Exergames: Game Prototype Using Maker Movement Assets

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Abstract. The world population is expected to grow until the year 2100. Also, the number of senior individuals is expected to surpass the number of children and teens in the populations. This growth in the raw number and number of seniors creates huge challenges for countries - especially in cost terms. It's well known that preventive healthcare could smooth those impacts through preventing disease. One of the most effective and easy to implement tools healthcare programs of this scope use is exercise. However, many individuals lack motivation for the practice. Since gaming is one of most used entertainment form, it seems a good way to attract and maintain people into exercise routines. Games of this type, that require the user movement as part of playing, are called 'Exergames'. This paper is consequence of a larger research towards game design methods for this specific type. Since initial surveys showed some lack of information about this subject, the need for this project emerged. A problem found along the research development was which device would be used to conduct further testing with design methodologies. Therefore, this paper shows the process of using maker movement assets to create an open source device capable of transforming body movement through cycling into command input to a platform game.

Keywords: Exergames · Health care · Maker movement

1 Introduction

In the last decades the world population has been growing constantly. According to predictions, we will reach 9.8 billion inhabitants by 2050, when the global population of people older than 60 is expected to jump to 2 billion [1]. This growth is expected to stabilize around the year 2100, when we expect to reach the number of 13.2 billion people [2]. In addition, the distribution of the population by age groups has taken a very different form from the past. This is due to declining birth rates and mortality rates. Thus, the distribution that could previously be represented by a pyramid (in which the base is much wider than the top) is gradually shaped into a column. As a result, the proportion of people over 60 years of age in the population has increased

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significantly, to the point that, excluding the African continent, it has surpassed the number of children between 0 and 14 years [2].

This aging of the population has a direct impact on the cost of health and on the existing structure of the health systems of countries [1]. In a traditional healthcare system, focused on reactive treatment services, this population increase should accentuate problems related to hospital and outpatient structure, health personnel, equipment, etc. One way to alleviate this rising cost is to invest in preventive health programs to reduce the frequent demand for hospitals and clinics [3].

However, a problem in implementing this type of approach is the culture and habits of the population. For example, it is commonly known and scientifically demonstrated that exercise practice prevents the onset of various diseases. However, about 10–50% of people who start structured exercise programs give up in the first six months, with most of these withdrawals occurring within the first three months [4].

From the point of view of this research, it is believed that it is possible to minimize this resistance to exercises if these are done concomitantly to the practices of entertainment and fun. To play is part of the human essence, in the course of history and in all cultures we find various manifestations of games spread across different regions and countries [5]. In the last decades, electronic games have increased in popularity due to the expansion of Internet access, the popularity of computers - especially smart phones [6]. Digital games, notably entertainment games, draw the attention of the media and researchers to the increasing spread of their use - thereby bringing about an equally increasing volume of capital movement [6]. Despite stereotypes, gamers come from all walks of life. Today, there are over two billion gamers worldwide - and they all play across a wide variety of genres and platforms. About 59% of gamers are males, and 41% are females - and the average age of a gamer is 38 years old [7].

Due to the immersive capacity and attractiveness of digital games, they have also been used for practical and serious applications, such as education, health, and for specific skills training - simulation games - thus being designated serious games [8]. Among these applications, we highlight serious games for health as the focal point of our research, due to the possibility of their application in the achievement of wellbeing for people of any age, gender, race, or social class.

The term ‘Games for Health’ (GfH) refers to games used in health and fitness treatments [9]. In the same way that the concept of health covers a wide range of areas [10], games in this segment have applications in a wide range of areas, such as: aid for the training of health professionals [9], physical rehabilitation [11], health education [12], and even aid in diagnosis [10].

Among the games used directly in treatments, there are two subtypes: those that work for mental and cognitive health, and those that care and treat the body, requiring the user to effectively perform some type of physical exercise [9]. Games of this second type are commonly known as Exergames - term from the union of the words exercise and game. These games require that the user execute movements with the body or members as an effective part of the game play.

This research began in 2016, with the accomplishment of a bibliographical review of academic works related to the Exergames, using works published in Brazilian and international journals as source. This sampling demonstrated the lack of methods and tools for the design process of Exergames [13]. Therefore, the main objective of the research was to explore several design methods and tools and, if necessary, create new ones specifically for this game genre.

However, as the research went on, it was clear that a device platform had to be developed before studying game design methodologies so that the specificities of the health area could be met. Thus, the research was directed to look for ways to create or adapt an equipment keeping it cost accessible and easy to use so that it made the application of Exergames more extensively available to a greater part of the population in the scenario of a developing country.

