Noname manuscript No.
(will be inserted by the editor)

A guide for making videogames accessible to users with cerebral palsy

Patricia Compañ-Rosique and Rafael Molina-Carmona and Francisco Gallego-Durán and Rosana Satorre-Cuerda and Carlos Villagrá-Arnedo and Faraón Llorens-Largo

the date of receipt and acceptance should be inserted later

Abstract Video games were initially considered as a form of entertainment. Today this perception has changed. Many video games have been designed for a wide range of purposes: education, rehabilitation, etc. This paper presents our experience developing video games in collaboration with an association of users with cerebral palsy. Cerebral palsy is characterized by a group of permanent disorders of the development of movement and posture, causing activity limitation. This means that people affected by this disease are unable to handle the usual devices used in video games. Moreover, video games offer these people a form of leisure that can also benefit them in many ways: autonomy, strength, coordination, self-confidence, learning from error, etc. Three adapted video games have been developed as well as a guide for designing accesible video games for people with cerebral palsy. This experience has served to study and design new ways of making video games accessible to disabled people, giving them the chance to exercise their right to entertainment.

Keywords · Accessibility · Accessible video games · Video games for disability

1 Introduction

Video games have changed the way young people (and adults) conceive reality and interact with each other [22, 37]. According to Prensky [28, 29] video games attract players for several reasons: they encourage participation, motivate users to gradually achieving small goals, offer rewards or immediate punishments, and allow the difficulties of each level to be adjusted according to the players skills.

A number of video games have been designed for different purposes, mainly for leisure and entertainment, but also for education, rehabilitation of people who have suffered an accident or illness, and so on. For example, in the field of education, Hamari et al. [11] have investigated the impact of flow, engagement and immersion in game-based learning environments.

Although some psychological studies focus on the negative effects of video games on people, particularly in adolescents, there are other studies that argue and document the benefits [27, 17]: voluntariness, competitiveness and cooperation, immersion, sense of control, achievement of goals (objectives), but especially satisfaction. For example, a study from the University of Rochester found that people who play action video games are able to make good decisions in a shorter amount of time [7]. This implies having developed a capacity from a videogame and, following the same line, other skills can be developed such as driving or memory, among others. In this sense, Granic et al. [10] have conducted an extensive review of the literature on the benefits of video games and their potential.

Moreover, the incorporation of video games to the therapies applied in hospitals for the rehabilitation of patients only reports positive results since this rehabilitation is no longer a simple daily task to follow, but an entertaining activity that helps a person recover. The same applies to treatments for people with disabilities. But this is not just about using them as therapy, there is one more consideration: should a disability, whatever it may be, incapacitate a user from being able to devote his or her leisure time to enjoying a good video game?

Cátedra Santander-UA de Transformación Digital

Universidad de Alicante, Spain
E-mail: {patricia.company, rmolina, fjgallego, rosana.satorre, villagra, faraon.llorens}@ua.es

From our point of view, leisure is an essential human activity and an individual right.

Definitively, developing accessible video games for all users is a necessity and even a must. However, few video games are adapted to be accessible by users with disabilities and far fewer are directly designed with the special features of these users in mind. While it is true that there are video games that require a level of control and handling that is not suitable for all types of people, this should not prevent the industry from creating video games that are adapted and accessible for people with disabilities.

If accessible videogames are scarce and most of them are experimental projects or from non-profit entities, the guides or recommendations to adapt a videogame or, better still, to design a videogame that is directly accessible are non-existent. Each adaptation that has been made is ad-hoc, so it is very difficult to take advantage of the knowledge acquired in developing an accessible videogame to use it in a new project and much less to be able to transmit it to other developers. Nevertheless, if we were able to formalise this knowledge and define some guidelines, however simple they may be, for designing accessible videogames, the development of this type of product would be much less costly and some companies would probably decide to design their products with this type of user in mind.

The aim of this research is to propose a guide for the development of videogames accessible to players with disabilities, particularly severe disabilities such as the ones produced by cerebral palsy. Based on our experience developing video games in general and accessible video games for players with cerebral palsy, we have discovered a series of guidelines that help us to identify the main characteristics that make a game fun and motivating, while also making it accessible to players with a wide range of abilities. Based on these guidelines, we propose a guide for the development of accessible videogames and a rubric to measure the quality of videogames, both from the point of view of entertainment and accessibility of the product.

The document is organised as follows. Section 2 presents the methodology of this research. The concepts and previous works about video games, disability and cerebral palsy in particular, and adaptation of video games are presented in section 3. Section 4 is devoted to explain in detail the iterative and incremental development of the adapted video games. Our proposed guide is presented in section 5, resulting in a list of lessons learned about adapting video games to users with cerebral palsy. Finally, the conclusions and future work are presented in section 6.

2 Methodology

In this section we present the methodology used to create the guide to develop accessible video games for players with cerebral palsy. The development of this guide has been carried out in three stages.

In the first stage, a review of the literature was carried out (it is detailed in section 3). This literature review allowed us to identify the following aspects:

- What elements make a video game fun, since it should not be ignored that this is one of the main purposes of a video game;
- What are the characteristics of players with cerebral palsy, to determine the main forms of interaction accessible to people with this disorder;
- What ways have been described in the literature to adapt video games to these players. In particular, the different interaction devices and strategies for designing accessible video games have been studied.

In the second stage, three adapted games were designed, over three years, in collaboration with an association of cerebral palsy patients. This is a long and iterative process, in which the knowledge acquired in the literature review was put into practice, along with the previous experience that the authors had developing other types of video games. As a consequence of this process, the knowledge was strengthened and new aspects were detected. In particular, after the development of the adapted video games we obtained the following:

- An interesting first-hand experience, identifying in practice which aspects of interaction are most important when adapting video games and how they can be applied empirically;
- The opinion of therapists, experts in cerebral palsy and the capabilities of people with this disorder;
- The opinion of the disabled players themselves, not only from the point of view of their capacities to interact but also about the characteristics of the game that make it fun and motivating.

In the third stage, the main contributions presented in this article were obtained. In short they are:

- A set of features that make a video game fun and a set of tips for the design and development of accessible video games for people with disabilities. These features constitute a brief guide, in the form of lessons learned, on the design of video games adapted for players with cerebral palsy;
- A rubric that makes it possible to evaluate whether a video game is accessible for these players and whether it still maintains its fun and motivational characteristics.

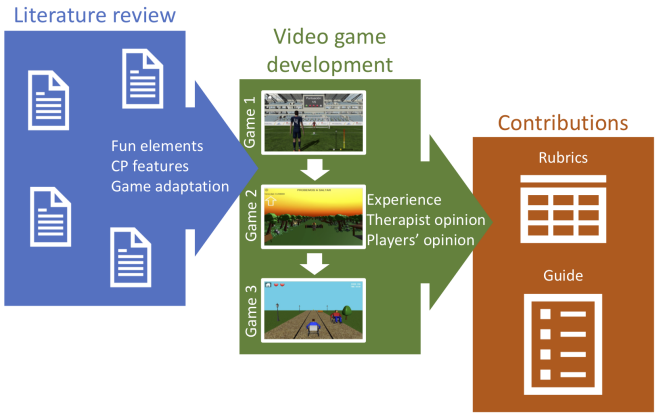

Fig. 1 Methodology to design the guide for making video games accesible to users with cerebral palsy.

Figure 1 presents these steps graphically. The following sections explain in detail each of the stages that have been followed in this research.

