# Blexer – Full Play Therapeutic Blender Exergames for People with Physical Impairments

Martina Eckert[1(✉)], Ignacio Gomez-Martinho[1], Cristina Estéban[1], Yadira Peláez[1], Juan Meneses[1], and Luis Salgado[2]

[1] Centro de Investigación en Tecnologías Software y Sistemas Multimedia para la Sostenibilidad (CITSEM), Universidad Politécnica de Madrid, 28031 Madrid, Spain
martina.eckert@upm.es

[2] Grupo de Tratamiento de Imágenes, E.T.S.I. de Telecomunicación, Universidad Politécnica de Madrid, 28040 Madrid, Spain

**Abstract.** This work presents the "Blexer" (Blender Exergames) environment, which aims at the design and implementation of generic, adaptive and customizable rehabilitation exergames for people with physical disabilities. Currently, it consists in one full play exergame based on the movements captured by the Microsoft Xbox 360 Kinect camera and a medical platform that allows the remote configuration of the game. Opposed to multiple mini-games with specific purposes found in literature, here the focus is set on the design of a full game, which includes a character, a story and advanced game mechanics to achieve the integration of currently four exercises into a 3D adventure videogame. The principle aim is to enhance the patient's motivation to perform daily exercises with help of the game, therefore we apply the Core Drives defined in the Octalysis framework. Furthermore, the game incorporates a motion amplification functionality to augment the immersive feeling of disabled people in the video games. Last but not least, the configuration possibilities of the exercises included in the game are described.

**Keywords:** Exergames · Physiotherapy · Rehabilitation · Disability Kinect · Gamification · Octalysis · Adaptivity · Blender · Web platform

## 1 Introduction

For people with physical impairments, the possibilities to do sports are very limited. Nevertheless, they need to keep fit just as anyone else; even more, if they are wheelchair dependent because muscles tend to reduce with a lack of usage. Many people suffering from chronical diseases need to visit a physiotherapist multiple times a week, which is a costly and time-consuming burden.

Due to this situation, exergames are becoming more and more popular, as they offer a cheap possibility to exercise at home. Many scientific studies for application in rehabilitation systems have appeared recently, especially with the availability of 3D motion capture cameras like the Microsoft Kinect, proving that home exercising in

© ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2018
B. Guidi et al. (Eds.): GOODTECHS 2017, LNICST 233, pp. 300–310, 2018.
https://doi.org/10.1007/978-3-319-76111-4_30

virtual reality environments is healthy and safe [1–3]. It has also been observed that video games, not specially designed for clinical purposes, are just as efficient as conventional therapies and can lead to even better therapeutic outcomes. Furthermore, games prevent monotony, increase motivation, provide direct feedback, and allow double-task training [2, 4].

Nevertheless, most proposals found in literature present exergames specifically designed for the rehabilitation of frequent diseases like Stroke or Parkinson's, which affect mainly the elderly. It is difficult to find solutions for a broader range of people with different disabilities. Furthermore, it is rare to find a solution that qualifies as more than a simple mini-game, i.e. incorporates some kind of story or purpose rather than the exercise itself, which would allow to engage the player and to motivate them to exercise without being conscious about it.

Engagement is a very important factor to increase the motivation of a person in many situations of life, as can be learned from Chou in his book "Actionable Gamification" [5]. Chou discovered the existence of eight main core drives (CDs) that usually engage people and analysed them in the so-called Octalysis framework:

CD 1 – Epic meaning & Calling
CD 2 – Development & accomplishment
CD 3 – Empowerment of Creativity & Feedback
CD 4 – Ownership & possession
CD 5 – Social Influence & Relatedness
CD 6 – Scarcity & Impatience
CD 7 – Unpredictability & Curiosity
CD 8 – Loss & Avoidance

They can be applied to every task to be gamified, so in this work, we took them as a guideline to create motivational factors in the game. CD 2 and CD 4 are the easiest and most straightforward elements to implement in a game: the goal to reach and the award obtained for it. However, the other core drives, although more subtle, are the ones that really engage the player. For example, CD 1 refers to a story and the identification of the player with a game character; CD 3 is expressed when users are engaged in a creative process; CD 7 keeps a player constantly engaged with the desire to find out what is happening next in the game.

