Astrojumper: Motivating Children with Autism to Exercise Using a VR Game

Samantha Finkelstein
UNC Charlotte
9201 University City Blvd
Charlotte, NC, 28223
sfinkel1@uncc.edu

Andrea Nickel
UNC Charlotte
9201 University City Blvd
Charlotte, NC, 28223
anickel1@uncc.edu

Tiffany Barnes
UNC Charlotte
9201 University City Blvd
Charlotte, NC, 28223
Tiffany.barnes@uncc.edu

Evan Suma
UNC Charlotte
9201 University City Blvd
Charlotte, NC, 28223
easuma@uncc.edu

Abstract
Children with autism have shown substantial benefits from rigorous physical activity, however, it is often difficult to motivate these children to exercise due to their usually sedentary lifestyles. To address the problem of motivation, we have developed Astrojumper, a stereoscopic virtual reality exergame which was designed to fit the needs of children with autism. We use electromagnetic trackers and a 3-sided CAVE to present virtual space-themed stimuli to the user, who must use physical movements to avoid collisions and gain points. We can use Astrojumper not only to motivate exercise, but to evaluate the different ways people with and without autism interact with an exercise tool. Preliminary playtesting of Astrojumper has been positive, and we plan to run an extensive evaluation assessing the effectiveness of this system on children with and without autism.

Keywords
Virtual reality, exergames, autism

CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA.
ACM 978-1-60558=930-5/10/04

ACM Classification Keywords
I.2.1 [Artificial Intelligence]: Applications and Expert Systems—Games; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Virtual realities

General Terms
Design, Human Factors

Introduction

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder which affects individuals with varying degrees of impairment [6]. There are many factors which are found to be consistent in all or most persons on the autism spectrum. For example, it is common that these individuals lack fine or gross motor control, enjoy interacting with technology and video games [5], and become fixated with a particular subject area referred to as a special interest, often dinosaurs, trains, or outer space. Children with autism also commonly engage in self-stimulatory behavior, or stereotypical behavior, such as hand-flapping, clapping, rocking, and vocalizations. These stereotypical behaviors can sometimes become chaotic, creating what is referred to as a meltdown. Sedentary lifestyles are common among children with autism, possibly due to these factors as well as fewer opportunities to engage in structured physical activity and increased social isolation [2]. These common lifestyle components increase the likelihood of obesity in these individuals, with 19% of children with autism overweight and another 35% at risk for being overweight [2]. Exercise is a healthy activity for most neuro-typicals (people without autism), though it has added benefits for the ASD community. Aside from keeping them healthy and lowering obesity rates, there is evidence which shows that rigorous exercise can foster academic success in students with autism, with increased improvement relative to the amount of time spent engaged in physical activity. In addition, exercise has also been shown to decrease chaotic meltdowns associated with stereotypical behavior [4], which can foster an overall improvement in their quality of life.

Regardless of the benefits of exercise, many children with autism do not engage in any voluntary rigorous activity. In this paper, we present Astrojumper: a virtual reality exercise game, or *exergame,* which may help motivate children with autism to engage is physical activity. We will be using Astrojumper to measure *psychological* reactions such as enjoyment and *physiological* reactions such as quality of workout to gauge the effectiveness of VR games as exercise tools for people with autism. We will also take these measurements on people without autism to compare the differences between these two populations. Exergames have shown to motivate neuro-typicals to engage in exercise more readily than they would without virtual simulation [7], though only anecdotal evidence suggests there are benefits for people with ASD as well. While we don't know specifics about what people with ASD need for successful exergames, we do know that immersive virtual reality technology can be effective for restoring balance in people with irregular movement patterns similar to those children with autism may experience [3]. We believe that a virtual reality exergame may be a successful motivation for children with autism to engage in exercise, helping to reduce their meltdowns and foster academic development.

Related Work

Virtual reality has been commonly paired with rehabilitation or exercise tools, with significant benefits directly related to the technology. This technology is able to distract users from doing a task they otherwise would want to avoid, including exercise or physical therapy, and mask the procedure with the excitement of immersion, thus motivating the participant to engage with the system. In addition, immersive virtual reality technology has shown to improve upon standard rehabilitation procedures which do not use virtual displays. In a study by Chuang et al, healthy older adults were asked to exercise on a mechanical bicycle with and without virtual simulation, and the authors found that the VR conditions provided less intense physiological responses to exercise-related discomfort [1]. While participants biked at comparable minimum and maximum speeds in both conditions, the VR condition was correlated with increased cycling duration, longer distances, and increased energy consumption. We are interested in assessing whether a virtual simulation can actually encourage a child with autism to begin engaging in physical activity by distracting them with interactive visual stimuli.