3 Background

3.1 Video games and fun

Fun is the key aspect of any video game. One of the best analyses that can be found about what fun is and how we can work with it is in the work of Koster [16]. Fun occurs in situations of pattern recognition by the human brain. This recognition depends on the prior knowledge of the individual and how new information enters and is processed by the brain. All these events trigger the release of dopamine, which is the substance that the brain uses to fix those adaptations that are successful. And precisely this release of dopamine produces positive feelings in the individual, which we call fun. Since fun involves new information fixed in the brain, the secret of optimal learning lies in the fun. Analysing how games achieve the objective of fun is essential to design similar strategies in other games, particularly in accessible videogames.

In a very general way, we can say that a video game is funny when it is able to motivate the player to keep playing. For this reason, we will start by focusing our attention on motivation. There are two types of motivation: extrinsic (external incentive) and intrinsic (personal satisfaction). The combination of both types can produce a more appropriate level of motivation, so both greatly influence the design of a game. For good results, the elements must be adequately sorted in search of intrinsic motivation, always with a proper balance of extrinsic motivation. Psychological Self-determination theory [32] indicates what factors determine the motivation of people to perform a task, and there is a continuum from the demotivation to the intrinsic motivation, with various intermediate degrees of extrinsic motivation. There are three key factors for a person to be in a state of intrinsic motivation to perform a task: autonomy, competence and meaning. The conclusion to be drawn from all this is that the elements of a videogame must be combined in such a way that intrinsic motivation is produced (offering autonomy, having meaning and being at the proficiency level of the players).

Another key aspect when designing videogames is progressiveness. There must be an adequate balance between challenge in the game and capabilities of the players, so that they can enter a state of flow [3], that is, they must have a feeling of complete involvement with the game, with a high level of enjoyment and fulfilment. In order to advance in the flow channel, it is important to have a structure of levels. To maintain the challenge and sense of progression, there must be achievement levels to overcome and a system of unlocking the next level.

3.2 Disability and cerebral palsy

Disability is defined as the consequence of damage that may be physical, cognitive, mental, sensory, emotional, developmental, or a combination of these. It affects how the individual interacts and participates in the society and it can be present from birth or occurring during a person's life.

According to the World Health Organization [42], more than one billion people live in the world with some form of disability, of whom almost 200 million experience considerable difficulties in functioning. People with disabilities have poorer health outcomes, lower education achievements, less economic participation and higher rates of poverty than people without disabilities. In part, this is a consequence of the obstacles in accessing services that many of us take for granted, in particular health, education, employment, transportation, or information. These difficulties are exacerbated in less favoured communities. In order to achieve development goals, it is necessary to provide means to make people with disabilities independent and to remove the barriers that prevent them from being an active part of the communities, training and finding a job [42].

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour [31]. Although the main characteristic of this

disability is movement disorder, of individuals affected by CP, 28% have epilepsy, 58% have communication difficulties, at least 42% have vision problems, and 23% to 56% have learning disabilities [15]. Cerebral palsy is characterized by abnormal muscle tone, reflexes, or motor development and coordination. There may be deformities and contractures of joints and bones or tight muscles and joints. The frequent symptoms are spasticity, spasms, other involuntary movements (e.g., facial gestures), unsteady gait, balance problems, or decreased muscle mass [4]. More specifically, depending on the functional effects, it is possible to distinguish between the following types of CP [24]:

- Spastic: this is the most common group; about 75% of people with CP have spasticity, that is, significant stiffness in the muscles, an inability to relax them, due to an injury to the cerebral cortex that affects motor centres;
- Athetoid: it is characterized by frequent involuntary movements that interfere with normal body movements. There are usually contortion movements of the extremities, the face and the tongue, gestures, grimaces and awkwardness when speaking. Hearing disorders are quite common in this group, which interfere with language development. Injury of the basal ganglia of the brain seems to be the cause of this condition. Less than 10% of people with CP show athetosis;
- Ataxic: the person affected in this case has poor body balance, an awkward gait and difficulties in the coordination and control of hands and eyes. Ataxic cerebral palsy is a relatively rare form of the disorder that stems from damage to the cerebellum;
- Mixed: it is not common to find pure cases of spasticity, athetosis or ataxia. Typically, cerebral palsy sufferers have a combination of the different types.

3.3 Video games and disability

Video games have become in recent years a mainstream form of entertainment. Their popularity may be explained, among other reasons, by the immersion produced by the continuous interaction, in contrast to other more classic forms of entertainment, such as books or cinema. Moreover, video games have transcended their role of mere outlets of entertainment, and nowadays many examples of leveraging the potential in other areas can be found. This is the case of teaching [34, 8, 14, 13, 40, 18] or health [35, 41]. However, there are a significant number of potential disabled players that may not be able to access video games if they are not thought of when designing the games. For this group of players, access to video games can mean a form of leisure that they did not know, and improvements in their education [5] or rehabilitation [19, 26].

Several initiatives have been carried out to bring the world of video games closer to cerebral palsy. Movement therapy is a type of upper extremity intervention that aims to improve patient functionality. This therapy requires high intensity, is repetitive and needs specific movements to improve performance. Tedium and lack of motivation lead to poorer execution of the therapy. One way to overcome these barriers is to combine movement therapy with virtual reality activities that may include video games. Another possibility is to use free video games available on the Internet. Internet games are diverse and they keep the players interested. The authors in [33] present an experience carried out with four children affected by cerebral palsy. The objective was to determine whether movement therapy could be performed with the use of free video games combined with the Microsoft Kinect motion sensor and the Flexible Action and Articulated Skeleton Toolkit software (FAAST). They also wanted to know the level of intrinsic motivation during the experience. Several tests were applied before and after the experiment and it was determined that the children improved in some of the tests. In addition, the participants showed high intrinsic motivation which was measured by the Intrinsic Motivation Inventory test (IMI) during the 12 weeks of the activity.

An experience with children affected by cerebral palsy is presented in [38]. This experience combined the use of traditional therapies with a series of video game sessions with the ENLAZA interface to exercise cervical flexion: extensions, rotations and inclinations in a controlled and attractive environment. Two groups were formed, one of which did only the traditional methods while the other group complemented with the play sessions. The results showed that the group that used video games improved head and trunk control more than the other group.

It is common for patients with cerebral palsy to have problems maintaining their balance when standing or walking, resulting in falls and injuries. Exercises to strengthen and stretch the muscles that move the center of mass are effective. In [30] a video game was designed for this purpose. In the game, users had to guide a paper plane towards a series of targets by changing weight in different directions on the Wii Fit Balance Board. The results showed that the patients enjoyed playing the therapeutic video game and they preferred it to more conventional exercises. The game also provided another form of feedback by indicating when the correct movement pattern was being used to achieve the goals. When

subjects performed compensatory tests of lateral trunk flexion and rotational movements, the system detected them and provided accurate and useful feedback, and subjects reduced the number of movements. Therapeutic video games that provide feedback are well suited to be performed at home where there are no physiotherapists to guide or provide information on movements.

In Table 1 a short summary of the main contributions on video games for CP patients is presented.

From the player's perspective, the basic flow of any video game is [43]:

1. Receiving a stimulus;
2. Determining a response to the stimulus;
3. Executing the response.

Creating an accessible video game means giving support and offering options to allow this flow to run correctly to players with any limitation. There are several ways to adapt the interaction so that the flow is maintained. Particularly, in the case of functional diversity in mobility, two main aspects must be considered: the access technologies (the adapted devices that allow the interaction), and the adaptation strategies (the game design decisions that make the game accessible).

