The Use of Multisensory User Interfaces for Games Centered in People with Cerebral Palsy

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Abstract. The evolution of user interfaces has improved the user experience, especially the sensory features. Also, the sensory aspect is crucial for the interaction, mainly for the development of effective assistive technologies. This study presents a game for people with Cerebral Palsy (CP). CP refers to a range of clinical syndromes characterized by motor disorders and postural changes that may or may not be associated with cognitive impairment and speech disorders. Due to restricted motor condition, sports and games become difficult for people with CP. Our challenge is to offer an alternative to people with PC based on tangible and multisensory devices. The use of a robotic ball allowed remote manipulation, which makes this solution useful for people with physical disabilities. Also, an user centered design process was adopted. The game encourages people to interact by using different control devices, making it an important resource for promoting play in these users.

Keywords: Assistive technology · Multisensory devices · Cerebral palsy · Games · User study · Tangible interfaces

1 Introduction

Human-Computer Interaction (HCI) is related to the functionality, design and evaluation of computer systems, to provide an effective and enjoyable user experience for individuals. To achieve these objectives is taken into account the process of communication between man and the computer system. Also you need to have knowledge about the characteristics of users, the contexts of the tasks that will be necessary for interaction to occur and the environments in which systems will be used. Human factors are therefore extremely important for the development and production of effective and efficient computational systems [1–3]. Currently, computer systems are increasingly dedicated to providing users with more sophisticated sensory experiences. Therefore, user interfaces and, consequently, computing systems are increasingly approaching ubiquity within our reality and our physical world. This fact is tangibly observable due to the proximity of physical elements, as the sensations of everyday life, such as playing, talking and listening [4].

Assistive technology (AT) is defined as the use of resources, products and services that work to provide independence and autonomy to people who show any dysfunction [5]. According to the Act the Americans with Disabilities (American with Disabilities

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Act), Assistive Technology is "any piece of equipment, product system, whether acquired commercially, modified or customized, used to increase, maintain or improve functional capabilities of individuals with disability" [6–8]. Also hardware or software can be consider as assistive devices of high performance in order to address the special needs of people with disabilities. That way they could fit within the TAs [9].

Several studies have been performed using TUI's in Assistive Technology with rehabilitate people with special needs A wide range of resources, products, and services that work to provide independence and autonomy for people who show any dysfunction have been developed [5]. The use of these technological devices may provide disabled children with enjoyable experiences in safe environments, in turn, enabling the patient to take risks and fearlessly try to achieve their goals. It is thought that this will ultimately cause a greater motivation and a higher engagement level during the child's rehabilitation. One use of these devices is to treat people with motor disabilities, such as cerebral palsy (CP).

Cerebral Palsy (CP) refers to a series of clinical syndromes characterized by motor disorders and postural changes which may or may not be associated with cognitive impairment and speech disorders. This ailment occurs from a significant lack of oxygenation of the brain cell within the first two years of life. The most common causes of this is the malformation of the central nervous system, in addition to genetic factors such as congenital infections [10]. Currently, the treatment of individuals with CP occurs with a multidisciplinary team with a focus on promoting the role of independence for the individual through the use of a large number of activities, based on the severity of the disorder. It is important to conduct a review of this subject matter in order to identify the areas with which these children have problems, in which ways they need to be assisted, and to what context their personal involvement is impaired. Additionally, to establish priorities for an intervention, environmental adaptations of objects should be performed to promote autonomy, prevent deformities and increased functionality. Early treatment is essential and leads to better outcomes and, consequently, greater independence of the subject [11, 12]. Stimulus is crucially important for the development of people with CP. Games can promote a therapeutic process for people with CP, as well as for people without physical disabilities and it provides the opportunity to try out new games while engaging in fun activities [13, 14]. Such games are, thus, a way to increase the motivation and engagement, to provide a greater social interaction, and to promote playing in patients who are in the process of motor rehabilitation [15–17]. The main goal of this paper is present a game for people with CP. We intend to put together the needs of a CP-users with the playability of a robotic ball. The robotic ball is a robotic device that allows remote control of its functions as movements and colors [18]. The use of a robotic device allows manipulation of the ball remotely, which makes this feature helpful for people with disabilities. For the development of this project, we need a multidisciplinary approach involving professional from occupational therapy, and computing. In the first section, our main interest is to present theoretical background. In the second section related work is detailed. After that the game is presented and also preliminary results achieved from an experience with an individual PC.

