Games for Children with Cerebral Palsy

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ABSTRACT

The objective of this study is to determine the suitability and feasibility of novel multimodal computer games utilizing Virtual Reality technology and gaming for children with Cerebral Palsy (CP). The goal of the games is to provide fun experiences and sensations to the user where he/she will become motivated to engage in physical activity, and thus, we may provide a medium for motor, speech, and memory rehabilitation.

A common problem with children with CP is a reduction in motivation. Immersive Active Gaming (IAG) may allow these children to engage in physical activities despite their negative motivation and other psychological disorders such as depression. With our games we hope to not only encourage and motivate the participants to engage in physical activity but also promote equality. We can promote equality by designing and enabling games to be played by children with and without CP; utilizing appropriate interaction devices based on a child's abilities. Sisters, brothers, parents, relative, and friends can all play the same games together with a child with CP. After all, we are all equal with our own strengths and weaknesses.

Keywords

3D multimodal Games, Cerebral Palsy.

1. INTRODUCTION

One of the most important problems in designing games for children with Cerebral Palsy (CP), is that each case is unique because the abilities of each child are often different. Children with CP see the difference between themselves and other children without disabilities. For example, playing at school recess, children with CP cannot run and jump on monkey bars as their classmates. Gymnastics classes look and feel different for them, going to the restroom is not an activity, depending on the severity, that can be performed easily and may require physical assistance. Even playing video games becomes a difficult task, since they are required to manipulate a dozen buttons and a couple of mini-joysticks present on most gaming console controllers. This could lead to depression and sadness. The rate of depression is three to four times higher in people with disabilities such as cerebral palsy and it seems to depend not on the disability itself but rather on how well they cope with the disability. Emotional support, self-esteem, and stress are all factors that impact one's mental health [1]. Questions they could ask to themselves are: "Why cannot I play like the rest of my friends at recess?", "Why do I have to go to physical therapy, which is not such a fun activity anyways?", "Why am I different? I didn't do anything wrong to deserve this". Instead of focusing on ones weaknesses, we should focus on strengthening one's abilities. This can be done if we have the right tools and mindset. As a starting approach, we first need to boost their self-esteem for two major reasons: a) to avoid psychological problems these children may develop, and b) to improve their self-esteem so that they feel less disadvantaged which will improve their lives. So, the games should be designed to utilize new devices and interaction techniques that could negate the physical differences in the ability of each player. For example, a child with no physical disabilities can play a game using a mouse, a keyboard, or a joystick. A child with difficulty moving his/her fingers, could play games where moving the whole arm indicates an event. Or if a child has severe hand movement difficulty, he/she could use the neck or legs to indicate turns and direction of movement in the game. A child with no movement abilities could use voice commands to achieve the same goal. Others have used Sony's PlayStation 2 EyeToy camera to capture mouse motion [2][3], and others a web camera [4][5].

When designing games for children with CP, it is important to take special care not to exacerbate the children's disabilities. Games that would not be well suited are those that are based on timing, speed, or dexterity since these games may frustrate the children and not allow them to enjoy the actual story of the game. In case of competitive games (children competing with each other), we should investigate carefully the potential difficulties in designing games that can adapt to physical disabilities. Then the question becomes: "How many differences in a player's ability can be accommodated and when real competition is compromised by such adaptations?"

To promote equality, games should be designed so that children with and without disabilities can play the games together. This will make the children with CP feel more equal since they can play the same game with other children without disabilities. However, a devise that works well for children with disabilities could impair a child without disabilities. Thus, the game should allow for different types of devices to perform the same tasks so that we don't take away the fun of the game play.

The intriguing component of our study is to "level the playing field" for children with CP, allowing them to play and compete on more equal terms with other players. This focus is rather different from the majority of other games for such audiences that tend to focus more on remediating the disability itself.

Current gaming interfaces draw their strengths from exploiting the user's pre-existing abilities and expectations rather than trained behaviors. For example, navigating through a conventional computer system requires a set of learned, unnatural commands, such as keyboard keys to be typed in, mini-joysticks on game pads to be manipulated, etc. On the other hand, navigating through Immersive Virtual Environments exploits the user's existing real-world "navigation commands" such as positioning the head and eyes, turning the body, walking toward something of interest, and pointing at the direction of interest. This naturalness can reduce the mental effort required to operate the system and thus enables one to focus on enjoying the game-play instead of the mechanics of how to play the game. As a result, this reduces the time needed to learn how to play a game because it avoids information overload, time pressure, and stress which directly affects the outcome of the gaming experience. This, most likely, takes away the fun of the game and possibly turns game-playing into an activity that provides no enjoyment, discomfort, and intimidation.