After considering many options, the path chosen was to use the tools from maker movement which could allow the construction of a device prototype based on an Arduino system. Also, using the maker movement bases, the research could make results more accessible through an open source and keep it low cost. All of this is aligned with goal #3 from United Nations 'Goals for a Sustainable Future' [14].

2 Health

Health is a term that has different definitions or interpretations, being considered as a simultaneously philosophical, scientific, technological, political, and practical issue [15]. Within the scope of this research, we understand that health is the second most important point for safety and security in the pyramid of Maslow's hierarchy of human needs [16], and also consider United Nations Sustainable Development Goal 3, which states that "*Ensure healthy lives and promote well-being for all ages*" is the third most important point to be worked towards developing a sustainable world [14].

The improvements in nutrition, hygiene, sanitation and a better health system achieved in the last decades have resulted in an increase in the longevity of populations, leading to a considerable escalation of the prevalence of chronic diseases in society, leading them to be considered the challenge of public health in the 21st century [17].

One of the ways to address this problem is to change the way people care for their health by changing people's health habits from a reactive approach to a proactive approach, by encouraging people to take basic care of themselves and become protagonists of their health. This can be accomplished with participation from health providers to encourage the patients to exercise, take prescribed medications and vitamins correctly, drink water, watch their weight, eat healthily, and schedule regular wellness exams with primary care physicians [3].

This new approach has the potential to change cost perspectives in the area around the world, considering that health occupied, in average, about 10% of the GDP (Gross Domestic Product) of the nations in 2014 - 8.3% in Brazil. There is also a tendency to a growth in this percentage, with an increase of about 1.5% in GDP revenue in the last two decades, as well as in the average value of investment per capita [18].

Prevention in health is defined as an anticipated action based on the knowledge of the natural history of the disease [19]. It is comprised of three phases: [a] Primary Prevention, corresponding to the actions performed in the pre-pathogenesis period, 'health promotion' and 'specific protection'. [b] Secondary Prevention, dividing between 'early diagnosis and treatment' and 'disability limitation', and finally [c] Tertiary Prevention corresponding to 'rehabilitation' actions [19].

3 Games for Health and Exergames

The percentage of the population with access to computers and the Internet has grown worldwide in the last decades. To illustrate this, in Brazil, according to IBGE - Brazilian Institute of Geography and Statistics, Internet access by computers increased from 6.3 million households in 2004 to 25.7 million in 2012 [20]. In this regard, it seems valid to think of a possible point of convergence among these three trends - increasing life expectancy in the world population, increasing gamer population, increased access to digital media that allow playing.

Some of the examples of the roles Games for Health can play are the training of doctors [21]; patient awareness [22], improving health [23]; and rehabilitation treatments [24]. This research proposes the study of these last two types of applications by design bias: the Exergames.

The term Exergames comes from the union of the words exercise and game, and covers a wide range of games that similarly require the user to perform some type of physical effort. Other terms used to define games of this type are: Active Video Game, Active Gaming, Movement Controlled Video Game, and Exertion Game.

It should be noted that many games that, at first glimpse, would not be qualified as Exergames, can be used for these purposes, even though they have not been created for this intention. As examples we have the series Wii Sports [25], also used in experiments of improvement of physical conditioning [11], and Pokemon Go [26], which was already pointed out as possible cause of the weight loss of some of its users.

The term Exergames should be understood, in the scope of this study, as digital games created with the primordial and main intention of physical exercise to improve some aspect of health - either for the physical-motor rehabilitation or improvement of the physical condition of its player.

3.1 Brief History of Exergames Devices

The first known device for Exergames was the Atari Puffer [27]. It was planned by Atari in the early 1980s when the company realized an opportunity to market entertainment games to exercise on exercise bikes. The project had three specific models, aimed at different markets: Pro model, for gymnasiums; Arcade Model, for arcades stores; and, Home Model for home use, with a more affordable price. The project ended up being filed due to the bankruptcy of the company.

Following this device, two other projects involving stationary bikes and games were developed - Autodesk HighCycle and RacerMate CompuTrainer. Few technical references exist about Autodesk HighCycle - just images of bike racing simulators. The RacerMate CompuTrainer was developed by a fitness equipment company, known to have an electromagnetic exercise load system, different from the conventionally used straps. This electromagnetic system allowed the sending of data to a computer [27].

Still in the 1980s, Nintendo entered the market with PowerPad and PowerGlove. The PowerPad was a rug with built-in buttons to be fired with the users' feet, consisting of 3 rows with 4 columns of buttons each, totaling 12 buttons. The use could be individual or double, the buttons were marked half blue and half red, signaling the ones that should be used by player 1 and player 2 in the case of double matches. The most well-known game of this device was the 1989 Dance Aerobics, a dance game that is considered the forerunner of Dance Dance Revolution, mentioned later in this section.