Access technologies are the intermediary devices between the player and the game. They manage to translate the functional intentions of the player into the opportune result produced by the game. In the case of motor impaired players, it is often difficult or impossible for them to interact using conventional input devices such as mouses or keyboards. There are some alternative input devices specifically designed to accommodate their abilities, such as [36, 43]:

- Mechanical switches: in the simplest case, a mechanical switch consists of two or more contacts and an actuator that connects or disconnects the contacts to close or open the switch, respectively. The mechanism may respond to specific mechanical stimuli, including changes in displacement, inclination, air pressure or force. These switches are controlled with an explicit physical movement. Some examples of mechanical switches are one-button switches, mouth switches or head switches;
- Infrared sensing: these sensors consist of a source of infrared light and a receiver. Receivers detect the radiation and generate a proportional output voltage, identifying the depth of the scene from the point of view of the source. An example of infrared sensor is Kinect sensor, from Microsoft;
- Electromyography (EMG): these devices consist of a set of electromyographic electrodes placed on the skin that record the electrical activity generated by the muscles at rest and during contractions. This allows devices to be controlled by EMG patterns associated with movements of different muscles, such as facial muscles for instance;
- Oculography: gaze-based communication systems can map eye movement or point-of-gaze to cursor position. There are two main technologies: Video-oculography (VOG) and electro-oculography (EOG). VOG is based on an infrared light source and a camera, so that the view direction is calculated from the displacement between the reflection of the cornea and the centre of the pupil. EOG is based on electrodes that are placed around the eyes and measure potential changes between the cornea and the retina that occur when the user changes the direction of the gaze;
- Computer vision: these systems track the location of a facial reference point of the user (e.g. nose or pupil) through a camera and translate the position changes in cursor movements on a screen;
- Brain-Computer Interfaces: these systems directly capture the brain activity through the use of different types of electrodes. Depending on the electrodes placement, the main technologies are electroencephalography (EEG) (superficial electrodes placed on the scalp), electrocorticography (ECoG) (surgically implanted epidural or subdural electrodes) and intracortical recordings (electrodes chronically implanted in the cortex).

Beyond the devices used for interaction, another aspect to study is how to design video games so that players with motor disabilities can easily access them. In this case, the main strategies for adaptation are [20]:

- Control with one button: it is possible to design games that are controlled only by using a button, or, at least, using the minimum number of buttons;
- Control with one hand: the controller interaction is designed to be used with one hand only;
- Non-simultaneous buttons: avoid that the accomplishment of an action entails to press more than one button at the same time;
- Configurable control sensitivity: provide the possibility of adjusting the sensitivity of controls;
- Configurable game speed: provide a possible decrement of game speed to make the game easier to be controlled;
- Various levels of difficulty: a mode of immunity or the ability to jump directly to the next episode of the game may be used to make the game easier to play;
- Control by microphone: provide the possibility of using the microphone as peripheral to control the game, either by voice recognition or simply by sounds that emulate the pulsations of a single button.

Table 1 Contributions of video games for CP patients

Paper	Objective	Interaction	Evaluation	Contribution
[30]	Demonstrate the technical feasibility, ease of use, appeal, and safety of a computer-based video game program designed to improve balance in children with CP.	Wii Fit Balance Board + Wii Motion Plus controller.	Exertion: Borg Rating of Perceived Exertion (RPE). Ease of use: Short Feedback Questionnaire Pediatric Version (SFQP).	The video game is very appealing to the subjects, but future research is needed to measure its effectiveness.
[33]	Test the feasibility of delivering their upper extremity motor training intervention to children with cerebral palsy; determine the level of intrinsic motivation during intervention participation.	Microsoft Kinect motion sensor + Flexible Action and Articulated Skeleton Toolkit software (FAAST).	Motivation: Intrinsic Motivation Inventory (IMI). Individuals active movement: Childs AROM . Manual coordination: Subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2). UE motor control: Modified UE Functional Targeting Reach Test.	The intervention could be successfully delivered in the laboratory and the home; there is a high level of motivation among the participants.
[38]	Proof of concept of a rehabilitation therapy for the enhancement of head and trunk posture in children with CP.	ENLAZA Interface (a head mouse based on inertial technology).	Gross Motor Function Measure-88 (GMFM-88). Visual Analogue Scale (VAS). Goal attainment scaling (GAS). Trunk Control Measurement Scale (TCMS).	A therapy for the rehabilitation of head and trunk motor control with inertial sensors and serious games is a good complement to traditional therapies, it can be more effective than traditional therapies alone and it promotes the motivation of the patients.

4 Previous experience developing video games

For several years we have been designing video games and analyzing how to make them fun [39]. We have also developed accessible video games [25]. An accessible videogame must have specific characteristics depending on the target group. In order to be able to design these video games, the characteristics of the disease must first be analysed. Next, video games can be designed to be played by patients. The video games presented in this paper are designed for users with cerebral palsy. Each video game has been developed in a different year. For this reason, it has been possible to make improvements to one game for the next, taking into account the opinions of both patients and medical staff who have been closely involved in the project. As a direct consequence of this process, we have been able to obtain the guide we propose.

The video games have been developed in collaboration with students and APCA (*Asociación de Paralíticos Cerebrales de Alicante*, Association of Cerebral Palsy of Alicante). The main objective of APCA is defending the rights of people affected by Cerebral Palsy, aimed at achieving normality [1]. APCA offers care, advice, education, training and leisure to affected people. The research team made contact with the association in 2013, starting collaboration, initially in an informal and voluntary way, to develop final degree projects for designing and developing accessible video games, adapted for users with cerebral palsy.

4.1 Footb-all game

Firstly, an accesible video game about football was developed. This first experience allowed us to understand the problem of making video games accessible to users with cerebral palsy, to identify the main strategies to reduce and adapt interaction, to use simple interaction devices such as mechanical switches, and to define the improvements for the next video games to be developed.

Once the contact with APCA was established, the first step was to meet up with them to know their needs. The participants were: the tutors of the projects, the students, the therapists of the centre and some final users. As a result, a list of general requirements was defined: simple design, configuration options, customizable user profiles, possibility to cancel an action, use of sweeps for element navigation, emphasis when the action succeeds or fails, and graphic support for textual elements.

Fig. 2 Configuration screen of Footb-all game. The profile is selected just clicking with the switch when the desired picture is highlighted during the sweep.

Fig. 3 Main game screen of Footb-all game. The sliders to select the horizontal and vertical direction and the speed are placed on the right bottom corner of the screen.

Fig. 4 Results screen of Footb-all game. It shows a ranking of the players.

The conceptual design of the video game was the next step: by decision of the final users, the game was about football. It consisted of a series of penalty kicks. The scenario of the game was a football field. The interaction should be very simple, using a mechanical switch, just to click. The way to select the parameters and characteristics of the shot (direction and speed, mainly) should be through the use of circular or bar meters (sliders), so that just a click is needed to stop the needle. The speed of the needle would also be configurable. The direction of the shot would be complemented with a random variable that represents the nervousness of the player to make the shot more unpredictable. There would also be some extras: choosing different teams, players, and avatars, and including a ranking.