2. CEREBRAL PALSY

Cerebral Palsy (CP) is a group of lifelong neurological disorders cased of irreversible damage to brain cells. It affects movement, learning, hearing, seeing, and thinking. It occurs due to problems with brain development as early as while the baby grown in the womb. But, it can occur at the time of birth and during the first 2 to 3 years of age. CP is a non-contagious and non-progressive brain disorder. The severity of CP varies from child to child and this makes every case unique. The United Cerebral Palsy Foundation [6] reports that about 750,000 children and adults in the United States have symptoms of cerebral palsy. An additional estimate of 8,000 babies and infants will be diagnosed every year.

The motor area of the brain's outer layer (cerebral cortex) is responsible for directing muscle movement. This is the affected area of the brain that leads to impairment of motor functions; the muscles continually receive signals to contract disabling a person to regulate their muscle tone, and this causes tightness and stiffness of their muscles. In most cases, the muscles and the nerves are healthy. But because the component of the brain that controls the muscles is injured, children with CP face difficulties controlling the movement of their muscles. Many children with CP have increase muscle spasticity in one or both arms and / or legs. As their muscles continuously contract, their muscles become stiff and tight and this interferes with walking, moving, and even speech. There are cases where there are bone and joint deformities where the muscles become permanently fixed and tight and may required surgical intervention. Additionally, CP often is accompanied by disturbances of sensation, perception, cognition, communication, and epilepsy.

Unfortunately, there is no known cure for CP yet. Therapy normally is performed by an occupational, physical, or speech therapist. Since there is no cure for CP, the goal of the treatment is to make people with CP as independed as possible to live an effective life. Because of muscle movement problems, which restrict people with CP to walk, run and in general exercise their muscles, it is possible that they end up with decreased muscle mass. By performing a specific set of exercises, physical therapy focuses in increasing the performance of the muscles by preventing the muscles to become atrophic and fixed in an abnormal position. On the other hand, occupational therapy focuses on enabling people with CP to master to perform daily activities such as dressing, eating, etc. Speech therapy may be required in many cases where the people with CP are unable to produce intelligible speech, or have problems in other areas of communications such as facial expressions and hand gestures and postures. In certain circumstances, a speech therapist can teach a one to use special communication devices such as a voice synthesizer. Recreational therapists can also help children with CP to improve gross motor skills by using, for example, horseback riding techniques.

3. BACKGROUND

Most of the recent Virtual Reality (VR) research is focused on the assessment of selected cognitive, functional and behavioral functions and processes. This can complement traditional in-person rehabilitation techniques, which makes VR technology a great tool for medical practitioners for both the assessment and cognitive/functional rehabilitation of people with CP. VR has been used as a medium for the assessment and rehabilitation of a variety of clinical populations. This includes populations with cognitive [7-10] and meta-cognitive [11-16] deficits, such as visual perception, attention [17], and memory [15-16] [18-23]. Other applications are directed at the rehabilitation of motor movement difficulties [24-26] to provide recreational opportunities for people with disabilities.

Virtual Reality has been adopted by many researchers as a suitable technology to be used as an assessment and a treatment tool in physical and occupational therapy [27-35]. The ability to provide simulated and meaningful virtual environments, Virtual Reality offers us opportunities to engage in purposeful tasks related to real-life events.

While VR is capable to provide fully immersed environment experiences, at times it seems more appropriate to reduce the level of immersion because of physical capabilities people possess. This reduces the sense of presence and realism in the Immersive Virtual Environment; however, it allows a subject to experience the environment in a less restricted form. For example, in a desktop-VR environment, users are not attached to heavy and relatively large head mounted displays (HMDs), or to be placed within a physical projection room such as the CAVE, or wear cumbersome gloves and other interaction devices to feel the texture and weight of virtual objects. VR is an attractive technology because of its advantage to provide synthetic environments and encourage participants to perform tasks that are difficult to achieve and deliver using conventional neuropsychological methods [36-38].

Since there is no cure for CP, major goals of therapy include enhancement of functional ability by improving sensory, motor, and cognitive functions. Using VR technology, this is achieved by enabling the participants to interact with synthetic environments, engage in activities required by the game or synthetic environment, manipulate objects in a way that immerses them within the simulated environment, which helps produce a feeling of presence in the virtual world [39][40]

There are some limitations of the VR technology, not because of the technology itself, but rather because of the one's ability to utilize awkward VR devices in order to interact with a synthetic environment. For example, muscle spasticity limits and makes uncomfortable a subject's ability to use equipment such as a glove, or wearing a relatively bulky and heavy-head-mounted display (HMD), etc [41], which could also have a side effect of nausea; something that is not present in desktop-VR. Low vision people are limited in using a HMD simply because of the subject's limited field of view and decrease peripheral vision [42], or in a case where the subject is a child, by overloading the neck muscles. In addition, it has been reported that low frequency flashing lights used as visual effects can trigger seizures [43][44].

