The EPIK Island
Serious Game for Stroke Recovery

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Abstract: In this paper we describe the features of a serious game with virtual reality for use as a complement in rehabilitation therapies for patients who have suffered a stroke with subsequent motor and/or cognitive sequelae. We will expose the importance of rehabilitation in this kind of patients, and how virtual reality video games can be a good complement to the classical rehabilitation method. The game is divided in two applications: one for the therapists where they can change the parameters of the game for adapting it to the patient's limitations, and the user's application where the patient can play the different scenes and can perform the prescribed rehabilitation exercises. Each one of the scenes allows the patient to perform some movements aimed at the rehabilitation of some of its limitations, both motor and cognitive.

1 INTRODUCTION

Nowadays, strokes are responsible for up to 10% of the total deaths in the world. Among the survivors, a large number of cases have a bad prognosis: 29% die in the first year, 30% cannot live independently, and 16% need to live in long-term institutions (Ruiz-Ares et al., 2015).

Specifically, in Occidental countries, stroke is the third most frequent cause of death, the second cause of neurological disability after Alzheimer's disease, and the leading cause of institutionalization for loss of independence in adults (Martín-Zurro et al., 2003). This means that it is one of the main reasons for the economic resources of health systems.

A stroke is undoubtedly a personal tragedy, as well as a social, health and economic burden. Therefore, it requires an important demand of care so that the patient adequately surmounts his sequelae and prevent future accidents.

In general, the identification and control of vascular risk factors are the basic preventive pillars of stroke. These can be developed at two levels: primary, controlling vascular risk factors, and in the symptomatic phase, treating the patients who have suffered previous accidents.

It is estimated that 50% of strokes occur in 10% of the population, who should benefit from the adequate treatment of its risk factors (Martín-Zurro et al., 2003).

The 90-95% of strokes are due to modifiable risk factors, so it is crucial to develop strategies to prevent them. (Feigin et al., 2016).

In Spain there are 186 cases per 100,000 inhabitants per year. Among people over 65 years, 7,500 cases per 100,000, being the second cause of general mortality and the first in women (Ruiz-Ares et al., 2015).

In recent years, the number of accidents has been gradually reduced, and their mortality has been decreased to 50% (Ruiz-Ares et al., 2015). The reduction in mortality and the better functional evolution observed in the stroke units is due to a greater adherence to care protocols, and a growing awareness of the specific rehabilitation needs of each patient (Cayuela et al., 2014).

The aim of rehabilitation is to help them to be as independent as possible and thus improve their quality of life. Helping them to relearn skills that are lost when part of the brain is damaged (coordination of movements, communicating ...), or teaching them to perform tasks in a new way to avoid or compensate for any residual disabilities.

A clear basis in any rehabilitation program is that it must be voluntary, repetitive and specific to the affected area.

Studies in multiple hospitals have shown that survivors spend about half the day alone and inactive, being most of the time in bed without exercising any muscle. In addition, at weekends, patients reach even lower activity levels (Stewart et al., 2016).

This creates the need to give opportunities for survivors to perform activities that allow them to be rehabilitated, both in hospitals without the continuous supervision of a specialist, and at home during vacation periods. Among those opportunities we find serious games of virtual reality.

Serious virtual reality games offer therapy based on multisensory devices and involves interacting with a simulated real-time environment. The basis of this rehabilitation is that a more interesting environment for a patient can improve motivation for practice. In addition, they offer the opportunity to practice activities that cannot be performed within the clinical setting.

The use of virtual reality programs designed for rehabilitation is still not very common in clinical contexts, but little by little a gap is being formed between therapies (Laver et al., 2017) (Alfageme et al., 2002). Rehabilitation studies with virtual reality try to determine if it really is a substitute for traditional rehabilitation, but one undoubted conclusion is that they are a good complement as long as the virtual world provides the patient a complete sensory reflection of the real world (Todorov et al., 1997) (Guzmán et al., 2016). In addition, there is no doubt that the patients' motivation to the therapies increases regardless of the age range studied (Broeren et al., 2008) (Sveistrup et al., 2003).