Nintendo PowerGlove was basically a glove with joystick-like buttons and sensors that sensed the movements made by the user's hand. There are reports that the device did not work very well, even when used in conjunction with a game developed especially for the glove – Myke Tyson's Punch Out [27]. Entering the 90's, Tectrix VR Bike and VR Climber were respectively a bicycle ergometer and a step device (simulating something between walking and climbing steps of a ladder). Both had a computer and CRT monitor coupled and came with six games, loaded via CD-ROM. Both had special versions of games developed for the use of the American military, and the price for the public was around USD 28,000.00 [27].

Dance Dance Revolution (DDR) is considered the first successful exergaming system [28]. Created by Bandai, based on concerns about growing obesity among young Japanese, DDR consisted of a dance-themed game running on an arcade device with push buttons to be triggered. These were arranged in a matrix of 3×3 buttons with the central neutral position (without drive) in which the player was initially stopped. In this way, the eight drive positions were around the player. The player during the match should fire the buttons at the correct time according to the song and the level of difficulty chosen - thus gaining points. This rhythmic drive together with music formed the central theme of dance.

Using a different approach, two command-trigger devices were created to replace the joysticks, the CatEye Game Bike, and the Bodypad for Fighting Games, which operated on conventional consoles such as PlayStation 2, being used instead of the original joystick [27]. The Cat-Eye Game Bike was a stationary bicycle geared towards racing games, where pedaling replaced the acceleration command of the joysticks. The Bodypad for Fighting Games was a series of sensor clamps that the user could use to capture the movements. A receiver received the data and converted it into blows from the fighting games.

3.2 Current and Near Future Devices

As current devices, the most popular and well-known are the Nintendo Wii and Microsoft Kinect. Through research, we verified the existence of other devices, which are not available in Brazil such as Expresso bikes, Goji Play and the Holodia VR system. Nintendo Wii was released in 2006 and discontinued in 2013 [25], for purposes of this approach, it is considered current because it is still used by rehabilitation clinics such as the Lucy Montoro Clinic [29].

The novelty of the device was to use sensors embedded in the joystick, allowing the console to calculate the spatial positioning (X, Y and Z axes) the joystick was in, thus perceiving changes in its positioning, which was then converted into action in games. Hence, the act of playing on Wii approached real actions such as boxing, bowling or sword fighting. Due to popularity and low cost, the console has been used in research for use in rehabilitation, child obesity [11] and physical education [30, 31].

To compete with Nintendo Wii, Microsoft introduced the Kinect in 2010 as an accessory to the Xbox 360 console [32]. Equipped with special cameras and microphone, the accessory could capture the body of the users and verify changes in the positioning of this or the limbs and head. A new version of the system was released in 2013 for the Xbox One and for PC (Personal Computer). The use with PC allowed the appearance of several studies and projects related to the use of Kinect for different applications from the evaluation and rehabilitation of motor deficit [33] to the improvement of balance in the elderly [34]. Microsoft Kinect had its production stopped in the second quarter of 2017 and a new version was presented in the second quarter of 2018 [35]. Once the technical features were released, this new version of Kinectic shows that Microsoft's mindset was quite similar to our approach, making this new version directed to makers and tinkers. This subject will be further commented in the Sect. 5 of this paper.

The bicycles of the brand Expresso [36] have a closed system with a monitor and computer docked. Roughly speaking, it can be considered an evolution of Tectrix VR with updated hardware and software. During the survey, a user of a US fitness club who has a model of the brand was contacted. In an initial conversation, he offered to informally interview some instructors of the gym about the use of the Expresso. They said that the equipment is little used and believe that the system is uninteresting for the local reality because the game consists of a simulation of cycling in streets. According to the comments of these instructors, the public of the gym prefers to ride bikes outdoors, in parks and streets instead of trying to simulate an immediate reality.

Another system found in the research was the Goji Play [37]. This consists of two small buttons that can be attached to the bicycle handlebars and can communicate with mobile devices. The company website features examples of various games that can be used with the system. In the first version of Gojy Play, only handsets running iOS were supported. The current version supports both iOS and Android. The company has VR system ads, but at the time the search was made, there were no available further details.

The Holofit [38] of the company Holodia is the most recent release found in this research. According to data from the manufacturer, Holofit integrates with modern stationary bikes, rowing, and step devices, providing integrated experiences in virtual reality.