4. GAMING ENVIRONMENT

Our gaming laboratory, where we develop the games and perform user studies, is located on the ground level at Williston Hall. The laboratory is handicapped accessible and it is located near the main parking lot. The dimensions of the lab are 24x16 feet and there are two high end PCs (Dell XPS 730X) running Windows Vista Ultimate with 6 G of memory, two drives in RAIN 0 configuration, a sound card and a dual NVIDIA GeForce GTX280 SLI enabled video card. Both PCs are equipped with 2 Intel i7 quad CPUs running at 3.2GHz.

Both PCs can direct their output, using Genfen (www.gefen.com) DVI switchers, to our main display which is a SHARP PN-S525 1920x1080 52 inches LCD monitor. The PCs are also connected to a 1000W ONKYO TX-SR707, 7.2 channel receiver. Below the display we installed a fan with adjustable speed control, which enables us to render wind. Its speed is controlled by the game using a Phidgets (www.phidgets.com) Advanced Servo controller. The fan is placed to aim at the player's feet and not the face to avoid breathing problems the fan might cause.

Figure 1. Servo controller connected to the adjustable speed fan, and the robotic arm.

Its idle speed is around 100 feet per minute while its maximum speed is around 500 feet per minute. The servo controller is connected via USB to a WiFi Phidgets SBC single board computer which is the gateway to the computer running the game. We also built a custom robotic arm for the final component of the game, which is also controlled by the servo controller as shown in figure 1.

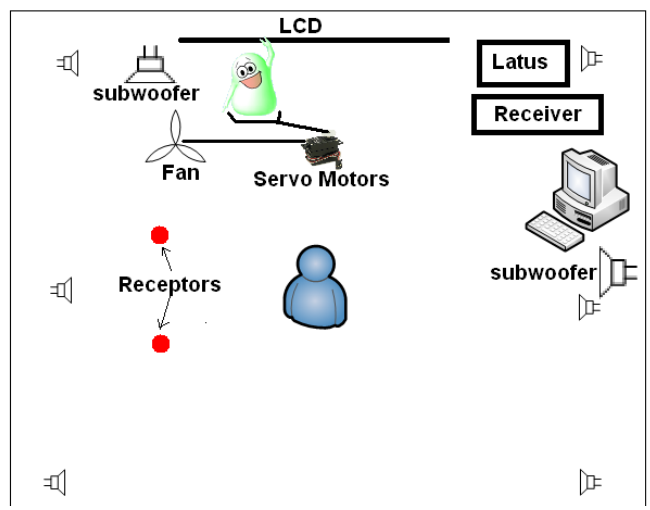

Figure 2. Diagram of the Gaming Laboratory.

For navigation, we use the Polhemus Latus (www.polhemus.com) 3D tracker with two receptors and one marker. The Latus system provides six degrees of freedom (6DOF) tracking wirelessly. Multiple receptors connect to the Latus to form a network of tracking units that extend the envelope of tracked space. The Latus tracks the light-weight wireless markers in space which contain their own battery and transmition frequency. The unique transmition frequency identifies each 6DOF marker. A diagram of the lab is shown in figure 2 and a snapshot of the lab setup is shown in figure 3.

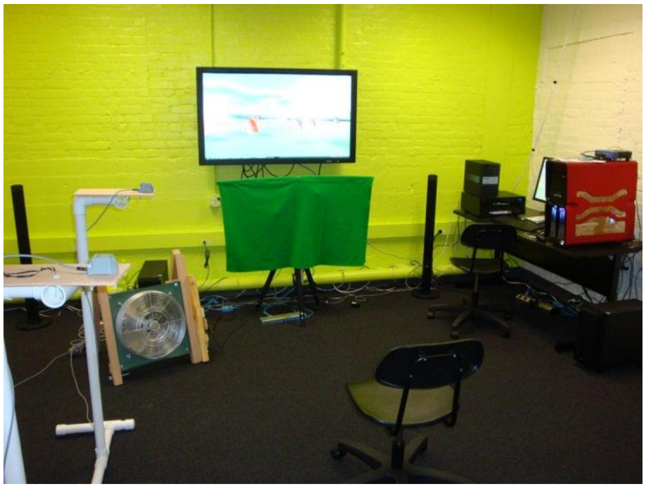

Figure 3. A snapshot of the set up in the Gaming laboratory

We placed all the furniture and the hardware equipment around the lab leaving the center area of the lab available for the players. There is enough room for two players to stay side-by-side to play a game. We removed all metallic furniture away from the Latus receptors and we secured the receptors on custom made 5/4 inches PVC pipe stands using plastic screws and glue to minimize signal interference as the Latus tracks the markers in space using a magnetic field.