Two particular case studies were done to investigate the use of immersive environments on balance and posture on individuals who had severely impacted movement problems due to spinal injury or stroke. In one of two studies performed by Kizony et al, a man in a wheelchair used VR technology to strengthen core muscles associated with balance [3]. In a similar study presented in the same paper, a man who had suffered a right hemispheric stroke which caused him to walk with a cane and suffer from attention deficits was presented with an environment similar to Astrojumper. Balls would appear in the virtual scene prompting the patient to reach up and tap them. In these separate studies, the patients had shown significant balance improvement. In addition, participants rated their physical therapy experience very highly, requesting to enter the environment for a second time. Children with autism often have gait problems as well, showing difficulty controlling their movements. Astrojumper is very similar to the second virtual environment described in Kizony's study, and we hope to find that our system provides similar balance advantages to participants with autism.

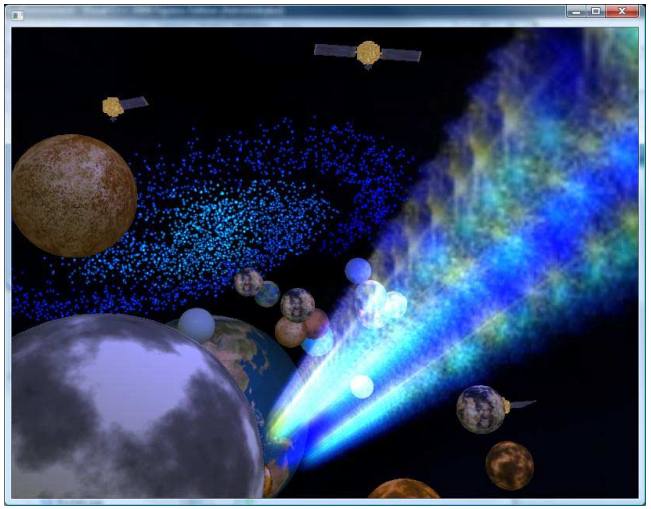

Figure 1: A screenshot from Astrojumper playing on the PC.

Game Design

While head-mounted virtual reality displays might be appropriate for many types of immersive single player games, they are too encumbering for use in a game requiring extensive physical activity. We deploy

Astrojumper on a three-sided CAVE with 8' x 6' rear-projected screens using two Barco stereoscopic projectors each along with circular polarized glasses. Four Polhemus Fastrak electromagnetic trackers were enclosed within sweatbands, which are worn on the user's forehead, wrists, and on a belt around the user's hips. The game itself is implemented using OpenSceneGraph for graphics and OpenAL for audio, with 3D models created using 3d Studio Max.

In Astrojumper, we provide the user with a virtual outer space environment where they can experience planets, asteroids, space craft, and stars speeding forward toward them. As mentioned previously, children with autism are often fascinated by outer space and find astronomical stimuli engaging. The goal of Astrojumper is to jump over, duck under, and swerve around the virtual objects flying forward, while also reaching out to tap bonus objects which provide points or in-game bonuses. Reinforcement such as score, feedback, special effects, and color are used to encourage the participant to succeed within the game.

Game Play Mechanics

There has been a significant amount of evidence which shows that virtual reality tools for exercise and rehabilitation are largely successful because they can provide appropriate, real-time feedback about the movements and interactions of the user [3]. Providing the user with feedback is not only helpful for training environments, but it is also one of the nine guidelines to follow when designing an exergame [7]. In physical environments, it is impossible for a physical therapist or coach to stop everything and explain to a child with autism what went wrong (or what was done well) in a task, while also providing specific feedback about their actions. In a virtual environment, though, we can help aid in this transfer of information by giving clear, unambiguous feedback about the user's movements through score, color, sound, and text. According to Sinclair et al., unambiguous feedback along with other qualifications such as providing rewards, merging of action and awareness, clear goals, and personal control in exergames help get user "in the zone" and become fully immersed in game play. In Astrojumper, we address each of the previous considerations.

In Astrojumper, a collision occurs when the user's tracked data coordinate is in the same location as a virtual object in the environment. This could either mean that the child was not exerting enough effort into dodging the object, or that he could not appropriately contort his body in response to the stimuli. In either case, the user's score will be reduced to stimulate more exertion and better body control. Conversely, successful avoidance of an object results in a score increase to promote the player's efforts. The amount of points the user gets at any given time is affected by characteristics of the user's movement, such as distance and velocity. Users accumulate a point every few milliseconds, and cumulative seconds spent between collisions will build up multipliers. To provide more diverse physical activity, brightly colored bonus objects in the environment are meant to be collided with, providing substantial score boosts. In future versions of Astrojumper, heart rate will be used a game mechanic as well. When the user's heart rate has increased by a certain percentage of their resting rate, they will be rewarded with increased score multipliers and other in-game bonuses. Certain objects in the environment, such as UFOs, will be challenge missions and are also meant to be collided with. These challenge

missions will provide increased interaction methods for 20-30 seconds, such as the ability to shoot virtual laser beams at the objects in the environment by the motion of pumping the arm back and forth. Other increased interaction methods may require jumping, arm-raising, punching, and other specified arm movements.