2 Theoretical Background

In literature we can find statements about the use of interactive technologies that explore multisensory qualities and help people to participate through their senses. Urbanowicz [19] emphasizes the power of these interactive technologies as important tools, which have the ability to enhance the perception of individuals. The same author also emphasizes that knowledge of the human senses led to the conclusion that sensory systems have a crucial role in the life of all beings, from the moment they allow the development of perceptual capacity of the environment in which we live [19]. The computer systems are dedicated to provide to its users sensory experiences. Besides intrinsic attributes of perception of shared environments, applications transcend the barrier of pixels and make the user part of it. Ishii [4] explains the concept of "radical atoms" through an analogy with icebergs and the ocean, as seen in Fig. 1. In this illustration, the iceberg is the interface that interacts with the user, the water is the digital world and outside of the water is the physical world. So, the first part of the figure, where the iceberg is totally submerged, shows a GUI (Graphical User Interface). The interaction with this interface/the forms below this surface is made through remote controls; such as a mouse, keyboard, or touchscreen. The second unit of the iceberg analogy refers to Tangible User Interfaces (TUI's) as they act as physical manifestations of Computing. Similar to the iceberg, with TUI's, there is a portion of the digital world reaching into the physical world, allowing a direct interaction with the tip of the iceberg/interface. The rightmost portion of Fig. 1 corresponds to the concept of "radical atoms." It is as if the iceberg emerged from the depths to reveal the mass that was submerged. This is the futuristic vision of Ishii, where he defines hypothetical dynamic materials that are computationally convertible and reconfigurable.

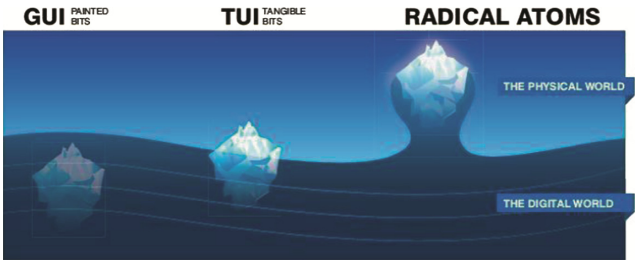

Fig. 1. Radical atoms [4]

Conceptually, all digital information contained in those dynamic materials has a physical manifestation that can be directly interacted with it.Additionally computational systems that develop user/computer relation from objects and environments in the physical world are made. In this sense, there are tangible interfaces (IT), which are based on the concept of tangible digital device, or touchable, that will ensure a realistic interaction between man and computer. The use of physical objects by ITs allows users to employ a wider range of actions and regain skills and knowledge acquired in the form of data

manipulation [20, 21]. The day-to-day life of every individual is filled with objects whose functions, textures and shapes, determine specific ways to catch, carry, throw, throw, and thus build practices that shall be recovered in other situations. Within this perspective, the mediations between the individual and his environment are key determinants for the production of meanings. The action is considered a prerequisite for perception. Thus, the sensory inputs, such as the recognition of the environment only start to have meaning the extent to which actions are performed and the space around the individual is explored [20, 21]. In addition, systems that include interaction by tangible interfaces has not only a software structure, but also a physical structure, represented by physical space and objects. Thus, this systems are embedded in real space and physically embodied. Applications can offer a framework which includes facilitation, prohibiting or hindering of the actions in the moment that directs user behavior. This way, it can influences human behavior and patterns and emerging social interactions. This makes the tangible interactions really embody facilitation [22].

3 Related Work

Works that uses some kind of interaction resources to improve assistive technology have often been the focus for investigations, for example [16, 17, 23]. In all three studies, the authors put conditions to improve games in order to maintain the motivation of the players with respect thereto. Furthermore, it is emphasized that the interest of the subject at stake is an essential factor to be used in rehabilitation. The gameplay is therefore present in all studies, with a view that all studies show an interest in maintaining the quality of the user interaction with the games. In the first work the author puts as attractiveness factor of the games, the fact that the movements are assisted by computer. The second puts the guesses of the therapist and patients to improve the quality of the system and increase the interest of the subject. This system is based on Microsoft Kinect [24], which is a device with two cameras and peripheral complement

Table 1. Related work comparison.