5. BLOB VILLAGE

The game we developed is the Blob Village. It is played by two players. Blobs are the creatures living on a beautiful little village by the snowed mountains where there is a little lake, a castle, and a swimming pool. Figure 4 shows a bird's eye-view of the Blob Village.

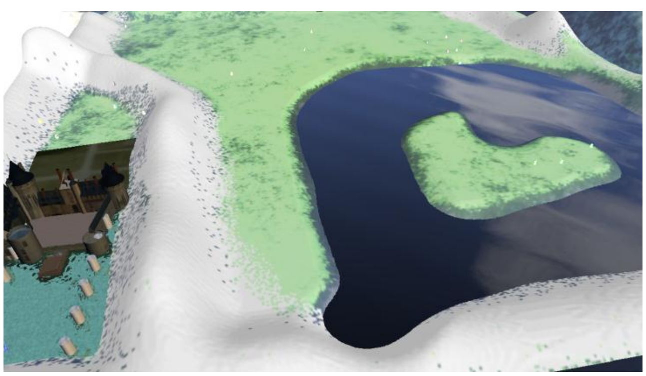

Figure 4. Bird's eye-view of the Blob Village.

The main characters of the game are the blobs that have their own personality. They wander around their village and provide verbal clues to the player as to what to do next. The blobs are friendly creatures who love to interact with children. In fact, if they see you approaching them, they will leave whatever they do and come to talk to you. They even try to get your attention by waving their hands and calling you to go closer to them. A snapshot showing a blob waving his hand is shown in figure 5.

The user moves around the village trying to communicate with the blobs to find the "blue" blob who feels sad today and wants to be hugged by a happy child and play together. During the play, the player is able to walk around and even fly to get to different places in the Blob Village. As the player walks and flies in the game, he / she experiences different 3D sound effects; while soft background music is playing. In addition, depending on the speed of the walk and whether the player if flying or not, the player feels the intensity of the wind. To walk and fly, two players need to coordinate to perform the right action. The players could even use different input devices to accomplish the same task. This depends on the physical abilities of the children and that is why every setup of the game could require different input devices. The duration of a day in Blob Village is much shorter than what it is in real life. This is reflected in the game by moving through the stages of dawn to dusk. Using shader programming, the effects of the sun, water, and everything else in the game, change depending on the time of the day in the Blob Village.

Figure 5. A blob in the game waving his hand.

After the player finally finds the sad "blue" blob, the blob asks the player if he or she wants to touch, hug, and play (physically) with the blob. When the player agrees to play with the sad blob so that the blob would feel happy again, the blob starts spinning in the game until it disappears from the display.

Figure 6. A snapshot of the Blob Village while the player is flying.

At that moment, a hidden custom made blob toy becomes visible. One of the servo motors kept this toy blob hidden from the player's view behind a curtain right below the display and it is emerged into view at this point giving the feeling of the blob being materialized. While playing a sound effect, the robotic arm turns slowly to reveal the blob toy right below the screen and asks the player to give it a hug.

This moves a 3D multimodal game from being a totally synthetic environment, into the reality where we can grab, hug, kiss, and play with the main character of the game. Meanwhile, to find the sad blob required the cooperation of two players, one with physical disabilities and without. None players could play the game all by themselves, it required two players – two equal players, it just happened that some of us have some difficulty in moving some parts of our body. On the other hand, the child's self-esteem could be increased by playing the game because at the end, after we experience the beautiful environment of Blob Village, we managed to find the sad blob and play with it and make it feel happy again. Figure 6 is a snapshot of the Blob Village while flying, and figure 7 is a snapshot of the final stage where the player found the "blue" sad blob which is located by the swimming pool.

Figure 7. A snapshot of the sad blob located at the swimming pool.

5.1 Blob Behavior

The Blobs, the main characters of the game, are three dimensional blob-like characters who wander around the blob village. Each blob is designed to have 4 animations, shown in figure 8: a) "idle" where they wobble left and right, b) "left wave" where they wave their left hand, c) "right wave" where they wave their right hand, and d) "jump" where they perform a jump.

We can animate the blobs while they are moving as well as when they are standing still. They are all of different color and there are 4 different textures we apply on them to dynamically animate their facial expressions; which are performed independently of their body animation. The four textures that we animate on the blobs, by swapping them in and out using a shader, are shown in figure 9.

Figure 8. The four animations of the blobs (idle, left wave, right wave, and jump)

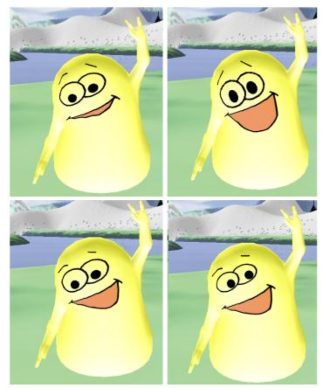

Figure 9. The four animated textures utilized to provide facial expressions.