So, the best way to really engage patients in their exercises, especially in long-time therapy (which is necessary in the case of chronical diseases), is to create full games with a complex story and purpose. In this sense, the first prototype of a full game, currently tested as an alpha version, has been created as part of the project "Blexer" (Blender Exergames), which aims at creating a complex exergaming environment for people with physical disabilities. The game is a follow up of our former work published in [6], where four mini-games have been tested with a group of people suffering from rare muscle diseases.

To the best of our knowledge, the work presented here is the first communication of a fully playable exercise game based on Kinect, as opposed to mini-games with very specific purposes. To give just two out of many examples: a rehabilitation game aimed at training dynamic postural control for people with Parkinson's disease is presented in

[7] and the authors of [8] designed "PhysioMate", a game for stroke patients and elderly, that helps to train the upper-body for balance and motor coordination.

The definition of a mini-game can be found as: "A minor or incidental game within a larger video game."[1] Furthermore, we observed that mini-games are simpler, less complex (usually only one scene, one character, one goal) and playable in a short time. Usually, there are no conditions that maintain the player engaged after finishing the game, other than beating their highest score. Nevertheless, in our opinion, exercises are too tiring for this and a better way would be to camouflage them in a large and compelling game environment. From now on, the authors will refer to a large game in contrast to a mini-game as a "full play game". It could include the exercises in form of mini-games, but they could also be resolved implicitly (by moving a character, opening/closing menus etc.).

In the remaining sections, the complete "Blexer" system architecture will be presented. Afterwards, the design and structure of our first integrated full play therapeutic game are described. Furthermore, as a major concern is the flexibility of the games and their adaptability to any patient, taking into account their capabilities and needs, it will be focused also on two important functionalities:

1. Amplification of weak user movements to wider ones in the game character, with the aim to enhance the immersive feeling.
2. Configurability of exercise difficulty by a clinician remotely via a web platform.

## 2 "Blexer" System Architecture

The gaming environment presented here can be divided into two main parts as shown in Fig. 1: the user side (left), and the clinical side (right, yellow part) called "Blexer-med", with multiple medical centers and as many therapists or doctors as needed.

The patient's PC is working as the playing station, with the Exergame and a modular middleware called "Chiro" [9] that transmits the data obtained from one or more sensors to the game. The middleware could be configured for the Xbox 360 Kinect camera, a mobile phone and a VR headset [10] to capture, apart from the skeleton information provided by Kinect, additional movements like wrist and head rotation. In the future, it is planned to add more sensor devices like a heart rate measure and an oximeter, to obtain also information about the physical state of the patient with the aim to adapt the course of the game to their actual condition. Nevertheless, for the game presented here, we only use the Kinect data.

The right side of Fig. 1 shows how the medical access to the games is resolved in the "Blexer-med" web platform. It consists of a web server connected to a MySQL database which handles the communication between the clinicians and the middleware. The clinicians (therapists or doctors of different centers) can register their patients, assign one or more games of those available in the platform (currently only the