	[17]	[23]	[16]
Devices	*Joystic* + mecanic arm	Kinect Xbox	*Wiimote/Wii Balance Board*
Interaction	TUI	NUI	TUI
Participants	18 people with CP	1 person with CP e 1 with muscular atrofy	10 people with CP
Gameability	Well-known games as spacecraft, balloons, sharks and football	Kinect games	Games with difficult levels

of the Xbox 360. The suggestions are related to the increased number of games offered by the system and the ability to play with another person, increasing social interaction. The third study puts, using guidelines, basic attributes for the development of digital games for CP users. The author states that the intention is to develop games in which players will maintain the high level of interest in the game. Four interactive games were produced. On those games the players used the Wii Balance Board [25] to navigate in the virtual environment Table 1.

4 Game Outline

Regarding the development of digital games, the user/game interaction is important to be analyzed. The gameability concept is related to the quality of the user interaction with the games. In this way, characteristics to determine criteria that define the quality of digital games have been developed [28]. The presented game also considered gameplay issues. The analysis of the above concepts becomes crucial in this project, since the proposal is the development of games, from assistive technologies for patients with PC. The characteristics that afford gameplay should be taken into consideration in order to achieve a good relationship between the user (patient) and the game [26–28].

4.1 Game Idea

The purpose of this study is to use multisensory devices to develop a game designed to promote the play in people with CP. In the conception phase of the project, we thought how can we develop games that can simulate real games that are common for children without Cerebral Palsy, but uncommon for children with the condition. So it was found the Sphero [18], a robotic ball that its movements can be manipulated by many different devices, detailed in the following sections. So, using the Sphero as a tangible device we focus on games that use a ball as the main object of the game, such as football and bowling. The main idea was to make the users with CP have the thrill with the movement of the ball that they may have never had, like kicking or throwing a ball. The next step was to think how the user will be able to manipulate the Sphero. So we came up with several ideas, such as a projector to project a scenario of the game (like a virtual crowd) to induce the fantasy property as suggested in [28]. This feature could collaborate for the immerse of the user into the game. And different ways to control the ball. Some possibilities are eye trackers, mobile devices or natural interaction devices as Leap Motion [29].

4.2 Game Design

For developing the proposed game we used an user centered design approach. This approach puts the disabled person as an active part of the team, contributing to the development of adaptations of interfaces according to their needs. Thus, user interaction with the devices will be efficient and effective. The user-centered design relates to the production of a customized computer system, i.e. facing the demands of a single

user. In this way, the specific attributes that must be in games in way to get a high jogability are easier to achieve. The main phases of the followed processed are conceptual view, architecture view and user experience. Depending on the embodiment, the service will aggregate professionals with different backgrounds to serve users of TA [6]. This team will develop the product according to the demands of each person in order to meet the needs of them and avoid disuse of technology. Still about the production of a TA product, the prescription of a TA feature demand the following set of actions: (1) review the state of the client; (2) evaluation of devices being used; (3) evaluation of customer needs and the family; (4) prescription item; (5) development of the project; (6) user training; (7) monitoring of the use; (8) reviews changes in framework [5].

4.3 Devices

The Sphero device is a robotic ball manufactured by Orbotix and is equipped with various internal motors which allows it to roll on a surface in any direction. The control of the robot is made mostly from applications for mobile devices with Android [31] and IOS [32] operational systems. Communication between devices is done via Bluetooth. But there are already programming libraries that allows the development of applications for other platforms such as Windows, Arduino and others. It can move at a speed of up to one meter per second, approximately, and also has an internal lighting system, which, by combining the colors of the lights it can shine in about sixteen million different colors. The Sphero also has a set of sensors, including an accelerometer, a magnetometer and a gyroscope, which enables the robot to know which direction it is being rotated. The Sphero is shown on Fig. 2 (a). One of the promising application areas of Sphero is the digital games. We have a lot of games using Sphero as Sphero Pet and Sphero Draw N' Drive from Orbotix Inc. [33]. Another devices used in games is the Leap Motion Controller [29], as shown in Fig. 2 (d). The Leap Motion was developed in 2012 by the company Leap Motion Inc, is a recognition device that uses light and infrared motion sensors to map the position, movement and gestures made with the hands and fingers of the user. The focus on capturing the hands promoted by the device provides a high rate of data obtained under high precision. It works in both Windows and IOS operational systems. In order to adapt keyboard devices to people with special needs, products were specifically designed to help them to use computers. The pull and click mouse's (see Fig. 2 (c)) and also the pressing buttons (see Fig. 2 (b)) are example of that. Included with all joystick products is a 'soft ball' and T-bar handle for those who find it difficult to use a conventional joystick. All the used products are PC and MAC compatible, 'plug and play' with auto detecting PS2 and USB protocols [30].