As the blobs wander around in their village, they try to avoid bumping into each other. When they are in a course of collision, depending on their unique age they either stop moving and make a sound, or go around the stopped blob making another sound. The player is a special entity in the game. So when the player is approaching a blob, the blob turns to the direction of the player, makes an inviting sound (plays one of the 33 pre-recorder by children phrases such as "hello", "hi there", "hey look at me", etc), waves his left or right hand, and walks towards the player. When a blob gets close to the player, he stops moving and provides verbal hinds such as "now go to the island", or "now fly over the mountains to go to the castle", etc. Because the blobs can wander all over the village, we constrained them to stay in one of the 4 areas in the village. This way there are blobs everywhere. The critical component is to always have the blue sad blob by the pool, since we are supposed to find the blue sad blob and make him feel happy again. The four rectangle areas define the main land, the island, the castle, and the swimming pool as shown in the figure 10 below.

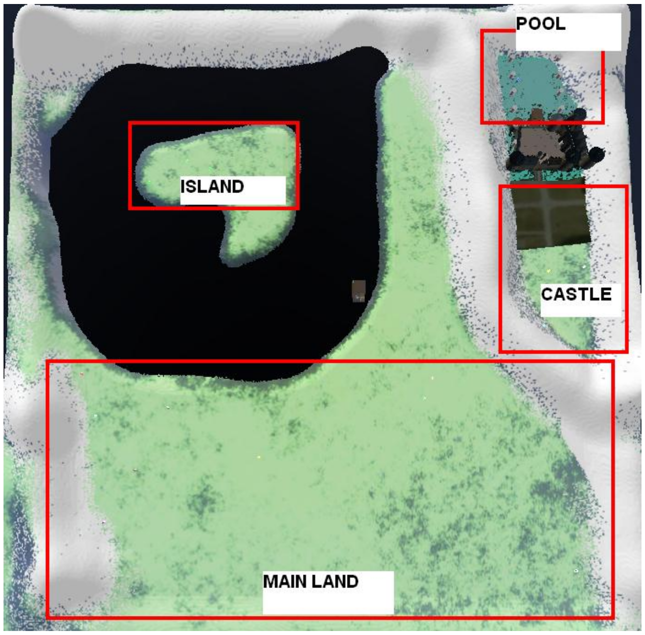

Figure 10. The four areas of the Blob Village

5.2 THE STORY

The story of the game is relatively simple, yet challenging for the players. The player starts off in the main land where she tries to communicate with the blobs to figure out what to do next. One of the blobs tells the player that there is a sad blue blob in the village that really wants to play with the player. To find the sad blob, the player needs to go to the island. This requires the player to fly over the lake around the island where she meets another group of blobs. These blobs instruct the player to go to the castle. At the castle, the blobs instruct the player to go to the swimming pool where the blue blob has been isolated there because he is sad and wants to play with the player. Finally, the player goes to the swimming pool where she meets the blue blob. The blue blob then becomes very happy and asks the player if she wants to play with him. Meanwhile, getting from place to place, the player experiences 3D sound effects, challenging navigation techniques, gained the ability to fly, etc. As the player flies, a fan renders the wind which depends on the player's speed and elevation. Now when a 3D character asks a child to play with him, our first reaction is "…but we are already playing the game". However, the game is about to turn from a synthetic 3D game into a game of reality. Upon the player's positive reply, the blue blob spins around faster and faster until it disappears from the display. At that moment, a robotic arm that is placed right below the display starts turning, revealing the blue blob toy right in front of the player. The player now is free to reach out a grab the real blue blob toy as shown in figure 11, and give him a hug.

Figure 11. The game reveals the toy blue blob that can be touched and hugged by the player.

6. RESULTS

We designed a large village with many components (3D terrain with collision enabled, water shaders, daylight effects, 3D models, etc), the main character of the game (the blobs with animations and facial expression animations), 3D sound effects (soothing music in the background, blob sounds and speech, which are recordings of real children), synthetic behavior (such as day, afternoon, and night effects), other environmental effects such as the utilization of a fan to render wind, as well as a robotic arm that reveals the blue toy blob. For navigation, we used the Polhemus Latus six degrees of freedom (6DOF) device.

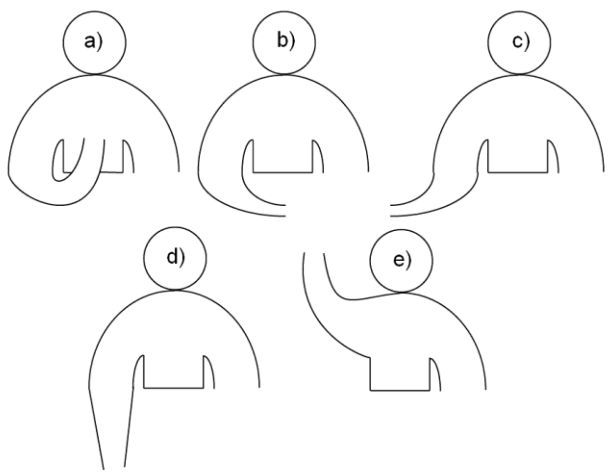

Figure 12. The five postures for navigating in the Blob Village: a) stop, b)left turn, c) right turn, d) forward, and e) fly.