[1] https://www.wordnik.com/words/minigame

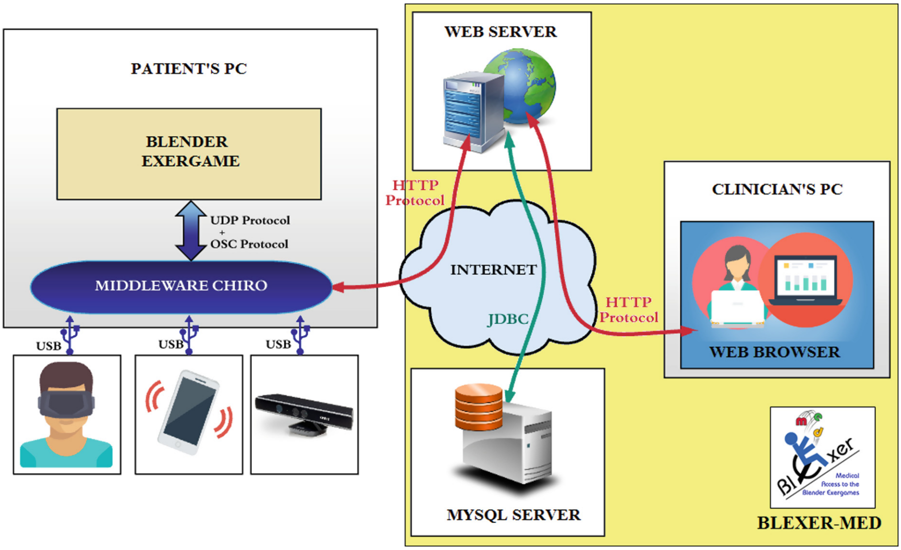


**Fig. 1.** "Blexer" system environment. On the left, the patients' PC represent the users at their homes; on the right, the "Blexer-med" system consists of a web server with the MYSQL database. The clinician's PC represent doctors and therapists at different medical centers. (Color figure online)

presented one) and adjust the parameters of the exercises involved in the games to the capabilities and needs of the patients.

When the patient starts the game at home, he/she first logs into the middleware, which then connects to the database and downloads the configuration information of the patient, stored in JSON (Java Script Object Notation) format, into a text file. After each playing session, the game writes the results (scores, playing times etc.) into a text file which is then uploaded by the middleware to the web platform. In case of a successful upload, the information is deleted from the file, if not, it is kept until the next successful internet connection. In this way, the clinician can analyze the results as soon as the patient terminated their exercise and evaluate their performance. According to it, the parameters can be readjusted for the next play.

The "Blexer" environment is modular and designed to manage an unlimited number of different games. Those games could be of any genre (action, adventure, role play, strategy etc.), as long as they are designed for a "corporal play", i.e. the player has to perform gestures and movements. Those inputs are modular and optional, and the prototype game presented in this article is only using the movements captured by the Kinect. It has been developed with the Blender modelling environment and game engine [11].

# 3 Full Play Therapeutic Exergame: "Phiby's Adventures"

## 3.1 Requirements

The goal of this work is the creation of a large game for people with disabilities, containing four different exercise types tested in [6], which have to be performed multiple times. The game should motivate and engage the user to maximize the playing time, therefore, the exercises have to be integrated into an interesting gameplay, which allows the repetition of the exercises without getting boring. To achieve this, specific game mechanics have to be added that motivate the player according to of the formerly introduced core drives.

## 3.2 Gameplay, Character, Story, World and Mechanics

The first decision to be taken before creating the game was choosing the right game genre. The decision fell on the adventure type, as it provides many possibilities to resolve the CD 1 (Epic meaning & Calling) with a cute game character and a nice story, as well as to integrate many tasks of different types, which give sense to the exercises.

As main character, a young amphibian called "Phiby" (see Fig. 2) has been created in different life stages (pollywog, toddler and infant), with the aim to represent the gaining of strength and skills due to the exercises (CD 2 – Development & accomplishment, CD 4 – Ownership & Possession). Nevertheless, in the game prototype presented here, it still does not appear in all forms.

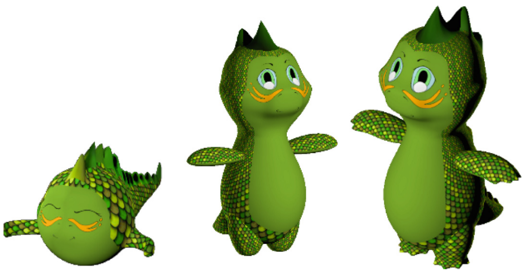

**Fig. 2.** "Phiby" in different states of development. Left: Pollywog. Center: Toddler. Right: Infant. In each state, his physique is developing a step further (growing limbs, fingers etc.).

The story can be resumed like: "Phiby" has fallen into an unknown world and has to find his family. In this first part, he explores the world around him to find the way out of a valley. To do so, he has to overcome certain obstacles like lakes ("Dive and eat"), rivers ("Row the boat"), and slopes ("Climb the tree"). There are also fallen trees that can be chopped to obtain pieces of wood ("Chop the wood"), which later can be used to build bridges over the rivers or little huts to rest and save the progress. These tasks are the physical exercises to be performed by the player (exercise names in brackets) and described in Sect. 3.3 in detail.