The application was built following the initial requirements. It needed an iterative refinement of the prototype. After each visit to the association, new or adapted requirements arose or it was necessary to modify some part of the game, generating new versions of the prototype. The final prototype, called *Footb-all* [9], was presented to the members of the association.

The game is played in three main stages: Configuration (the players profile about interaction, the selected team and the avatar are selected, see Figure 2), game (the direction and speed are setup and the ball is kicked, see Figure 3), and results (the ranking is presented, see Figure 4).

During the game development many data were gathered from the users (CP patients and their therapists) but also from the development of the project. It allowed us to determine the progress and make the necessary adjustments for the project to succeed. The analysis of this information and the comparison against the design and the requirements showed that there was little deviation during the implementation, so the plan to develop the game was appropriate and complete.

We also sounded out the final users and the therapists to obtain their opinions about the game and how to improve it. The therapists affirmed that the video game enhances the emotional well-being and the motivation for personal improvement. They also considered that playing in a continued way could favour the strategic planning and perceptual abilities, as well as spatio-temporal organization and increased physical response speed. Final users, besides, found to access new technologies very attractive, especially when they are related to leisure. They also pointed out that there had been some competition between them.

This first experience allowed us to understand the problem of making video games accessible to users with cerebral palsy, to identify the main strategies to reduce and adapt interaction and to use simple interaction devices such as mechanical switches. All the gathered information and the analysis allowed us to define an improvement plan with two main objectives:

– Explore new ways of interaction: Although the users found the use of adapted switches very easy, the interaction turned out to be too limiting in many cases;

– Introduce characters which the player could identify with: The use of disabled characters could achieve a higher level of empathy of the player.

4.2 Formula Chair game

The following year was devoted to design and develop a video game about wheelchair races, an adapted sport that many players do. We also introduced the use of a more advanced interaction device, Kinect, using simple movements. The evaluation phase made us detect that Kinect was a good choice.

In this case we proposed the following objectives, defined in the improvement plan of the previous video game:

– Maintain the main successful elements of the interface, such as the sweep concept for the selection of profiles, the structure of the profiles and the final screen of ranking;
– Introduce a character and a context in which the users could relate and identify themselves in;
– Incorporate a new interaction device that would increase the range and variety of movements, but maintaining the requirement of simplicity.

As a result, the *Formula Chair* game [6] was designed taking these requirements into account. The game would consist of a character that is infinitely moving in a scenario with three lanes. Some different objects (coins, obstacles or other people) may appear and they must be avoided or collected. The score would be calculated according to the play time without losing all lives, the number of collected coins and the number of dodged obstacles and people.

The user could decide which extremity to use to interact with the game: head, right arm, left arm, right leg or left leg. The capture of the movement of the chosen extremity would be performed using the *Microsoft Kinect* device [23].

An agile and incremental methodology was used. As a result, successive prototypes were obtained, so the work of monitoring the progress and the adaptation to the requirements were facilitated. The main milestones were:

– Start up and configure the interaction using the Kinect device;
– Determine the interaction. Each user had a profile in which he or she selected the extremity for interaction;
– Define the ranges of movement of the extremities. In particular, two configurable ranges were defined: right range (minimum movement range of the extremity to the right to change to the right lane) and left range (minimum movement range of the extremity to the left to change to the left lane);
– Calculate the score in function of collected coins and dodged obstacles and people.

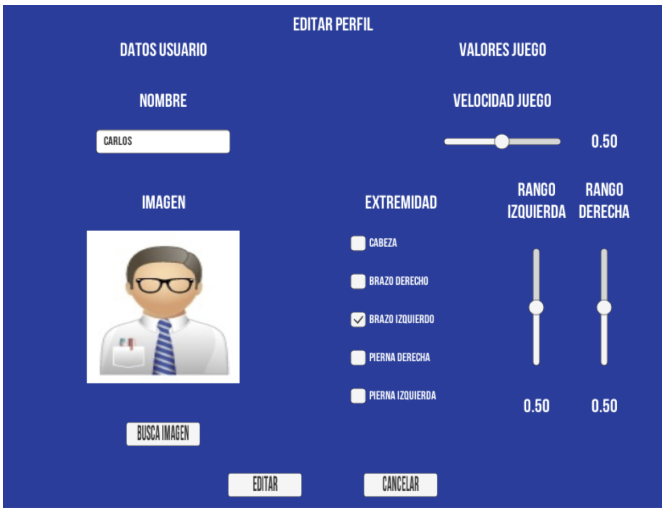

Fig. 5 Interaction configuration screen of Formula Chair game. The profile allows the selection of the extremity and the movement ranges.

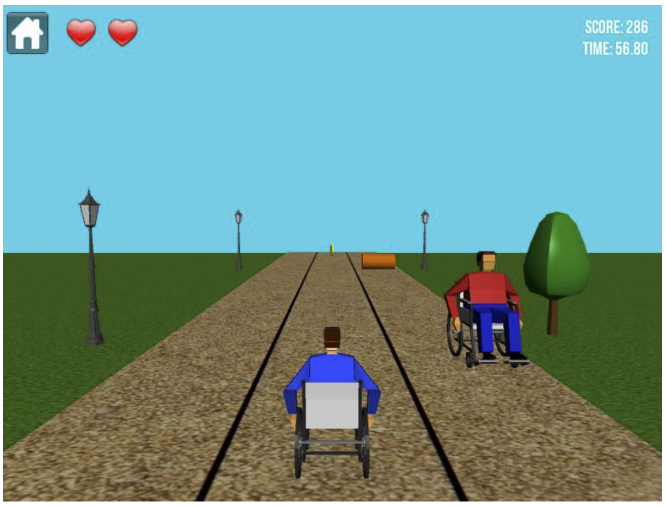

Fig. 6 Main game screen of Formula Chair game. The player must change the lane to avoid obstacles and people and collect coins by moving the selected extremity.

During the realization of the project, we detected some aspects to be redefined: for example, it was necessary to implement a pause function. The game is paused at the beginning, until the user is ready to start, and there is also an automatic pause if the Kinect device loses the user's reference. Figure 5 shows a screenshot of the interaction configuration screen and Figure 6 the main screen of the game.

Once the video game was implemented, several tests were carried out to verify the functionality of the game and to obtain the opinion of the therapists and the

Table 2 Questions and answers of therapists about the use of the video game for physiotherapy

Question	Average value	Opinion
I would use this video game as a possible method of physiotherapy	5	It helps to work with an extremity. The users are motivated to improve their score
The video game can help improve the mobility of people	5	Configuration (speed, extremity and movement range) improves therapy possibilities
The video game is fun and suitable for people with cerebral palsy	4	The game is suitable and fun, but there may be other more interesting topics
What would you improve in the video game?	-	Improve user capture, especially for those who use a wheelchair

users. Therapists responded to three questions on a Likert scale with values between 1 (strongly disagree) and 5 (strongly agree), in addition to providing their personal opinion. An open question was also set out. These questions try to explore the possibility of using video games to complement the work of physiotherapists. Since only two therapists participated, the results are not statistically significative, however they allow us to propose improvements for the next video game. Table 2 shows the questions and answers obtained.

Eight users responded to a more general questionnaire about their user experience. All of them liked the game, considered it as a good tool to be incorporated in their physiotherapy sessions and had a high opinion about developing this type of collaboration between APCA and the University. Some of them, however, found the game difficult to use because of the limited movements.