4 Proposal: Use of Maker Movement Technology

For the study of methods and tools for Exergames Game Design, it is necessary to define the device to be used for capturing user movements. Points to consider for this choice are: [i] device availability - that is, if it is currently in production and sale; [ii] the system allows for easy development, not being blocked or in need of expensive/specific development kits; [iii] ease of device reproduction and replacement of parts; [iv] availability for use in social projects, thus increasing the impact that Exergames can have on improving the health of the population.

Considering the points discussed above, a decision was made to use a prototype exercise device for Exergames, a common stationary bicycle, modified using the technology of the Maker Movement to provide communication with the computer and/or mobile device. This section is subdivided into four parts relating: the Maker's Movement, the process of choosing the stationary bicycle, the prototyping of the platform game, and the comments on the results obtained.

4.1 Maker Movement

Vilém Flusser was a philosopher whose thought approached what he called Homo Faber, that is, the human that becomes human through doing. For Flusser, the factory of the future will be a place where the potentialities of Homo Faber can be realized [39]. Also, from this perspective, everyone can take ownership of existing things, transform, and use them.

Flusser passed away in 1991, but his texts anticipated the change in the concept of factory in at least a decade. Only in 2001, with the implementation of the first FabLab at MIT (Massachusetts Institute of Technology), did these Flussian concepts begin to appear [40]. The FabLabs are a laboratory-factory model that makes CNC machines (computer numerical control) that receive instructions directly from the computer available to the general public. The operating system of the FabLabs has ideological foundations in what is now known as the Movement Maker.

According to Anderson [41], this movement has in its foundations the practice of Do-It-Yourself (DIY) that involves the unprofessional development of manufacturing skills - commonly regarded as a hobby. It covers the term a wide variety of activities, from crafting practices such as woodworking, to the use of high-tech electronics.

Practitioners of this movement are popularly known as Makers. Anderson [41] points out two aspects that separate these from the makers and inventors of the past: [i] they are using digital tools - projecting on the screen, and manufacturing them using computerized machinery; and, [ii] they are sharing their creations over the internet. These, in turn, promote the democratization of innovation around bits (digital archives) just as fast prototyping machines, such as 3D printers and laser cutting machines, provide the democratization of innovation in the physical-material plane. Briefly, the Maker Movement is characterized by:

- Use of digital tools to design new products and to prototype them (called ‘digital DIY’ by Anderson);
- Common sense in distributing and collaborating on collective projects through online communities;
- Use of a standardization in these files that allows anyone, if he so desires, to send those files to companies with the intention of manufacturing these products in any desired quantity - as easily as producing it on the bench itself [42].

Although, in general terms, the Makers use any available material or technology, observing the application list of FabLabs [42], we can observe that they must have Computer Numerical Control (CNC) cutting machines of different types, additive manufacturing machines (popularly known as ‘3D printers’), and electronic equipment of the Arduino type.

CNC cutting machines can receive commands directly from computers, making cuts with precision and speed. There are both those that use cutter-type cutters (cutting and beveling), depending on the profile of the cutter, as well as laser cutting machines - used both for sheet cutting of various materials and for engraving textures on surfaces of materials.

Additive Manufacturing (AM) Machines also receive commands via computer and function by principle of depositing material to form the desired object - as opposed to the traditional method of removing material to achieve the final shape of the object. There are several types of AM machines, varying the material type, speed, final object precision, etc. In recent years, the price drop has made the equipment more affordable. One of the most popular types is the filament AM machine, which is fed by a plastic coil to produce the objects. An example of this type, is the Arduino Materia 101 [43] which costs close to US $ 800.00.

As for electronics, one of the most popular systems is the Arduino. This is an open source electronic platform that is easy to assemble and easy to program. Arduino is capable of receiving electro-electronic pulses either through sensors, buttons or even a message via Twitter and turn it into a command to drive a motor, connect a LED lamp etc. [44]. For example, with Arduino it is possible to create an automatic irrigation system of the gardens of a house [45].

Given the possibilities of creation provided by the technologies used in the Maker Movement, in the understanding of this research, it is believed that the use of these technologies are quite feasible and bring two important factors for the application of Exergames in Brazil: cost and dissemination. Considering cost, the materials are considerably more affordable when compared to closed systems. As for dissemination, the principles of the Maker Movement favor the reproduction of the experiments to be carried out during this research, not only by teaching and research institutions, but also by companies of different sizes and individuals from different parts of the country - thus increasing the possibility of dissemination of Exergames in our society.

4.2 Device Selection: Ergometer Bicycles

For the equipment, a stationary bicycle was chosen. Factors that led to the choice were: [i] acquisition cost, [ii] the amount of basic electronics shipped, [iii] equipment popularity, and [iv] the possibility of future expansion adding new functionality.