The Latus uses wireless tracking of markers making the entire game totally untethered; the player is not attached to any wiring. For navigating in the game, we used 5 gestures that implement: a) "stop" to stop motion, b) "turn left" to turn the player's view to the left, c) "turn right", to turn the player's view to the right, d) "forward" to move the player's position forward, and e) "fly" to change the elevation of the player as shown in figure 12. Some of the gestures can by performed by the second child playing the game in cooperation.

We plan to begin our formal evaluation with children with CP soon, using Robson's scale [46] for the measurements. During development and after we finished BlobVillage, 11 students taking our Introduction to Games Programming course, three faculty members and 4 children without CP tried the game and they gave us positive feedback. This is encouraging to us to continue our research with formal evaluations. They found the usage of the fan to render wind, the 3D sound effects, and the final stage of the game (when the blue blob toy is revealed using the robotic arm) very interesting and new. They found the scenery beautiful but they thought that the fan speed was a little bit high and also that the sound volume was a bit too high as well. We plan on adjusting the fan speed and the volume in the final release of the game.

7. FUTURE WORK

We plan on developing more interaction and navigation techniques using the Polhemus (http://www.polhemus.com/) Latus 6DOF device as well as other custom-built devices, the Wiimote controller from Nintendo, and the Kinect 3D camera from Microsoft. We have several families with children with Cerebral Palsy that cannot wait to come to our lab for the formal trials. We want to find out if using inexpensive off the shelf devices such as the Nintendo's Wiimote, or the Kinect camera, is as effective as using the relatively expensive Polhemus Latus tracker. What makes the Wiimote and the Kinect attractive is that they are wireless. Our game does support the Wiimote but its usage in the current version of the game as an interaction device is left out for future research.

8. CONCLUSION

We want to enable children, and adults, who may otherwise feel social isolation secondary to self-esteem issues to engage in game playing [45]. The importance and originality of our work is not only in the use of game-play to boost self-esteem, but also in the inclusive nature of game-play for people who might not otherwise benefit from standard commercially available games because of their standard interface models. The concept of inclusion is important for socio-cultural standpoints as well as practical standpoints. The bigger picture is not simply whether a person with physical disabilities can hold and use a game control device, but what the implications of excluding these people from the technology are.

In this paper we presented a sophisticated multimodal game that will become the basic platform for our future research. From the feedback we received from our students, faculty members, and children that played the game we have no doubt that we can use similar games to boost the self-esteem of children with CP. In addition, by playing these games in a multi-user environment we can promote equality among children with or without CP since these games are played cooperatively to achieve a common goal.

REFERENCES

[1] National Institute of Health, National Institute of Neurological Disorders and Stroke http://www.ninds.nih.gov/disorders/cerebral_palsy/cerebral_palsy.htm Retrieved Jan 21 2010

[2] D. Rand., R. Kizony, PL Weiss., "Virtual reality rehabilitation for all: Vivid GX versus Sony PlayStation II EyeToy", Proc. 5th International Conference on Disability, Virtual Reality and Associated Technologies, Oxford, UK, 2004, pp. 87-94.

[3] Patrice L Weiss, Debbie Rand, Noomi Katz, and Rachel Kizony, "Video capture virtual reality as a flexible and effective rehabilitation tool", Journal of NeuroEngineering and Rehabilitation Vol. 1(12), 2004

[4] Margrit Betke, James Gips, and Peter Fleming, "The Camera Mouse: Visual Tracking of Body Features to Provide Computer Access for People With Severe Disabilities". IEEE Transactions on Neural Systems and Rehabilitation Engineering, Vol. 10 No. 1, March 2002 pp1-10.

[5] Rick Kjeldsen, "Improvements in Vision-based Pointer Control". Proc. of the ACM SIGACCESS conference on Computer and Accessibility, Portland, Oregon, Sep. 29 2006 pp 189-196

[6] United Cerebral Palsy Foundation, http://www.cerebralpalsysource.com/Resources/foundation_cp/index.html Retrieved Jan. 25 2010

[7] Rizzo, A.A., Buckwalter, J.G., Humphrey, L., van der Zaag, C., Bowerly, T., Chua, C., Neumann, U., Kyriakakis, C., van Rooyen, A. & Sisemore, D. "The Virtual Classroom: A Virtual Environment for the Assessment And Rehabilitation Of Attention Deficits". CyberPsychology and Behavior, Vol. 3(3), 2000, pp.483-499.