This second video game allowed us to approach to the access to games from two different points of view: the interaction through new devices and the possible use of games as therapy tools. As a consequence, the new improvement plan has as its main objective placing the requirements of the physiotherapists in the centre of the design process. In the previous video games the aim was providing fun but in the following one this aim should be balanced with the use of the game as a physiotherapy tool.

4.3 Fisio Run

Finally the team of physiotherapists of the association was included in the project, developing a new game with two main objectives: serving as entertainment and helping the physiotherapists to achieve their goals with the patient. This game should use several movements to obtain different results, so that it helped the players to distinguish different movements.

The main objective was to develop a video game that, besides being fun, had a therapeutic purpose. The therapists of the centre considered that this type of applications could motivate the users to make more complex movements to achieve their goals, thus it would help in their rehabilitation. Therefore, it was decided that this new video game should include more complex movements than the previous ones.

The video game was decided to be about running while jumping and ducking to avoid the obstacles. The movement should be controlled by different parts of the player's body. The good results obtained in the other video games led us to maintain the definition of profiles to configure the system (adding the necessary elements to incorporate a more complex interaction) and the sweep scheme for the selections.

The implementation used an agile methodology to carry out the successive prototypes, as in the previous video games. These prototypes led to a final version of the game, which was called *Fisio Run* [21], which included the following features:

- The scenario was created automatically, from an infinite plane in which two types of obstacles to avoid, by jumping or crouching, were randomly incorporated;
- Two game modes were created for one and two players. This motivates users through competition between them;
- Each player created a profile to configure, among other aspects, the speed, the extremities to interact and their movement. In total, three types of actions must be configured: running, jumping and crouching;
- Each player initially had three lives (the number of lives was configurable though to help the users with higher difficulties), discounting a life each time the avatar crashed an obstacle. The final score was calculated in function of the time the player is able to stay in the game.

Figures 7 and 8 show the configuration and the game screens.

The collection of data during the previous phases and the constant communication with the therapists allowed us to make an adequate evaluation of the development process and the opinion of the users. The main results are:

- From the point of view of the interaction, Kinect is a tool of reduced cost and quite acceptable results.

Fig. 7 Interaction configuration screen of Fisio Run game. The profile allows the selection of the extremities for each movement.

Fig. 8 Main game screen of Fisio Run game. The player must jump or crouch to avoid the obstacles by moving the selected extremities.

However, it leaves out certain users with a very low level of mobility and it still has some problems when detecting users in a wheelchair;
- From the institutional point of view, the need to establish stronger ties between the University and APCA has been detected in order to carry out new joint actions.

The collaboration between the University and APCA is close and easy. However, we must go further to develop other projects. Moreover, the Kinect device should be complemented with other interaction devices. Therefore, the next improvement plan had as main objectives the following:

- Signing a formal agreement between our organization and APCA to deepen our relationship and develop new more ambitious projects;
- Explore the use of other interaction devices to widen the scope of the projects to users with very low level of mobility.

The first action was made: signing a formal agreement between the institutions. We have planned two main objectives for the following years:

- Develop new games, exploring the new interaction devices;
- Improve our dissemination actions by letting every development at the disposal of any other institution through the institutional platform of the university.

5 Guide for the design of accessible video games

Game is a human activity that requires a high cognitive level. Although related to other activities, several authors have tried to identify the main properties that characterize games [12, 2]. In short, these characteristics are:

- It is a free activity: it is a voluntary event, nobody is obliged to play;
- It has rules, established formally or informally, that impose limitations accepted by all players;
- It is a creative, spontaneous and original activity, with uncertain results;
- It is a manifestation that has an end in itself, is free, selfless and trivial;
- It takes place in a separate, fictional world with a symbolic message;
- It is universal, that is, people of all cultures have played throughout history.

These general premises have enabled us to develop a set of specific characteristics suitable for the development of video games.

In this section we indicate some characteristics of video games in general and of adapted ones in particular, citing their possible beneficial effects on the player. The characteristics of video games in general are:

- **Recognition of partial achievements**: Progress can be measured during a game. It can be overcoming levels, allowing to save the state in intermediate points or by giving recognition. The potential effects are sense of progress, motivation, feedback, recognition and incrementality;

- **Incremental difficulty**: Games have increasing levels of difficulty. Some games also adapt their difficulty to the player's style in a dynamic way. The potential effects are sense of progress, flow channel and motivation;
- **Trial and error**: Faced with mistakes, it is possible to understand what has produced them, to repeat them and to practice in order to learn how to do them well. The potential effects are learning from error, experiential learning and cause-effect;
- **Alternatives**: In the game it is possible to choose between several paths or tests and their difficulty. The potential effects are autonomy, experimentation and risk/reward estimation;
- **Randomness**: Events occur with a random component, resulting in unexpected events and causing the player's attention to be drawn. The potential effects are surprise, breakdown of monotony and unpredictability;
- **Feedback**: Immediate feedback is provided on every action taken, allowing cause-effect learning by association. The potential effects are learning by causality, sense of progress and experimentalism;
- **Competence level**: Games award points or measure merits that recognize the experience acquired and the evolution of the player. The levels reached are consolidated. The potential effects are competition, status and sense of progress;
- **Social component**: A game can be designed to play with one or several players. The potential effects are fostering personal relationships and social integration.

Most people who suffer from cerebral palsy have movement limitations. This implies that many of them do not have the physical capacity to respond quickly to certain stimuli, to interact with precise movements or to make combinations of movements that many video games demand. Our experience in developing accessible video games tells us that the adaptation of the interaction can be done through several strategies. Next, we present a list of features that video games adapted for people with cerebral palsy might well have. These features offer multiple beneficial effects for players. Players can improve their quality of life: visual coordination, spatial-temporal organization, memory, social contact, etc. These strategies can be combined in several ways and they can serve as a guide for future developments.

Interaction reduction: One of the most effective way of making a video game accessible is reducing the interaction so that it can be performed with a single button, by means of just a click, avoiding combinations of buttons, multiple buttons or pointing devices. In general, this is achieved by using mechanical switches that can be pressed with the hand, foot or head, or by other more specific devices. The potential effects are autonomy and experimentality.

Sweeping: Reducing the interaction to a single click can be achieved through sweeping strategies. This technique is used to navigate between several options and select one of them. All the options are highlighted, one at a time, at a certain speed, and then changed after a defined time. The user must click on the moment the desired option has the focus. Apart from the option with the focus, the other previous and future options must be displayed on the screen, so that the user can anticipate the next option and prepare to perform the action. The potential effects are autonomy, sense of control and feeling of influencing the environment.

Sliders and circular meters: Sliders and circular meters allow the selection of a value within a range. They have a needle that runs the slider automatically, so that the user can stop it at the desired value with a single click. This strategy allows the selection of different values without requiring a pointing device that needs to be handled with greater precision. The potential effects are increased self-confidence and self-esteem and independence feeling.

Configurable Speed: The speed of each user when handling the interaction devices during the game can be very varied. Therefore, it is important to allow the configuration of the speed, both during the selection of the characteristics and the profile, and during the game action. The potential effects are usability, accessibility and less frustration.

Interaction devices: In addition to switches, the inclusion of other more versatile interaction devices can be very interesting. In particular, the use of Kinect in our games has given us very good results. On the one hand, not having to hold any element in the hand facilitates freedom of movement. On the other hand, it is possible to define with which part of the body we want to perform the interaction. It is necessary, therefore, that the games allow different configurations and ranges of movement. The potential effects are usability, accessibility, improved balance, strength and flexibility, improved coordination, increased self-confidence and self-esteem, improved motor skills and increased functional independence.