In terms of acquisition cost, models ranging from USD 125.00 to USD 1,750.00 were surveyed. The main factor of this big cost difference is in the structural part of the bicycles that, due to several reinforcements, end up bringing up the cost of the models destined to clinics and gymnasiums – which have a very high daily load of use. It was noticed that even the most basic bicycles had basic electronics and had an on-board computer in which data such as speed, distance traveled, spent calorie, and heart rate are shown.

As for the popularity, it was noticed in visits to gymnasiums that had bicycles among their equipment. These are offered both in the upright pedaling position (also called spinning position, similar to racing bikes, where the pedals are under the seat) and in a seat configuration similar to a common chair (known as horizontal model, in which the pedals are in front of the chair). Rehabilitation clinics such as the pulmonary disease treatment laboratory at the University of São Paulo Medical School Hospital (HCFM-USP) and the Lucy Montoro Clinic, have been found to use bicycles (horizontal model) in the physical treatment of patients.

Lastly, the possibilities of scope expansions of the device were considered - that is, the possibility of introducing new features to the project. At this point, we highlight new technologies such as wearable's (clothing and accessories with built-in computing) and virtual reality equipment (VR gear), the latter being particularly interesting given the great interest of the media and the devices that are being developed by companies.

Taking into account all these factors, a KIKO brand bicycle, model KV31i [46] was purchased with the authors' own resources, with an acquisition cost of around USD 250.00. It contained embedded electronics (on-board computer); integrated heart rate monitor and vertical pedaling position. Also, we considered this model since in conversations with some local gym instructors the brand was one of the recommended for its quality and reliability.

4.3 Bike Prototype for Exergame

This section describes the steps of the prototype of the bicycle and is divided into two sub-sections. In the first one, a complete planning of the stages of this research is presented.

In the second section, we present the work done until now, which consists in the first stage of this study, resulting in a prototype, where we show what was worked on the electronics using Arduino, C# programs, and the game platform developed to validate the game idea using only the pedaling as input.

Complete Planning Steps for this Research

For the complete development of the bicycle for Exergames, we adopted system of development in stages, in which a new characteristic or functionality would be added to the device in each step. Thus, the research is developed in six stages, the first of which has its completion described in this paper.

For the planning of the stages, the know-how of the researchers, the acquisition of equipment, and the maturity of the technologies involved were taken into consideration. Thus, the planning of the stages went from the simplest functionality – verifying the speed of the user's pedaling – to the most complex – virtual/augmented reality addition. The stages are shown in Fig. 1 and described below.

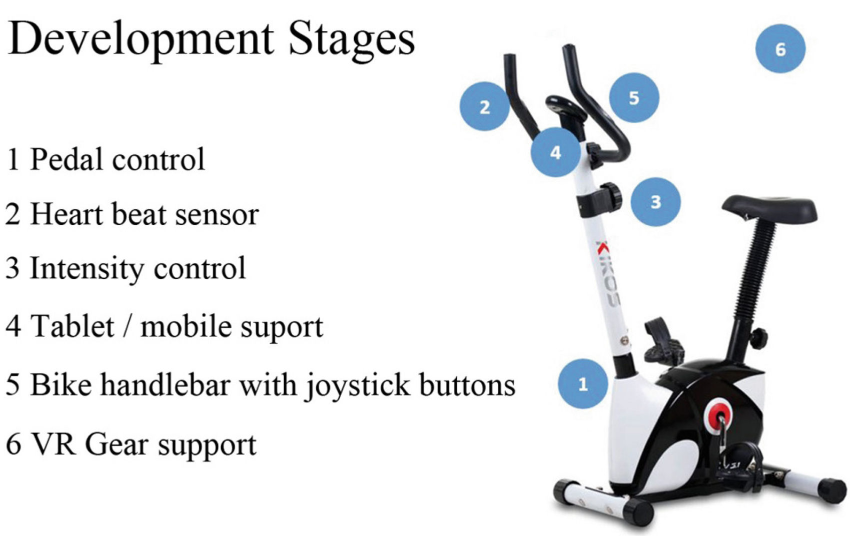

Fig. 1 The schematic of all planned project stages.