[8] Zhang L, Abreu BC, Masel B, Scheibel RS, Christiansen CH, Huddleston N, Ottenbacher KJ. "Virtual reality in the assessment of selected cognitive function after brain injury". Am J Phys Med Rehabil. Aug. 2001. Vol.80(8), pp597-604.

[9] Grealy MA, Johnson DA, Rushton SK. "Improving cognitive function after brain injury: the use of exercise and virtual reality". Arch Phys Med Rehabil. Jun. 1999. Vol.80(6), pp661-667.

[10] Weiss PL, Naveh Y, Katz N. "Design and testing of a virtual environment to train stroke patients with unilateral spatial neglect to cross a street safely". Occup Ther Int. 2003. Vol.10(1). pp39-55.

[11] Lam YS, Tam SF, Man DWK, Weiss PL. "Evaluation of a computer-assisted 2D interactive virtual reality system in training street survival skills of people with stroke". Proceedings of the 5th International Conference on Disability, Virtual Reality & Associated Technology. Oxford, UK, 2004, pp27-32

[12] Larson, P., Rizzo, A.A., Buckwalter, J.G., van Rooyen, A., Kratz, K., Neumann, U., Kesselman, C., Thiebaux, M., Van Der Zaag, C. "Gender issues in the use of virtual environments". CyberPsychology and Behavior, 1999, Vol. 2(2), pp113-123.

[13] Robert S. Astur, Maria L. Ortiz, Robert J. Sutherland, "A characterization of performance by men and women in a virtual Morris water task: A large and reliable sex difference". Behavioural Brain Research, Jun. 1998, Vol.93(1-2), pp185–190.

[14] Thomas, K.G., Laurance, H.E., Luczak, S.E., Jacobs, W.J. "Age related changes in a human cognitive mapping system: Data from a computer-generated environment". CyberPsychology and Behavior, 1999, Vol.2(6), pp545-566.

[15] A Rizzo, J G Buckwalter, P Larson, A van Rooyen, K Kratz, U Neumann, C Kesselman, M Thiebaux, "Preliminary findings on a virtual environment targeting human mental rotation/spatial abilities". Proc. of the 2nd European Conference on Disability, Virtual Reality and Associated Techniques, 1998, Sköve, Sweden, pp 213–220.

[16] McComas, Joan., Pivik, Jayne., Laflamme, Marc. (1998). "Children's transfer of spatial learning from virtual reality to real environments". CyberPsychology and Behavior 1998, Vol.1(2), pp121-128.

[17] Wann, J.P., Rushton, S.K., Smyth, M., & Jones, D. "Virtual environments for the rehabilitation of disorders of attention and movement". Virtual reality in Neuro-Psycho -Physiology. Amsterdam Netherlands, 1997, Vol.44, pp. 157–164.

[18] Luciano Gamberini, "Virtual Reality as a New Research Tool for the Study of Human Memory". CyberPsychology & Behavior., Vol.3(3), June 2000, pp337-342.

[19] Paul N. Wilson, "Active Exploration of a Virtual Environment Does Not Promote Orientation or Memory for Objects", Environment and Behavior, Vol.31(6), 1999, pp752-763

[20] Jaime Sánchez, Héctor Flores, "Memory enhancement through audio", ACM SIGACCESS Accessibility and Computing, Issue 77-88, 2003, pp24-31

[21] Rose FD, Brooks BM, Attree EA, Parslow DM, Leadbetter AG, McNeil JE, Jayawardena S, Greenwood R, Potter J., "A preliminary investigation into the use of virtual environments in memory retraining after vascular brain injury: indications for future strategy?", Disabil. Rehabil., Vol.21(12), 1999, pp548-554

[22] Dinh, H.Q.; Walker, N.; Hodges, L.F.; Chang Song; Kobayashi, A., "Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments", Proc. of the IEEE Virtual Reality, 1999, Los Alamitos, CA, pp. 222-228.

[23] Grealy, M.A., Johnson, D.A., Rushton, S.K., "Improving cognitive function after brain injury: The use of exercise and virtual reality", Archives of Physical Medicine and Rehabilitation, 1999, Vol.80(6), pp661-667.

[24] Rachel Kizony, Noomi Katz, Patrice L. (Tamar) Weiss. Adapting an immersive virtual reality system for rehabilitation. The Journal of Visualization and Computer Animation, Special Issue: Virtual Reality in Mental Health and Rehabilitation, Nov. 2003 Vol.14(5), pp261-268.

[25] Sveistrup H, McComas J, Thornton M, Marshall S, Finestone H, McCormick A, Babulic K, Mayhew. "A. Experimental studies of virtual reality-delivered compared to conventional exercise programs for rehabilitation". Cyberpsychol Behav. Jun. 2003 Vol.6(3)6, pp245-249.