Game interface and graphics: The game interface should be simple so as not to divert users' attention from the main focus. The design of the interaction elements should allow easy identification, making use of appropriate colors and sizes. As for the game scenario, we must avoid too many superfluous elements that divert attention from the main character. The potential

effects are increased concentration, strategic planning and space-time organization.

Identification with the avatar or environment game: In the game there is the possibility of choosing an avatar with which the player can fully identify himself. The potential effects are immersion and empathy (both affective and cognitive).

5.1 Videogames rubric

In the previous paragraphs the characteristics of video games have been defined. In this section we propose a rubric to evaluate these characteristics and to be able to assess a video game especially for its adaptation characteristics for people with cerebral palsy. Table 3 shows the assessment for the general characteristics of video games while Table 4 shows the assessment for the characteristics of adapted video games.

This section is not intended to be strict in any way because it will depend very much on the characteristics of the patient for whom the video game is intended. For example, a Kinect device is much more suitable for therapeutic use with motion therapy than a brain-computer interface. On the other hand, for patients with absolute immobility, the latter option is more appropriate.

Finally, the rubric is applied to video games previously shown to obtain their score. Table 5 presents the results of applying the rubric to Footb-all game, Table 6 shows the scores for Formula Chair game and, finally, the resulting scores for Fisio Run game are presented in Table 7.

6 Conclusions and further work

This experience has served to study and design new ways of making video games accessible to disabled people, giving them the chance to develop their right to entertainment. Video games offer these users a form of leisure that also benefits them in many ways, both physically (strength, coordination, etc.) and emotionally (self-confidence, independence feeling, etc.)

The use of the proposed incremental and agile methodology has been proved to be very suitable for this type of projects. It has the advantage of allowing students to gradually introduce themselves in the knowledge of adapting video games to make them accessible. In addition, in this way, the successive meetings and tests with the users of APCA allow the students to know the problems of users affected with cerebral palsy and to strengthen the bonds between students and users. This gives students an important awareness of the need to give all people, regardless of their conditions, access to digital platforms and, why not, to digital leisure.

As a result of the design and implementation of several video games, we have also developed a guide for designing and developing adapted games. This is a preliminary version that will be completed in the future as new video games will be designed. This guide can also be extended to other types of digital systems that must be adapted to disabled users. One strength of this guide is the fact that it also includes aspects related to the general design of games, so that, the resulting games will not only be accessible but also fun. In short, it allows the design of true video games.

This work is considered as a seed for the digital transformation of interaction environments adapted to users with disabilities, and for the involvement of professionals of the future in this transformation. Therefore, the lines of future work are many and widely open. In particular we propose for the future to explore other interaction devices. We are particularly interested in Brain-Computer Interfaces. We also plan to consider new ways of adapting the interaction to complete the guide and lessons learned about adapting video games to disabled users. As a consequence, we will widen and strengthen the links between our University and APCA and other associations of disabled users, and improve the diffusion of the results so that they can be used for any disabled user.

References

1. APCA (2016) A.P.C.A. Asociación de Paralíticos Cerebrales de Alicante. URL `http://www.apcalicante.com`
2. Caillois R (1958) Les Jeux et les Hommes (Le Masque et la Vertige). Revue Économique 9(6):1001–1001, URL `https://www.persee.fr/doc/reco_0035-2764_1958_num_9_6_407336_t1_1001_0000_003`
3. Csikszentmihalyi M (1991) Flow: The Psychology of Optimal Experience. Harper Perennial, URL `http://www.amazon.com/gp/product/0060920432/ref=si3_rdr_bb_product/104-4616565-4570345`
4. Disabled World (2016) Cerebral Palsy: Types, Diagnosis & Research. URL `https://www.disabled-world.com/health/neurology/cerebral-palsy/`
5. Durkin K, Boyle J, Hunter S, Conti-Ramsden G (2013) Video Games for Children and Adolescents With Special Educational

Table 3 Videogames rubric

Characteristic	0	1	2	3
Recognition of partial achievements	The activity is performed in a single step or is binary (correct / incorrect)	Intermediate steps can be performed, but are not necessary or evaluable	Intermediate steps are evaluable but are scheduled and/or not many	There are many measurable and unplanned intermediate steps
Incremental difficulty	The difficulty of the activity is unique and constant or not measurable	The game has different difficulty variants, unstructured or not incremental	There are different incremental levels of difficulty	Selectable and incrementally distributed difficulty
Trial and error	Error is not allowed. If there is a mistake it cannot be recovered	It allows error and recovery, but reducing the best achievable result	It allows error and recovery without reducing better results, but in a limited way	It allows error and recovery without constraints
Alternatives	There is only one way or way to do the activity	There are alternative ways or means of carrying out the activity but they are similar	There are a limited number of different paths or ways of doing the activity	High number of different ways of carrying out the activity
Randomness	There are no random components. Every event is predictable	Some part may be unpredictable but is not designed on purpose	Purposefully designed events that happen with estimated probability by eye	Random events with well-studied probabilities are included.
Feedback	There is no feedback of any kind	Delayed feedback over time that limits cause-effect association	Timely feedback to enable cause-effect learning	Immediate feedback
Competence level	No recognition of the user's level of experience or evolution	The user's evolution is measured, but without defined recognitions	There are levels or recognitions that can be obtained by improving the level of competence	The user gains recognition with the activity and it adapts to his level
Social component	One player	Several players for consecutive turns	Several players interacting	Several players interacting online

Needs. Zeitschrift für Psychologie 221(2):79–89, DOI 10.1027/2151-2604/a000138, URL http://econtent.hogrefe.com/doi/abs/10.1027/2151-2604/a000138

6. Font Puig A (2015) Proyecto Final de Grado: Formula Chair. Universidad de Alicante, Alicante, URL http://hdl.handle.net/10045/49408, proyecto Final de Grado
7. García A (2012) Videojuegos de acción para mejorar el cerebro y la visio?n. URL https://www.eurogamer.es/articles/2012-07-18-videojuegos-de-accion-para-mejorar-el-cerebro-y-la-vision
8. Gee JP (2007) What video games have to teach us about learning and literacy, rev. and updated ed edn. Palgrave Macmillan, New York, oCLC: ocn172569526
9. Gómez Davó R (2014) Proyecto Final de Grado: Videojuego adaptado para personas con parálisis cerebral. Universidad de Alicante, Alicante, URL http://hdl.handle.net/10045/40272, proyecto Final de Grado
10. Granic I, Lobel A, Engels RCME (2014) The benefits of playing video games. The American psychologist 69 1:66–78
11. Hamari J, Shernoff DJ, Rowe E, Coller B, Asbell-Clarke J, Edwards T (2016) Challenging games help students learn. Comput Hum Behav 54(C):170–179, DOI 10.1016/j.chb.2015.07.045, URL http://dx.doi.org/10.1016/j.chb.2015.07.045
12. Huizinga J (1955) Homo Ludens: A Study of the Play-element in Culture. Beacon Press
13. Jenkins H (2016) Game Theory. URL https://www.technologyreview.com/s/401394/game-theory/
14. Kebritchi M, Hirumi A (2008) Examining the pedagogical foundations of modern educational computer games. Computers & Education 51(4):1729–1743, DOI 10.1016/j.compedu.2008.05.004, URL http://linkinghub.elsevier.com/retrieve/pii/S0360131508000778
15. Kent RM (2013) Cerebral Palsy. In: Barnes MP, Good DC, Aminoff MJ (eds) Neurological rehabilitation, no. ser. ed.: Michael J. Aminoff ... ; Vol. 110 = 3. Ser., [Vol. 32] in Handbook of clinical neurology, Elsevier, Edinburgh, pp 443–459, oCLC: 817269354