- 1st Stage (complete) - the capture of the most basic movement of the bicycle was defined: the movement of the pedal. This was then sent to a computer, so that communication with Unity for the development of games was possible;
- 2nd Stage - capture the heart rate using the sensor built into the bike itself. Through this monitoring, it will be possible to carry out prototypes and tests with users;
- 3rd Stage - measurement of the load (pedaling effort). For this, we'll need to study and test different types of sensors, since bikes in this price range have no native sensors;
- 4th Stage - the development of support for mobile devices. The idea is that this support is printed on machines of additive manufacture so that it is easy to reproduce, in the molds of the Maker Movement. Larger tests with more users should start at this stage, because at this point the bike will work with games running on tablets or smartphones, making it easier to move and use;
- 5th Stage - tests on the modification of the bicycle handlebar for the addition of extra buttons, of the type found on joysticks. This addition can be in two ways: adding a new "handle" on the handlebar, with the buttons built-in (in a similar concept to Goji Play); or redesigning the entire handlebar, adding the buttons and with the option to make the handlebar moveable, adding a turn sensor for control of left-right turns;
- 6th Stage (Final) - VR technology will be added to the system. Regarding this aspect, it is important to highlight the concern with the use of this technology for health applications, especially around sickness and malaise that have been reported and studied.

VR technology has returned after a long hiatus since its rise in the 1990s. Recent technological developments have made HMD (head-mounted display) smaller, lighter, cheaper, and faster response devices [47]. Despite all technological advancement, most virtual reality helmets still depend on computers to process images, and power cables, and image transmission connecting the computer to the helmet, what ends up limiting users' movements, which would hinder performance and ergonomics of the project.

In 2015 the company Google launched the Cardboard, a product to bring virtual reality to the public with a cost around USD 15.00. The idea is that almost everyone carries a virtual reality device in our pockets: our own smartphone. The Cardboard is nothing more than a pair of lenses coupled to a cardboard structure in the shape of a helmet, which is attached to the user's head through an elastic strap.

In parallel to the development of the Cardboard, the Korean company Samsung developed a more advanced option of helmet that uses the mobile device called Gear VR [48]. With better construction material, it has superior image quality and is more robust. Gear VR and Cardboard are the two viable options for the project, both of which have applications developed through the Unity gaming engine, and is easily portable so that it can be used on different platforms. The choice of the virtual reality device would end up being guided by the cost or the mobile device of the user, since the Gear VR requires the use of a Galaxy line phone.

Virtual reality in mobile handsets creates challenges that are more easily transposed when target platforms are computers. Because of the lower graphics processing power of mobile devices, care is required regarding application performance so that it maintains an update rate of 60 fps (frames per second), which is the recommended minimum value. Another important factor in choosing Gear VR is that it has a latency of less than 20 ms, which reduces cybersickness, which is a kind of motion sickness or movement caused by user exposure in virtual reality environments. According to Carmack [49], cybersickness is one of the biggest impediments to a greater adoption of virtual reality in the gaming industry.

The exercise bike is safer than an electric treadmill, for example. Cybersickness can pose a threat to the balance of users who are more susceptible to motion sickness, who are prone to seasickness when reading while traveling by car, or with the uneven movements of a boat trip [50].

Due to all these factors, the development with VR was left to the last stage of the project in view of the longer time for studies and the development of new hardware and software by the industry.

Making the 1st Stage Prototype

The elaboration of the prototype of the 1st Stage had three phases:

- Hacking the basic electronics of the bicycle;
- Handling of the bike data for use in Unity;
- The confection of the platform game in Unity.

For the hacking of basic electronics, the bike was first taken to the FabLab Livre of São Paulo City Hall, in the São Paulo Cultural Center unit. There, the initial tests of the general functioning of the bicycle and of the original electronics were made. After this verification, measurements of the working voltages of the sensors of the bicycle were made, obtaining values below 0.5 V. With this value, it would not be necessary to put resistors to decrease the voltage because they were within that which is supported by the Arduino Uno board.

Since the normal working voltages of the bicycle sensors were safe for the electronic part, the bicycle wiring was connected to the sold-board and from the Arduino board to a PC running Linux through the USB port. The programming part was done with the Arduino IDE [44]. Once the connection was established, the voltages were shown by the Serial Monitor screen of the Arduino IDE.

To facilitate the visualization of the values, Processing [51] was used to construct a light graphic application. An image of the type of graph obtained is shown in Fig. 2. The chart roughly resembles an electrocardiogram in which each time the plotted graph reached zero, it meant that the pedal of the bicycle had taken a turn.

Fig. 2 Graphic plotted by processing program, showing the electric signals sent by bicycle through Arduino to the computer.

For the second phase, the bicycle was then transferred to the Games Laboratory of the Anhembi Morumbi University. The goal at this stage was to process data that were required for the use of electric bicycle signals by the Unity gaming suite [52]. Adjustments had to be made using Microsoft's Visual Studio [53] because some of the features needed were not supported by the Unity code editing tool.