[26] Alma S Merians, David Jack, Rares Boian, Marilyn Tremaine, Grigore C Burdea, Sergei V Adamovich, Michael Recce and Howard Poizner. "Virtual reality-augmented rehabilitation for patients following stroke". Physical Therary. Sep. 2002, Vol.82(9), pp898-915.

[27] Albert "Skip" Rizzo, "A SWOT Analysis of the Field of Virtual Reality Rehabilitation and Therapy", Presence: Teleoperators and Virtual Environments, Vol. 14(2), April 2005 pp 119-146

[28] Patrice L. (Tamar) Weiss, Noomi Katz, "The potential of Virtual Reality for rehabilitation". Journal of Rehabilitation Research and Development Vol.41(5) Oct. 2004 pp:vii-x

[29] Elkind, James S." Uses of virtual reality to diagnose and habilitate people with neurological dysfunctions". CyberPsychology and Behavior, Fall 1998 Vol. 1(3), pp263-274.

[30] Pugnetti, Luigi, Mendozzi, Laura, Motta, Achille, Cattaneo, Annamaria, Barbieri, Elena, "Evaluation and retraining of adults' cognitive impairments: Which role for virtual reality technology?" Computers in Biology and Medicine, March 1995, Vol.25(2), pp213-227.

[31] Rose, F.D., Attree, E.A., and Brooks, B.M." Virtual environments in neuropsychological assessment and rehabilitation". Virtual Reality in Neuro-Psycho-Physiology. 1997, Amsterdam, Netherlands, pp. 147-156.

[32] Christiansen C, Abreu B, Ottenbacher K, Huffman K, Masel B, Culpepper R., "Task performance in virtual environments used for cognitive rehabilitation after traumatic brain injury", Archives of Physical Medicine and Rehabilitation, Vol.79(8), 1998, pp888-892.

[33] Davies, R.C., Johansson, G., Boschian, K., Lindé, A., Minör, U., Sonesson, B., "A practical example using virtual reality in the assessment of brain injury". The International Journal of Virtual Reality, 1998, Vol.3(4), Sweden, pp. 1-7.

[34] Strickland, D., "Virtual reality for the treatment of autism", Stud. Health Technol Inform, Vol.44, 1997, pp81-86.

[35] Cromby, J.J., Standen, P.J., Newman, J., Tasker, H. "Successful transfer to the real world of skills practiced in a virtual environment by students with severe learning difficulties". Proc. of the First European Conference on Disability, Virtual Reality and Associated Technology, Maidenhead, UK, 1996, pp. 103–107.

[36] Greenleaf, W.J., and Tovar, M.A. "Augmenting reality in rehabilitation medicine". Artificial Intelligence in Medicine, 1994, Vol.6, pp289-299.

[37] Kuhlen, T., and Dohle, C. "Virtual reality for physically disabled people". Computers in Biology and Medicine, 1995, Vol.25(2), 205-211.

[38] Wilson, P.N., Foreman, N., and Stanton, D. (1997). "Virtual reality, disability and rehabilitation". Disability and Rehabilitation, 1997, Vol.19(6), pp213-220.

[39] Slater Mel, "Measuring presence: A response to the Witmer and Singer Presence Questionnaire", Presence: Teleoperators and Virtual Environments Vol. 8(5), 1999, pp560-565.

[40] Eric B. Nash, Gregory W. Edwards, Jennifer A. Thompson, Woodrow Barfield, "A Review of Presence and Performance in Virtual Environments". Int. Journal of Human-Computer Interaction, Vol. 12(1), May 2000, pp1-41

[41] Wikipedia "Spasticity" http://en.wikipedia.org/wiki/Spasticity. Retrieved Jan. 5 2010

[42] Scholar pedia "Hemineglect" http://www.scholarpedia.org/article/Hemineglect Retrieved Jan. 5 2010

[43] D Kasteleijn-Nolst Trenité DG, Martins da Silva A, Ricci S, Rubboli G, Tassinari CA, Lopes J, Bettencourt M, Oosting J, Segers JP, "Video games are exciting: a European study of video game-induced seizures and epilepsy", Epileptic Disord, vol. 4(2), pp. 121-8, June 2002.

[44] Michelle Bureau, Edouard Hirsch, and Federico Vigevano, "Epilepsy and Videogames", Epilepsia Vol. 45(s1) pp24-26 Jan 2004

[45] J. Beecham, T. O'Neill, and R. Goodman, "Supporting young adults with hemiplegia: services and costs", Health Soc. Care Community, vol.9(1), pp. 51-9, January 2001.

[46] Robson, Philip. J. (1989). Development of a New Self Report Questionnaire to Measure Self Esteem. *Psychological Medicine*, 19, 513-518.