4.4 Storyboards

The players should have the ability to understand the proposal and how the games will be handled the ball. Fig. 3 shows the storyboard for the proposed soccer game. In Fig. 3 (a) the desire of playing soccer controlling a ball. Fig. 3 (b) the explicit goal of the proposed game: the goal. In addition, it's possible to spice up the game by adding new levels of difficulty that will work with the driving characteristics of the user in order to

exercise him too. So, Sphero can be used as the ball and it keeps the integration with other interactive devices which are used to control Sphero. This feature highlights the flexibility of this work. Once the project uses a user-centered design, the devices can be used in accordance with the user needs and capacities.

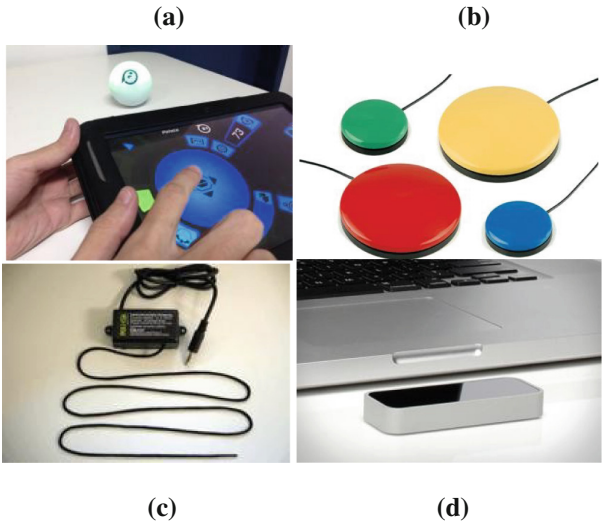

Fig. 2. Devices. In (a) Sphero, in (b) pressing buttons, in (c) pull and click mouses and in (d) leap motion.

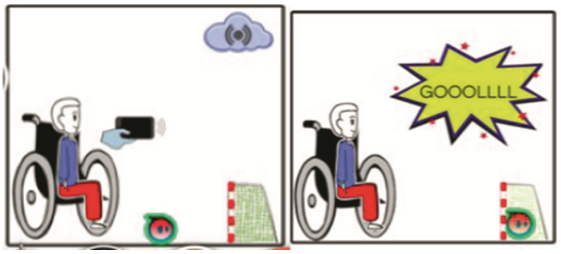

Fig. 3. Storyboards.

4.5 Early User Feedback

According with the used design process to have an early user feedback was one of our goals. For do that, we had the opportunity to realize user experiments in the Clinic School in the Departament of Occupational Therapy (TO) of Federal University of Paraíba (UFPB). A patient with 19 years old with spastic quadriplegic cerebral palsy participated of the design process as a team member representing our endusers. It is important to point out that the presented solution fits our patient needs. Other patients with the same disease could have different solutions, so why the flexible options of controller is so

important to us. In the beginning, the patient and their parents were invited to participate in the process, which occurred in meetings with distinct goals: one for evaluate the devices and other to get the impressions about the game. Sphero was introduced to our patient in order to validate it as a multisensory device. And for do that, we performed simple tasks with Sphero, small movements and color changes. We moved the ball around the patient so he could follow its movements and understand how it works. The patient was placed in a way so that he could view the ball moving in the ground. The patient uses wheelchair. So, one thing that called our attention was the best ergonomic position to set up the game. Next step was introducing the game. Soccer is very common in Brazil, especially during the World Cup. So, understand the game goal was quite easy. The game set up included a small green field and the goalkeeper. We put the field in the ground. The wheelchair was placed in a way that the patient could control the ball but keep the visual connection with the Sphero. The Sphero could be controlled by using the tablet and the pull and click mouse. During this experience, we evaluate how the control devices fits with the user physical abilities. Such movements in the Tablet were performed with the patient's finger. Also, the boy was positioned in a way that could see the whole scenario of the game so that he could show good performance. The difficulty level used was minimal and the playful environment included a goal and two side chains extending from the goal posts on each side barriers. Such barriers had the intention of not allowing the ball to go in another direction than the goal direction. In this way, some instructions was given for the patient related to the game.