There was also a need to make some Unity configuration adjustments to allow communication with the C# tool (reads C Sharp). The developed program was used to pick up the electrical signal sent by the Arduino card through the USB port and rework the signal as a time count between the interruption of one signal and another, thus calculating factors such as time and speed of pedaling. In this way, the C# tool allows Unity to receive the data and use it.

In the third phase of the prototype, the development of the game prototypes was carried using the Arduino-bicycle interface developed in the previous phases. The project group was composed of three undergraduate students in digital games divided into 3 main expertises: game design, programming, and art. The students were briefed that the game should demonstrate the use of a different scenario from a real race simulation, since several applications of the type were already found. The students had total freedom of creation in the other options of game type and ambiance.

For game and theme choice, students gathered and brainstormed ideas and outlining concepts. From these meetings, they came to the concept of a 3D platform game, in which the character would move jumping from platform to platform until reaching the goal. The students used some Wii games as initial inspiration for game mechanics. A first draft of the project can be seen in Fig. 3.

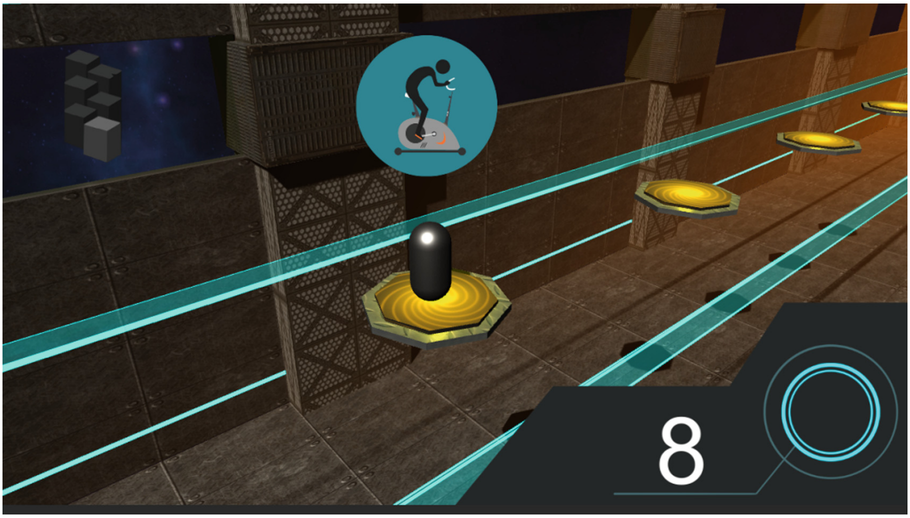

Fig. 3 Early game prototype (draft), testing the game mechanics.

The prototype then received textures and the final character. Students sought various thematic references and adjusted the intended plot in free brainstorming meetings for their elaboration. As a result, they came to an environment inspired by the game Limbo [54]. The plot chosen was a person trapped in a dream world whose foundations are eroding and he must find the way out. The Figs. 4 and 5 show the final result of the prototype with the textures and the character.

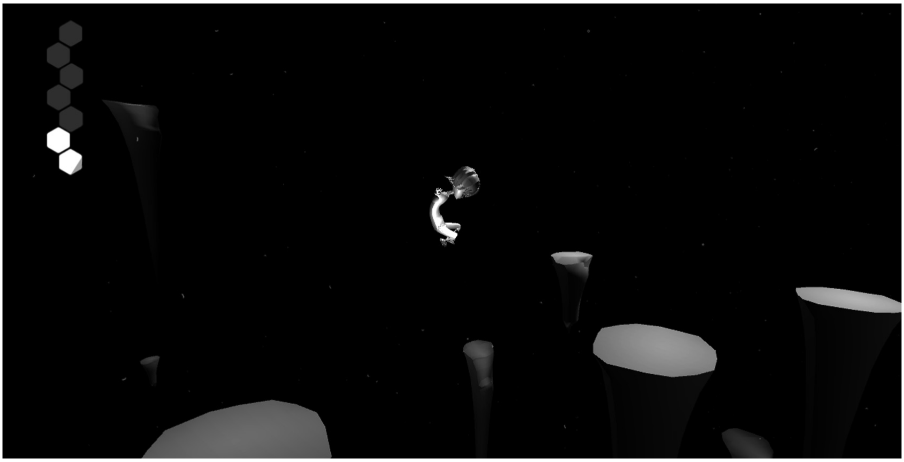

Fig. 4 Final game prototype, showing the character midair during a jump.