In a previous work (Garrote et al., 2015), we presented the serious game EPIK, designed by the ASPAYM Foundation Castilla y León (Spain), institution which works for getting a better life for people with disabilities (strokes, spinal cord injury, etc.), and developed by Telematics and Imaging Group, University of Valladolid, Spain. EPIK Platform was focused on allowing the therapist to evaluate the exercises of the patients so that they could carry out their rehabilitation at home and without a specialist controlling him. It was concluded that it was a good way to evaluate and treat patients in a simple and cheap way.

In this article, we will show the continuation of that idea, the serious game The EPIK Island. Unlike EPIK, it is designed to offer a greater gameplay, so

the patient finds it more entertaining and helping with their attitude towards therapies. It is designed as a graphic adventure in which the player moves, thanks to the camera of capture of movements Microsoft Kinect 2.0, by different scenarios getting points and resources.

2 METHODS

2.1 Purpose of the Game

The main objective of this system is to complement the rehabilitation of patients with some type of motor and/or cognitive limitation due to stroke, facilitating the work of the therapist in controlling the correct execution of the different movements, and increasing the motivation of the patient.

In addition, it offers a great flexibility in face of the different limitations of patients, because it allows to calibrate motor ranges, to determine a series of difficulty parameters, to differentiate in real time between sitting and standing, and offers a guided game mode for patients with very severe limitations. All these differentiations have been determined through different tests with ASPAYM patients, as well as evaluating the opinions of physiotherapists.

2.2 Technologies

The EPIK Island game, uses the Microsoft Kinect 2.0 motion capture camera (http://www.microsoft.com/en-us/kinectforwindows) as it allows us to evaluate the patient's entire body without the need for added elements.

It has been developed through the Unity game engine (http://unity3d.com), which allows us to create 3D or 2D games and implement them on numerous platforms.

The integration between both is done through the plugin Kinect for Windows SDK 2.0, and thanks to it we can take full advantage of the technology that both offer for the evaluation of the different movements of patients.

2.3 Main Features

The EPIK Island needs the implementation of two applications:

Web application: in this application (developed by the Javacoya team, belonging to ASPAYM) the therapist will be able to define the scenarios that each patient should perform and their difficulty parameters (Figure 1). With these parameters,

therapies can be customized for the patient limitations, as well as the therapist can control if he's making progress in solving increasing difficulties.

Figure 1: Web application developed by Javacoya.

User application: in this application, the patient will interact with the different scenarios that have been developed. Currently two game modes are implemented: in the first one, the patient will download through the net the work plan determined by the therapist and must complete all the scenarios with their parameters, and in the second one, if any node of the network fails, the patient can work on a local plan with the basic parameters.

As we have explained previously, this game pretends to be flexible for all the patients with motor limitations that have suffered a stroke. Specifically, it differentiates between patients with lower limb limitations (if the limitation is severe, it will be detected that the patient remains seated whereas, if it is mild, the therapist can select a guided mode to facilitate the therapy), and also allows, if the patient has low mobility in one arm, to select a lateral restriction in each scenario.

2.4 Game Modules

The user application is divided into three general scenes:

Login scene: in this scene the patient enters his data (Figure 2). If they are correct and there is a correct connection to the server, the sessions predefined by the therapist will automatically be downloaded. If the connection fails, a file will be loaded with the basic parameters.

Figure 2: Login scene.

Scenario selection scene: in this scene the patient will select one by one the scenarios to perform (Figure 3). If there has been a correct web communication, he must do the scenarios in the order that the therapist has determined. If not, he will have full access freedom.
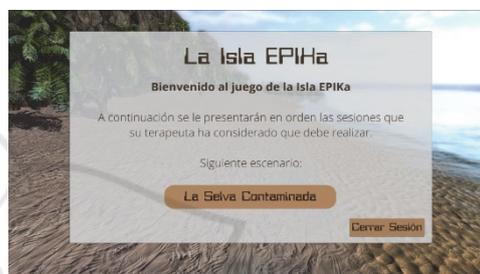
Figure 3: Scenario Selection Scene.

Developed Scenarios: In these scenes, the patient will rehabilitate their motor functions, moving through the camera Kinect an avatar that will represent their movements, and picking up different objects that he will find on the stage for a time determined by the therapist. The number of objects collected will be saved as points, and will motivate the patient to get new records in future sessions. If there are exercises for arm rehabilitation, a calibration option is added previously to the game in which it will be determined to how much distance it is able to pick up the different objects, in order to adapt it even more to the patient.