Table 4 Videogames adapted rubric

Characteristic	0	1	2	3
Interaction reduction	The game requires several interactions of various devices using combinations of them (e.g. moving the joystick while pressing a button on the console)	The game requires several interactions of various devices (e.g. several keyboard keys and the two mouse buttons) but without combinations	Multiple interactions of a single device (e.g. click and double mouse click)	Only one interaction is required to play
Sweeping	There is not one. To choose an option you need to use a pointing device	There is a continuous screen sweep showing one option after another with fixed speed	There is a continuous screen sweep that shows one option after another with configurable speed	There is a continuous screen sweep that shows one option after another with a speed that automatically adapts to the player
Sliders and circular meters	There are no such meters	The game shows sliders or circular meters with fixed speed	The game shows sliders or circular meters with configurable speed	The game shows sliders or circular meters with the speed that automatically adapts to the player
Configurable speed	It is fixed	It has three speeds: high, medium and low (discrete)	It has a control that allows you to set the speed	It adapts progressively to the player's pace
Interaction devices	Common devices	Mechanical switches for a hand, foot or head	The body is used as an interaction device (Kinect)	Brain-computer interfaces
Game interface and graphics	The game has a lot of details and superfluous elements with colours that are not suitable to fix the attention	The game has a lot of details and superfluous elements with appropriate colors to fix the attention	The game has only relevant elements but the colours do not help to determine the focus of attention	The game presents only relevant elements with the appropriate colors to facilitate interaction
Identification with the avatar or environment game	No choice of avatar	There are avatars available but none that are associated with a disability	There are several avatars and some of them have disabilities	Disability and avatar are configurable

16. Koster R, Wright W (2004) A Theory of Fun for Game Design. Paraglyph Press
17. Li Q, Cheng TC (2017) New evidence in physical violent behaviors among school-aged children: A multiple disadvantages model. Children and Youth Services Review 81:301 – 308, DOI https://doi.org/10.1016/j.childyouth.2017.08.021, URL http://www.sciencedirect.com/science/article/pii/S0190740917305236
18. Llorens-Largo F, Gallego-Durán FJ, Villagrá-Arnedo CJ, Compañ Rosique P, Satorre-Cuerda R, Molina-Carmona R (2016) Gamification of the Learning Process: Lessons Learned. IEEE Revista Iberoamericana de Tecnologias del Aprendizaje 11(4):227–234, DOI 10.1109/RITA.2016.2619138, URL http://ieeexplore.ieee.org/document/7600433/
19. Lohse K, Shirzad N, Verster A, Hodges N, Van der Loos HFM (2013) Video Games and Rehabilitation: Using Design Principles to Enhance Engagement in Physical Therapy. Journal of Neurologic Physical Therapy 37(4):166–175, DOI 10.1097/NPT.0000000000000017
20. Mairena J (2009) Videojuegos accesibles, por qué y cómo hacerlos. In: IV Congreso de la CiberSociedad 2009. Crisis analógica, futuro digital, URL http://www.cibersociedad.net/congres2009/es/coms/videojuegos-\%20accesibles-por-que-y-como-hacerlos/317/
21. Martínez Martínez A (2016) Proyecto Final de Grado: Fisio Run. Videojuego adaptado para personas con parálisis cerebral. Universidad de Alicante, Alicante, URL http://hdl.handle.net/10045/58492, proyecto Final de Grado
22. McGonigal J (2011) Reality is Broken: Why Games Make Us Better and how They Can Change the World. Penguin Group, URL https://books.google.es/books?id=leAa_gAACAAJ
23. Microsoft (2016) Meet Kinect for Windows. URL https://developer.microsoft.com/en-us/windows/kinect

Table 5 Videogame 1: Footb-all

Characteristic	Option	Explanation	Points
Recognition of partial achievements	Intermediate steps are evaluable but are scheduled and/or not many	The game features five or ten penalty kicks where each of them gets a goal or not	2
Incremental difficulty	The difficulty of the activity is unique and constant or not measurable	The goalkeeper's artificial intelligence to clear the balls is always the same	0
Trial and error	It allows error and recovery, but reducing the best achievable result	Based on the result of the shot, the player can better estimate the parameters for subsequent shots but only gets points for the goals.	1
Alternatives	There are alternative ways or means of carrying out the activity but they are similar	There are several ways to kick the ball to get the point	1
Randomness	There are no random components. Every event is predictable	There are no unpredictable events that bring surprises into the game	0
Feedback	Immediate feedback	After each shot the player knows if he has scored a goal	3
Competence level	No recognition of the user's level of experience or evolution	There are no different levels that can be progressively surpassed, such as beginner, expert, etc.	0
Social component	Several players for consecutive turns	The game allows several players to play in turn and shows a ranking of them	1
Interaction reduction	Only one interaction is required to play	The strength and direction values of the shot are determined with a click, as well as the actual shot	3
Sweeping	There is a continuous screen sweep that shows one option after another with configurable speed	The parameter to be set is highlighted at every moment	2
Sliders and circular meters	The game shows sliders or circular meters with configurable speed	The game uses sliders to select the parameter values. The speed inside the slider is set at the start of the game	2
Configurable speed	It is fixed	The game consists of a series of shots on goal and there is no variation in the speed at which they are produced	0
Interaction devices	Mechanical switches for a hand, foot or head	A mechanical switch is used for each input to be made to the game	1
Game interface and graphics	The game presents only relevant elements with the appropriate colors to facilitate interaction	The design presents the player at the point of attention with the sliders to determine the direction and speed of the ball	3
Identification with the avatar or environment game	There are avatars available but none that are associated with a disability	The game allows you to choose different avatars but none of them is represented as a person with a disability	1
		Total score	20

24. Minear WL (1956) A classification of cerebral palsy. Pediatrics 18(5):841–852
25. Molina-Carmona R, Satorre-Cuerda R, Villagrá-Arnedo C, Compañ Rosique P (2017) Training Socially Responsible Engineers by Developing Accessible Video Games. In: Zaphiris P, Ioannou A (eds) Learning and Collaboration Technologies. Technology in Education, vol 10296, Springer International Publishing, Cham, pp 182–201, DOI 10.1007/978-3-319-58515-4_15, URL http://link.springer.com/10.1007/978-3-319-58515-4_15
26. Muñoz JE, Villada JF, Muñoz CD, Henao OA (2014) Multimodal system for rehabilitation aids using videogames. IEEE, pp 1–7, DOI 10.1109/CONCAPAN.2014.7000395, URL http://ieeexplore.ieee.org/document/7000395/
27. Pérez MDM, Duque AG, García LF (2018) Game-based learning: Increasing the logical-mathematical, naturalistic, and linguistic learning levels of primary school students. Journal of New Approaches in Educational Research 7(1):31–39, DOI 10.7821/naer.2018.1.248, URL https://naerjournal.ua.es/article/view/v7n1-5
28. Prensky M (2001) Digital game-based learning
29. Prensky M (2006) Don'T Bother Me Mom–I'M Learning! Paragon House Publishers