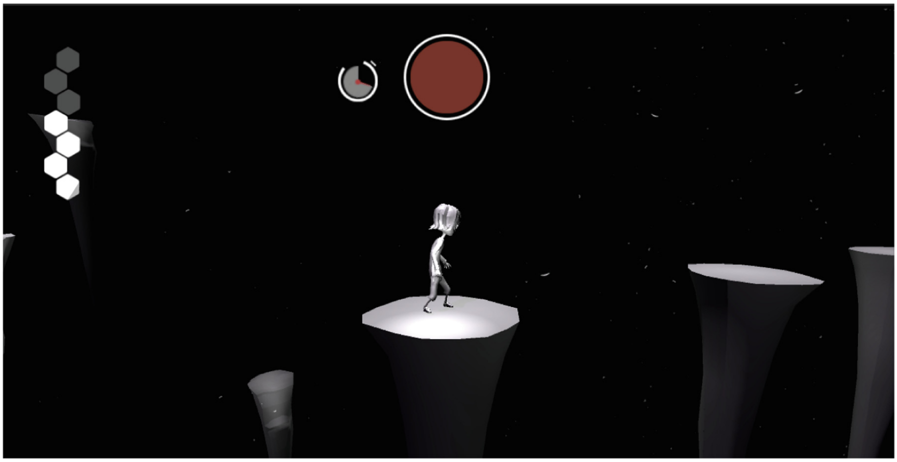

Fig. 5 Final game prototype, showing energy circle in red and timer (little clock). (Color figure online)

The game play happens as follows: the character finds himself inside a nightmare standing on top of a column. In front of him, there are a series of columns, and to jump, the player must pedal the bike within a certain speed range. This way, the speed is converted into the logic of the game to boost the character to make the leap forward - and for this there is a time count. If the user does not pedal and/or pedal out of the speed range, the character does not gain sufficient momentum and, in the fantasy of the nightmare story, ends up being thrown back to the previous column. The victory condition in the stages is pedaling within certain speed ranges before the time runs out.

Results Achieved and Future Steps

The results of the survey have been satisfactory so far. As for the 1st Stage of the bike, the Arduino system proved to be very practical and adaptable. There are some communication problems between the signal sent by the board and Unity, which was bypassed with the C# counter and changes to the default configuration of the program.

In this regard, future steps will be to improve this Arduino-Unity communication whether through new Arduino tests, new circuits and components, or through add-ons (called assets) by Unity that could improve such communication and make application creation easier.

The future step in relation to the game is precisely the creation of levels (level design) and expansion of the scope to include cardiac monitoring in gameplay. The platform-type gameplay mechanics enables specific adjustments such as:

- Exercise intensity (speed + pedal loading);
- Exercise time;
- Time scheduling of intervals between exercises;
- Self-tuning of the game through feedback with heart rate, changing previous factors.

These adjustments would compose the elements for tests with users around the problematic of dual flow [55].

5 Final Considerations

This article presents the partial results of an ongoing research on methodologies for the design of Exergames, arising from a problema raised in an article presented in SBGames 2016 [13], one of the first issues that surfaced early in the process was the inquiry into which device would be ideal to be used for experimenting with these methodologies.

Research into the devices for Exergames has paved the way from the early models to those still in the developmental stage by the industry. During this historical research process, the possibility of using open source technologies, of the so-called Maker Movement, was developed to create a device of its own.

An interesting fact, the new Microsoft Kinect model was released as a tool for developers powered by a more sophisticated camera module and Microsoft's cloud-based AI technology, especially targeted for hackers and tinkerers [35]. This approach shows a similar path this research took in the sense of developing a pure game device, but a platform that allows the creation and use by a wide range of applications from games and simulators to rehab systems.

At this point, the research has been done around the maker technologies and the choice of an exercise apparatus to be adapted for use with Exergames. As a result, it was chosen to use an ergometer bicycle adapted with the Arduino system, in order to create a communication protocol between the exercise apparatus and a computer.

Once the bike was chosen and the means adapted, a six-stage construction plan was developed, from the basic pedal movement to the insertion of virtual reality technology. This article presents the 1st Stage of this project - the process of constructing the first stage of the ergometric bicycle for Exergames, and the subsequent creation of a prototype of game platform for system testing.

Thus, within the scope of this research, the results have been promising in the sense of creating a platform to test the design methodologies for Exergames of reduced cost and with great possibility of dissemination through the practices of the Maker Movement and open source technologies.

This research intends to carry the next five developments on the ergometric bicycle, and once they are completed, to use it to elaborate Exergames prototypes using selected design methodologies through bibliographic research. From this process of prototyping, it is expected to extract data that validate the selected methodologies or, if not, point a direction to the development of specific methodologies.

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