2.5 Developed Scenarios

2.5.1 First Scenario

This scenario, called "*La Playa del Alivio*", focuses on the rehabilitation of the upper limbs, causing the patient to collect some coconuts that will fall to their sides, along with a part of cognitive rehabilitation, because he will must to avoid collecting bananas.

The dynamics of the game is that the avatar must move along a beach reaching different palms, which

must hit by stretching the arms or lifting them a predetermined number of times, and later pick up the coconuts that fall to their sides (Figure 4).

Figure 4: Scenery of collecting objects from "*La Playa del Alivio*".

The game parameters that the therapist can vary are: the playing time, the number of palms that the patient is, the number of times that each palm has to be repeated, the blows for the coconuts to fall, the difficulty of the distance of collect depending on the calibrated range, the number of objects falling, the percentage of coconuts relative to the total number of objects, the difficulty in the speed of falling of the objects, and whether the patient can move freely, guided by a path, or the avatar automatically advances.

2.5.2 Second Scenario

This scenario, called "*La Selva Contaminada*", focuses on the rehabilitation of the upper and lower extremities, causing that the patient must collect two types of objects: trunks that appear on the ground and for which he will need to do a squat, and leaves in the trees for which he will need to stretch his arms upwards.
The dynamics of the game is that the avatar must cross a jungle collecting the objects that appear for getting points (Figure 5).

Figure 5: Scenario of "*La Selva Contaminada*".

The game parameters that the therapist can vary are: the playing time, the number of logs and leaves that will appear, the difficulty of collecting the trunks and leaves, and the freedom of movement that the patient will have around the stage.

2.5.3 Third Scenario

This scenario, called "*La Cueva del Volcán*", focuses on the rehabilitation of balance, causing that the patient must collect objects by lateral inclinations of the trunk. Specifically, he must collect diamonds while avoiding to collect some red gems, which will allow a cognitive rehabilitation.
The dynamics of the game is that the avatar automatically moves in a wagon on rails along a cave, and the user only has to lean to pick up the diamonds (Figure 6). In addition, in some cases, the wagon will stop at a bifurcation and the patient must have to choose the side that wishes to choose to continue, with a lateral inclination.

Figure 6: Scenario of "*La Cueva del Volcán*".

The game parameters that the therapist can vary are: the playing time, the number of objects that appear, the percentage of diamonds that will appear in relation to the total objects, the speed of the car, and the minimum angles of inclination that the patient must perform to collect objects.

2.6 The EPIK Island in the Rehabilitation Center

Three testing sessions with patients were conducted at the rehabilitation center during the developing process. The feedback collected allowed to fix bugs, incorporate different parameters for the scenarios, and adjust the difficulty levels. Thanks to these modifications, therapists can customize the sessions depending on the needs of every patient.
In these sessions we have instructed the therapists in the use of the game: how to control the parameters, where to place the patient correctly and, finally, how to read the quantitative measurements of the sessions (Figure 7).

Figure 7: Testing the game with the therapists.

After installing the final version in the rehabilitation center, the opinions of the therapist are:

1. The game is beneficial for getting a better static balance of the patients.
2. The scenarios of the beach and the jungle improve the lateral reaches, and the cave improves the lateral translations.
3. The anterior-posterior stability is trained with the anterior translation, needed for moving the avatar.
4. We can incorporate unstable fitness training devices such as bosus or balls (Figure 8), for users with a higher level of balance.
5. Is really useful the constant requirement of cognitive processes, such as attention, reasoning and spatial perception to achieve improvements in postural control and mobility ranges.
6. Finally, the variability of the parameters will allow them to adapt the game individually to the needs of the patients.

Figure 8: Testing the game with fitness training devices.

3 CONCLUSIONS

The main objective of this serious game is to complement the therapies of rehabilitation of patients of stroke using virtual reality, in such way that it increases significantly the motivation of these before the therapies. Due to the great playability of the scenarios patients perform the exercises in a repetitive and completely voluntary way. Therapists find this system flexible enough to be easily adapted for the training of patients with different sequelae.

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