Table 6 Videogame 2: Formula Chair

Characteristic	Option	Explanation	Points
Recognition of partial achievements	Intermediate steps are evaluable but are scheduled and/or not many	The player moves along the track while avoiding obstacles	2
Incremental difficulty	There are different incremental levels of difficulty	The speed of the game can be set progressive, increasing the difficulty of the game as the game progresses	2
Trial and error	It allows error and recovery without reducing better results, but in a limited way	If there is a collision with an obstacle you lose a life but you can get the same number of points as if you do not lose any life as long as you do not exhaust all your lives	2
Alternatives	There are alternative ways or means of carrying out the activity but they are similar	The player moves from one track to another to avoid obstacles so there are several possible paths	1
Randomness	Purposefully designed events that happen with estimated probability by eye	From time to time, obstacles and coins appear	2
Feedback	Immediate feedback	A life is spent when there is a crash	3
Competence level	No recognition of the user's level of experience or evolution	There are no different levels that can be progressively surpassed, such as beginner, expert, etc.	0
Social component	Several players for consecutive turns	The game allows several players to play in turn and shows a ranking of them	1
Interaction reduction	Only one interaction is required to play	The game is controlled by means of the movement of the selected tip	3
Sweeping	There is a continuous screen sweep that shows one option after another with configurable speed	The parameter to be set is highlighted at every moment	2
Sliders and circular meters	The game shows sliders or circular meters with configurable speed	Sliders allow you to set the range of motion	2
Configurable speed	It has a control that allows you to set the speed	The game has a slider that allows you to choose the speed that can also be stable or progressive	2
Interaction devices	The body is used as an interaction device (Kinect)	At the beginning of the game the player decides which tip to use to interact. Motion capture is done via Kinect	2
Game interface and graphics	The game presents only relevant elements with the appropriate colors to facilitate interaction	The look of the game is very simple, you can see the avatar to be controlled in the spotlight. There are no superfluous ornaments that can distract the player's attention	3
Identification with the avatar or environment game	There are several avatars and some of them have disabilities	This game has been designed specifically for people in wheelchairs	2
		Total score	29

30. Radtka S, Hone R, Brown C, Mastick J, Melnick ME, Dowling GA (2013) Feasibility of Computer-Based Videogame Therapy for Children with Cerebral Palsy. Games for Health Journal 2(4):222–228, DOI 10.1089/g4h.2012.0071
31. Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, Dan B, Jacobsson B (2007) A report: the definition and classification of cerebral palsy April 2006. Developmental Medicine and Child Neurology Supplement 109:8–14
32. Ryan RM, Deci EL (2000) Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. The American Psychologist 55(1):68–78
33. Sevick M, Eklund E, Mensch A, Foreman M, Standeven J, Engsberg J (2016) Using free internet videogames in upper extremity motor training for children with cerebral palsy. Behavioral Sciences 6(2), URL http://www.mdpi.com/2076-328X/6/2/10

Table 7 Videogame 3: Fisio Run

Characteristic	Option	Explanation	Points
Recognition of partial achievements	Intermediate steps are evaluable but are scheduled and/or not many	The game progresses as obstacles are avoided	2
Incremental difficulty	The difficulty of the activity is unique and constant or not measurable	The difficulty is not increased during the game	0
Trial and error	It allows error and recovery without reducing better results, but in a limited way	If there is a collision with an obstacle you lose a life but you can get the same number of points as if you do not lose any life as long as you do not exhaust all your lives	2
Alternatives	There is only one way or way to do the activity	The player has to overcome each obstacle in a unique way: there are obstacles that have to be jumped and others in which the player have to bend down	0
Randomness	Purposefully designed events that happen with estimated probability by eye	Every now and then a fence comes out that the player will have to overcome by jumping or bending over	2
Feedback	Immediate feedback	The player has three lives (this number may be increased) and loses one life each time the avatar hits an obstacle	3
Competence level	No recognition of the user's level of experience or evolution	There are no different levels that can be progressively surpassed, such as beginner, expert, etc.	0
Social component	Several players interacting	The game has two game modes for one or two players	2
Interaction reduction	Only one interaction is required to play	The game is controlled by means of the movement of the selected tip	2
Sweeping	There is a continuous screen sweep that shows one option after another with configurable speed	The parameter to be set is highlighted at every moment	3
Sliders and circular meters	There are no such meters	The game does not have these elements	0
Configurable speed	It has a control that allows you to set the speed	The game has a slider that allows you to choose the speed	2
Interaction devices	The body is used as an interaction device (Kinect)	At the beginning of the game the player decides which tip to use to interact. Motion capture is done via Kinect	2
Game interface and graphics	The game presents only relevant elements with the appropriate colors to facilitate interaction	The game has a simple look where you can see the avatar in a plane. The player has to avoid obstacles.	3
Identification with the avatar or environment game	There are avatars available but none that are associated with a disability	The game allows you to choose different avatars but none of them is represented as a person with a disability	1
		Total score	24

34. Squire K, Squire K (2005) Changing the Game: What Happens when Video Games Enter the Classroom? Innovate: Journal of Online Education 1(6), URL https://www.learntechlib.org/p/107270/
35. Street RL, Gold WR, Manning T (eds) (1997) Health promotion and interactive technology: theoretical applications and future directions. Lawrence Erlbaum Associates, Mahwah, N.J
36. Tai K, Blain S, Chau T (2008) A Review of Emerging Access Technologies for Individuals With Severe Motor Impairments. Assistive Technology 20(4):204–221, DOI 10.1080/10400435.2008.10131947, URL http://www.tandfonline.com/doi/abs/10.1080/10400435.2008.10131947
37. Turkle S (2011) Alone Together: Why We Expect More from Technology and Less from Each Other. Basic Books, Inc., New York, NY, USA
38. Velasco MA, Raya R, Muzzioli L, Morelli D, Otero A, Iosa M, Cincotti F, Rocon E (2017) Evaluation of cervical posture improvement of children with cerebral palsy after physical therapy

based on head movements and serious games. BioMedical Engineering OnLine 16(1):74, DOI 10.1186/s12938-017-0364-5, URL https://doi.org/10.1186/s12938-017-0364-5

39. Vicedo Carbonell C (2016) Proyecto Final de Grado: Diseño de videojuegos basado en la diversión. Universidad de Alicante, Alicante, URL http://hdl.handle.net/10045/58491, proyecto Final de Grado
40. Villagrá-Arnedo C, Gallego-Durán FJ, Molina-Carmona R, Llorens-Largo F (2016) PLMan: Towards a Gamified Learning System. In: Zaphiris P, Ioannou A (eds) Learning and Collaboration Technologies, vol 9753, Springer International Publishing, Cham, pp 82–93, URL http://link.springer.com/10.1007/978-3-319-39483-1_8
41. Whitehead A, Johnston H, Nixon N, Welch J (2010) Exergame effectiveness: what the numbers can tell us. ACM Press, pp 55–62, DOI 10.1145/1836135.1836144, URL http://portal.acm.org/citation.cfm?doid=1836135.1836144
42. World Health Organization, World Bank (eds) (2011) World report on disability. World Health Organization, Geneva, Switzerland, oCLC: ocn742386216
43. Yuan B, Folmer E, Harris FC (2011) Game accessibility: a survey. Universal Access in the Information Society 10(1):81–100, DOI 10.1007/s10209-010-0189-5, URL http://link.springer.com/10.1007/s10209-010-0189-5