To achieve a repetitive execution of the exercises without getting bored, a game flow has been designed that lets the user decide which tasks to do next, therefore he/she will be motivated by the following additionally integrated game mechanics. Most of them are objectives and awards that provoke CD 4 (Ownership & possession) and CD 6 (Scarcity & Impatience), but some also tackle others as indicated:

- **Wood.** Every chopping exercise rewards 7 kg of wood.
- **Bridges.** 5 kg are required to build a bridge over a river, such that there is no need to row over it. A bridge allows also to go back to the former cell.
- **Huts.** Every 10 kg of wood allow building a hut in a specific point of the map. At this point, the status of the game will be saved, such that the user can resume the game from that point on.
- **Map.** Whenever one of the tests is passed, a new area of the "world" is discovered, so step by step the player gets aware of the surroundings and is motivated to keep on exploring the landscape and to bring "Phiby" to his destination (CD 1 – Epic meaning & Calling). Whenever a hut is built, a larger part of the map is discovered, such that it is easier to find the way to the end (CD 7 – Unpredictability & Curiosity).
- **Apples.** In-between the obstacles, some apples are placed to recover the energy lost during the exercises. Every apple recovers 10% of the energy lost in an exercise.

Figure 3 shows a simplified diagram of the game structure as it is currently implemented. The layout of the current game environment is stored in an XML file and consists of a map of 16 × 8 square cells, each representing a patch of the landscape to be explored. The XML parser reads the information of the scenes to be built from the file and passes it to the game engine. Every cell has one obstacle (lake, trunk, river, tree or a wall) in each border, which has to be passed to enter the adjacent cell by executing the corresponding exercise, DIVE, CHOP, ROW, and CLIMB, except for the wall,

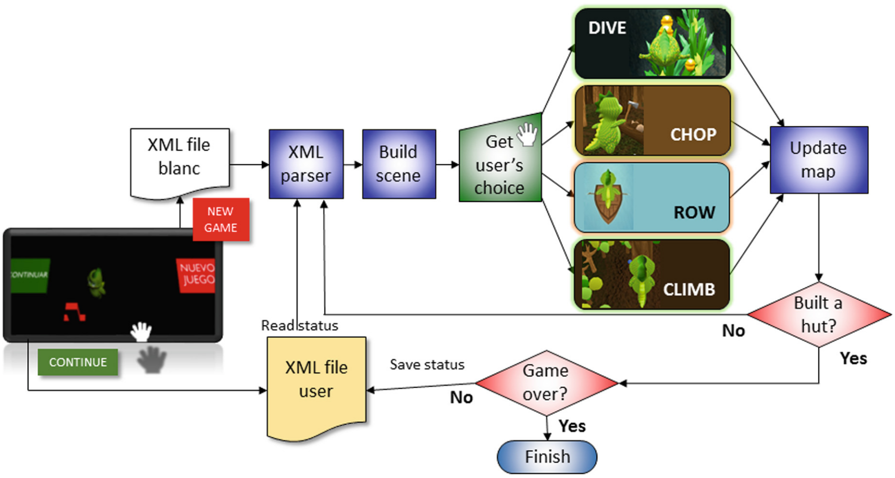


**Fig. 3.** Game outline of "Phiby's Adventures". (Color figure online)

which is an insurmountable barrier. The user can freely choose where to go by moving a red arrow with the right hand, which is followed by “Phiby”. When “Phiby” reaches the arrow close to an obstacle, the scene of the corresponding exercise is loaded.

Figure 4 shows the scenes built out of two cells: the left one with a river, a lake, a wall and a tree, the right one with a trunk, a lake, a wall, and already chopped wood to the south. “Phiby” is following the red arrow, moved by the user’s right hand. Once reached the arrow placed on an obstacle, the corresponding exercise starts. The right image also shows the map of the already explored cells, which can be opened by raising the left hand. The game is then paused until the map is closed by raising the other hand. The map shows the explored parts. Next, “Phiby” can go to the west to chop more wood or to the east to dive into the lake. The title of Fig. 4 explains the information presented to the player.


