conversations contained specific questions about all the previously presented points, ranging from general and objective questions (about gameplay and difficulty) to questions about the feelings that the game aroused in the players/patients or if they felt it affected them in any way. These conversations were different for all the three groups mentioned, as they had different points of view on the matters we meant to evaluate. Most of these factors checked out and we obtained good results in the mentioned tests, so we considered that we have a good game that will have a positive impact on the life of Parkinson's disease patients. Even if we did not accomplish all of these goals, the people we worked with gave us cues on how to improve gameplay aspects and the rehabilitation process included in the game.

Factors to Evaluate	Results
Player/patient's reaction to the game (if it excites them or not; we want to avoid a feeling of strangeness)	The player/patient had an overall positive reaction to the game, they felt happy to be playing it and could pick up almost immediately after the rules were explained to them.
Player/patient's evolution and progress regarding their symptoms (if the game brings delay on symptoms' progression)	We could not assess the player/patient's evolution or progression regarding their symptoms because there was not enough tests or time spent playing the game to evaluate these factors.
Player/patient's motivation towards playing and going under treatment (if the game motivates them for further treatments)	The player/patient was very eager to play the game and keep playing it in the future.
Time under treatment and estimated time player/patient spend playing the game (thus obtaining better results)	We could not assess how much time the player/patient would spend playing the game overall, since they were always in a controlled environment and we were the ones asking them to play through the levels of the game.
Quality of gameplay (if the activities in the game are consistent with the treatments they are normally under)	The quality of the gameplay was validated by our supervisors and the therapists and doctors who worked with us through the whole development time; the activities were considered consistent with the treatments the patients are subjected to, mapping the activities in the levels of the game to the exercises.
Precise tracking (player/patient's movements should be correctly tracked in order to avoid frustration)	The player/patient's tracking was well done and there was no frustration related to the movements not being detected or being incorrectly detected.
Overall improvement of player/patient's wellbeing and welfare (be able to perform day-to-day movements with ease, feeling more positive and more motivated to keep the treatments and exercises)	The player/patient was consistently feeling motivated and with a positive attitude towards the game; we could not asses improvements in the movements for the long term or their wellbeing and welfare.

Table 1: Factors evaluated and corresponding results after testing the final prototype.

6. CONCLUSIONS

Serious Games have a potential positive impact for patients' treatments and rehabilitation. In the work presented here we studied this potential impact for Parkinson's disease. To achieve this, it was essential to fully understand Parkinson's disease. Parkinson's disease has its own particular struggles that must be addressed when planning an alternative or additional method of treatment and rehabilitation. As we presented above, there is already some work being done in the area of Parkinson's disease rehabilitation that resorts to videogames or different technologies. We can look to these great examples and advancements in research to learn from them, further exploring their successful and failed experiments. Learning from experiences of other researchers was a key point to achieve success in our project.

We focused our work on the most important aspects of a Parkinson's disease patient rehabilitation, and on symptoms that we know we can help them improve: movement and motion, as well as some cognitive symptoms like attention span and depression. To help with the physical symptoms, our goal was to develop activities that offer a wide range of movements, although keeping them simple and motivating. Our approach for the cognitive symptoms had to be a little different, based on the need of engagement created by the activities and also in order to provide a fun factor associated to them. As it was previously mentioned, there was an additional challenge, which was the older age of the players for this game. This is a group of people (older adults) who are not as used to playing videogames as much as younger generations. This obliged us to redefine our requirements, such as the need to make them want to keep playing, tutorials creation and making them notice the progress they make day by day, maintaining engagement and immersion.

Based on this, the game was designed with several objectives in mind. The first one was simplicity. Since the game was to be played mostly by elder people with some physical impairment, it was essential that the game was as easy as possible to interact with. Moreover, although the graphical design was not a priority for the current prototype, we tried to develop an environment as close as possible to reality. The asset and environment system can easily be configured with new objects, characters, scenarios and props in a later stage of development to account for the specific necessities of each therapy. Also, the technological prototype developed for this study was designed to be as flexible as possible, in terms of assets, plot and events. As we mentioned before, we expect to develop a flexible story line editor that can adapt to different scenarios and objectives, as well as to provide the means that allow therapists to create real-time events and dialogs or change the goals in mid-game. Finally, each layer of the game engine is currently being measured for several parameters that include time spent in menus or in game, player choices, performance and score. This will allow us to extract relevant data that can be further analysed by specialists on a back-office and combined with the data from other patients in order to generate new knowledge about the disease, its effects and the results of the therapy with games.

The results of the first tests were quite satisfactory, since the players were able to interact and obtain good scores (few missed objects) on the overall training sessions.. However, we quickly realized that there was not true for all patients and the game should compensate its difficulty based on the player's performance. Although, this adaption must be guided by therapists it proved efficient while taking autonomous decisions on later tests. Nevertheless, this is still an early concept of the idea that will require further testing and is therefore proposed as future work. The feedback that we obtained from the specialists was also very good and helped us to develop the game in the right direction. We improved several aspects of the platform based on this feedback and the experiences that were performed with the patients, namely in terms of data acquisition, player adaption and specific goals to include in the game. Despite the fact that the patients did not show any necessity of a plot, we believe that this could be an improvement over the current solution. The therapists also agreed that it would be interesting to add an alternative play mode with a story-based gameplay in order to assess if there was any relative impact of the plot in the therapy.

As a result, we believe that this project was a success due to the obtained results and overall feedback of both patients and medical personnel. However, we present some indications for future work, which we believe that will result in a deeper understanding of this disease, its symptoms, and the impact of serious games for this type of therapy.

7. ACKNOWLEDGEMENTS

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