In addition to motivating physical activity, Astrojumper may help a user with autism gain better control of their movements after extended, regular exposure to the application. There is a foundation of research supporting virtual reality applications for use as rehabilitation software to help individuals regain back movement in their limbs. Frequent sessions of play may help the user become more aware of how they need to move their limbs to get the environment to respond in the way they want.

Preliminary Evaluation

We have recently finished preliminary playtesting to locate any potential bugs and ensure Astrojumper's level of difficulty was appropriate. This playtesting was done with eight healthy, neuro-typical people: four between the ages of 11 and 16, two between the ages of 18 and 25, and two between the ages of 40 and 50. We took demographic information including their age, gender, exercise habits, and video game preferences, let them play one session of Astrojumper, and had them fill out a questionnaire. Overall, participants' ratings on the 7-point Likert scale questions were extremely positive (M = 6.50, SD = .53) and qualitative feedback also suggested that the game was fun and motivating. This number got even higher when we only looked at questions regarding the player's motivation and enjoyment, with almost all participant's "strongly agreeing" that Astrojumper was engaging, (M = 6.75, SD = 0.46). Some questions in this category include, "I would exercise more if I could use Astrojumper," "I thought Astrojumper was fun to play," and "Astrojumper was as or more fun than the Nintendo Wii fit." Other questionnaire items asked how strenuous the workout was and if participants thought they were getting a good workout, and these reports were more varied, (M=5.00, SD = 1.51). From our qualitative feedback from the participants, we found that people with different backgrounds viewed the game in different ways. For example, a 14 year old male who does not typically engage in rigorous exercise and considers himself a hardcore gamer had said, "*The virtual reality was so cool, it was like I was actually flying. I would move around and exercise if I could be in the virtual reality whenever I wanted*." A 48 year old who considers himself a non-gamer and exercises vigorously 3 times a week responded that Astrojumper was a lot of fun, but more like a stress reliever than an intense

Figure 2: A neuro-typical individual playtesting Astrojumper.

workout. At the time, the tracker wires were being held behind the user, and we found that this sometimes results in small tugs which hindered the player's mobility. This was the only criticism we received of the system, and we are now utilizing a backpack to hold the wires to prevent this problem from happening again.

Future Work

We have plans to begin a full evaluation this spring which will help us understand the differences in how different types of people interact with and perceive exergames. We're very interested in evaluating if there is a significant difference between neuro-typical and autistic individuals with different exercising and gaming habits. We will be using measurements such as positive affect and negative affect to view how the participant's self-assessment of their state of being changes after exposure to Astrojumper. We're also finalizing the plans to run an evaluation testing the effectiveness of Astrojumper as a rehabilitation tool for people with autism, and we are interested in using cognitive ability, movement patterns, and frequency and intensity of meltdowns as measurements to gauge success.

Conclusion

People with autism may be able to benefit from exergames, but we don't have enough formalized information about how they interact with exergames to properly design these tools. From our preliminary playtesting on neuro-typicals, Astrojumper appears to be an exciting game which participants genuinely enjoyed interacting with. While these preliminary results are definitely promising, they give us no insight on how people with autism spectrum disorder may respond to the system. Thorough evaluation is needed to discover the different ways people with and without ASD respond to exercise tools to ensure the tools that are being created are the best fits for the target population.

References

[1] T. Chuang, C. Chen, H. Chang, H. Lee, C. Chou, and J. Doong. Virtual reality serves as a support technology in cardiopulmonary exercise testing. *Presence: Teleoperators & Virtual Environments*, 12:326-211, 2003.

[2] C. Curtin, L. Bandini, E. Perrin, D. Tybor, and A. Must. Prevalence of overweight in children and adolescents with attention deficit hyperactivity disorder and autism spectrum disorders: a chart review. *BMC Pediatrics*, 5(1): 48, 2005.

[3] R. Kizony, N. Katz, and P. Weiss. Adapting an immersive virtual reality system for rehabilitation. *The Journal of Visualization and Computer Animation*, 14:261-268, 2003.

[4] H. Nicholson. The effects of antecedent physical activity on the academic engagement of children with Autism Spectrum Disorders. PhD thesis, University of Connecticut, 2008.

[5] C. Putnam and L. Chong. Software and technologies designed for people with autism: what do users want? In *ASSETS '08: Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility*, pages 3-10, New York, NY, USA, 2008. ACM.

[6] C. Sicile-Kira. Autism Spectrum Disorders: the complete guide to understanding autism. The Berkley Publishing Group, New York, USA, 2004.

[7] J. Sinclair, P. Hingston, and M. Masek. Considerations for the design of exergames. In *GRAPHITE '07: Proceedings of the 5th International Conference on Computer Graphics and Interactive Techniques in Australia and Southeast Asia*, pp. 289-295, 2007.