**Fig. 4.** Screen shots of intermediate scenes. Left: a river (Row the boat), a tree (Climb the tree), a lake (Dive and eat), and a wall (no passing). The energy is on top and still there has no wood been gained to build a bridge or a hut. Right: “Phiby” just passed the “Chop the wood” exercise and gained 7 kg. The energy is at 90%, but there is an apple to eat to increase the energy. (Color figure online)

### 3.3 Technical Description of the Exercises

As stated at the beginning, apart from enhancing the motivation of the users to play and do their exercises, two more objectives are inherent to the work presented here:

(1) Augment the immersive feeling during the play by amplification of the user’s movements.
(2) Adapt the difficulty of the exercises to the user’s possibilities and needs by adjustment of the corresponding parameters.

The amplification of the user’s movements means that the real movements are represented as larger ones by the game character as if they were simply copied. If the game character has to raise an arm to get an apple, but the patient is not able to raise it as high as needed, the maximum point of the patient’s arm movement is calibrated to the maximum point of the game character’s arm movement. In this way, every movement is scaled inside the game and appear the same as if a user without physical restrictions were playing. Figure 5 visualizes this principle and how it is applied to the skeleton of "Phiby". To achieve these scaling factors, a first step is always the measurement of the user's maximum motion ranges of all limbs, head and trunk [6, 9].

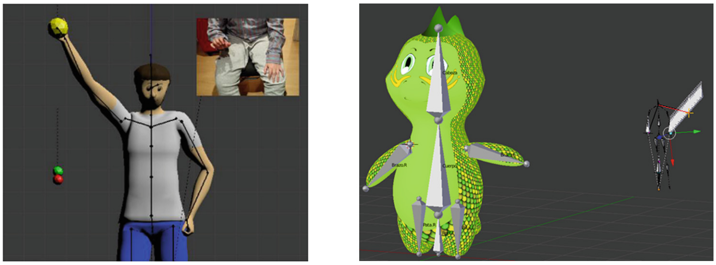

**Fig. 5.** Left: illustration of motion amplification principle: the user's real maximum movement (photo) corresponds to the green sphere of the avatar, the yellow sphere marks the scaled movement. Right: visualization of the character's skeleton and in the background the (invisible) Kinect skeleton with amplified motion transferred to the arm. (Color figure online)

The four exercises implemented in the game and the parameters needed to adjust their difficulty are described in the following subsections. Figure 6 illustrates some screen shots taken during the play.


**Fig. 6.** Scene shots of the currently implemented exercises: (a) "Chop the wood" (3 of 8 trunks chopped) (b) "Dive and eat" (2 of 8 planktons eaten) (c) "Row the boat" (distance left to the shore: 12 m) and (d) "Climb the tree" (7 m left to the top)

**Chop the wood**

The movement to be performed in this exercise is an up and down movement of the right arm. The user has to keep the arm up during a certain time to "charge" the axe which is visualized with a silver ring around the axe as shown in Fig. 7 on the left. When it is charged, a flash appears and the user can move the arm down to chop the wood (Fig. 7, 2nd image). The focus of the exercise is set on endurance, precision and speed are not necessary. It's more, patients with muscular dystrophies should try to not simply let the arm fall down. Therefore, the difficulty of this exercise can be adjusted with four parameters: height to raise the arm, duration keeping the arm up, time to hit the trunk, and the number of pieces to chop.

**Fig. 7.** Details of the scenes. Left: the axe in "Chop the wood" when it is charging and when it is ready to use. Right: a piece of plankton in the "Dive and eat" exercise. (Color figure online)

**Dive and eat**

The diving exercise focuses only on the movement of the trunk, in the directions forward, backwards and sideways. This is a very important exercise for wheelchair users, as they have to strengthen their back and pelvic muscles. In this exercise, the pollywog is diving through a lake and its direction is controlled by the user's movements. The goal is to capture the pieces of plankton floating in the water (Fig. 7, right image) and to eat them. The unique parameter to adjust is the number of planktons to control the duration of the exercise. It could be considered to implement a speed factor to enhance the movements in case the therapists considered this to be useful.

**Row the boat**

In this scene, the character is sitting in a rowing boat and has to cross a river. Here, the only adjustable parameter is the distance to the shore. To push the boat, both arms have to be moved back and forth, without the need of an exactly symmetrical movement. Currently, the boat is moving quicker with a quicker movement, so the user is engaged to finish the exercise earlier. As further possible enhancements of difficulty, obstacles or wild animals could be added in the water to be avoided or escaped.