The realized experiments included the participation of the occupational therapist of the patient. When we used the tablet, the patient was instructed to just direct his finger in the direction of the goal and helped by his therapist. About the pull and click, the patient was instructed only to pull the cord that was aggregated to the mouse. This would be enough to move the Sphero. After the instructions, the game was initiated. The parents decided to stay in the room what made this experience a fun activity for the patient. It is important to affirm that the user was an active part of the team and the tangibles interfaces was used in order to provide the best interaction according to his needs. Figure 4 show the game objects: goalkeeper, the field limited by side barriers and the Sphero.

5 Discussion

From informal observation and parents' reports were possible to identify that the patient correctly understood the purpose as well as the instructions of the game, as it managed to manipulate the Sphero from Tablet towards goal, as well as pull the cord of the click mouse device. Moreover, another important point was the fact that he managed to achieve the goal of the game to make a goal when he used the pull and click mouse. The patient recognized the participants and remembered how manipulated the Sphero ball in the meeting that followed its presentation. More difficulty was observed to direct the ball towards the goal using the Tablet. Because its needed higher dexterity to manipulate the Tablet itself and the ball through the screen, the user failed to achieve the goal of the game.

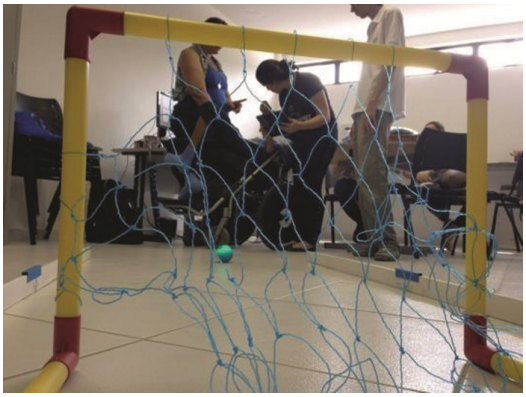

Fig. 4. User experience.

Moreover, the fact of having to perform the movement in Tablet with greater precision and strength made it difficult to driving the ball. However it can be used other applications, like one which the ball goes only into one direction. This way, the player do not have to worry about drive the Sphero into a exactly direction. In the meantime the patient has shown satisfactory performance and good interaction with the Tablet, because it was possible to try out a game that he could never have done before. From this it can be stated that there was interaction between the individual and the Sphero. Also the participation in a game in which the objective is to score, was made possible because of the effective interaction between the user and the technological devices, mediated by the use of a tangible interface. Some attributes that makes a good gameplay, like the main objective of the game is presented to the player from the beginning; the challenge of the game can be adjusted according to the player's skill; the player should be rewarded for their achievements in a clear and immediate way and controls should be clear, customizable and physically comfortable has been achieved. This means that the interaction between the user and the game was satisfactory.

The different user interfaces allow several adaptations that meet the needs of different users. The tangible user interfaces, therefore, correspond to a potential alternative to promote greater independence and autonomy for people with special needs, including persons with CP. That way the user interfaces play an important role in the rescue of function to people with physical dysfunctions. From the moment we can develop a customized computer system according to the capabilities of a user skills, facilitation of interaction and hence greater chances of achieving personal goals occurs. Thus we can produce a more efficient and personalized TAs product. This feature demystifies the series production of TA's, which are not centered on the capabilities of each individual user. Therefore, tangible user interfaces can be used as high technology, which Incorporate electronics and computers.

After all the considerations, it is recommended, that interventions be performed in order to validate the use of multisensory devices in promoting play in individuals with cerebral palsy. It is recommended also that the games offered are graduates and adapted according to the cognitive and motor skills of the patient.

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