**Climb the tree**

Here, "Phiby" has to climb up a tree, which is adjustable in height. In the current environment, the goal is to overcome a wall next to the tree; but the movement is adaptable to other scenes, i.e. to climb up a steep face or to get out of a hole. The only adjustable difficulty parameter is the height of the tree, which implicitly determines the number of arm movements to be made. The movements have to be alternated, where a blue ball appears to indicate the hand the user needs to raise at the moment. When a movement is successful, the character is animated and climbs a step up. Another possible parameter to implement would be the speed of the movements, i.e. the time it takes to reach the top.

## 4 Conclusions and Future Work

In this work, we present the "Blexer" system together with the first prototype of a full play game for therapeutic purposes for persons with physical impairments. The system described here is currently tested in its alpha phase to reveal and fix consistency errors. Afterwards, long term tests will be driven with a greater number of volunteers. Results will be analyzed and compared with former results.

In our ongoing work, we are currently porting the system to the Unity 3D game engine and also integrating Xbox One Kinect v2 body and face data. The middleware will be enhanced with other sensors as heart frequency measure and oximeter to capture information about the user's physical state. Together with an emotion detection process, the possibilities to realize a Dynamic Difficulty Adjustment (DDA), i.e. to adapt the pace and course of the game intelligently to the user's performance and mood, will be studied to achieve a maximized motivation.

Further on, the story will be developed with more detail, including additional NPC (non-player characters), further stages of development and advanced exercises. Also, the possibility to add a multiplayer mode will be considered, as this would potentiate a further core drive as a motivational factor: CD 5 (Social Influence & Relatedness).

**Acknowledgements.** This work was sponsored by the Spanish National Plan for Scientific and Technical Research and Innovation: TEC2013-48453-C2-2-R.

## References

1. Webster, D., Celik, O.: Systematic review of Kinect applications in elderly care and stroke rehabilitation. J. Neuroeng. Rehabil. **11**(108), 1–24 (2014)
2. Pompeu, J.E., et al.: Feasibility, safety and outcomes of playing Kinect Adventures!TM for people with Parkinson's disease: a pilot study. Physiotherapy **100**, 162–168 (2014)
3. Hondori, H.M., Khademi, M.A.: Review on technical and clinical impact of Microsoft Kinect on physical therapy and rehabilitation. J. Med. Eng. **2014**, 846514–846530 (2014)
4. Bonnechère, B., Jansen, B., Omelinab, L., Van Sint Jan, S.: The use of commercial video games in rehabilitation: a systematic review. Int. J. Rehabil. Res. **39**(4), 277–290 (2016)
5. Chou, Y.-K.: Actionable Gamificación. Beyond Points, Badges, and Leaderboards. Octalysis Media, Fremont (2015)
6. Eckert, M., Gómez-Martinho, I., Meneses, J., Martínez, J.F.: New approaches to exciting exergame-experiences for people with motor function impairments. Sensors **17**(2), 22 p. (2017). Article no. 354
7. Madeira, R.N., Costa, L., Postolache, O.: PhysioMate-pervasive physical rehabilitation based on NUI and gamification. In: Proceedings of the International Conference Exposition Electrical Power Engineering, Iasi, Romania, pp. 612–616 (2014)

8. Galna, B., et al.: Retraining function in people with Parkinson's disease using the Microsoft Kinect: game design and pilot testing. J. Neuroeng. Rehabil. **11**, 60 (2014)
9. Eckert, M., Gómez-Martinho, I., Meneses, J., Martínez, J.F.: A modular middleware approach for exergaming. In: IEEE International Conference on Consumer Electronics, Berlin, pp. 172–176 (2016)
10. Eckert, M., Zarco, J., Meneses, J., Martínez, J.-F.: Usage of VR headsets for rehabilitation exergames. In: Rojas, I., Ortuño, F. (eds.) IWBBIO 2017. LNCS, vol. 10209, pp. 434–442. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-56154-7_39
11. https://www.blender.org. Accessed 02 July 2017