Astrojumper: Designing a Virtual Reality Exergame to Motivate Children with Autism to Exercise

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ABSTRACT

Children with autism show substantial benefits from rigorous physical activity, however it is often difficult to motivate these individuals 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. During the game, virtual space-themed objects fly forward toward the user who must use their own physical movements to avoid collisions. Preliminary playtesting of Astrojumper on neuro-typical participants has been positive, and we plan to run an extensive evaluation assessing the psychological and physiological effects of this system on children with and without autism.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; K.4.2 [Computers and Society]: Social Issues—Handicapped persons/special needs; K.8.0 [Personal Computing]: General—Games

Keywords: virtual reality, exergames, autism

Figure 1: An individual playtesting Astrojumper.

1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder which affects individuals with varying degrees of impairment [8], though 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 [6], and become fixated with a particular subject area referred to as a special interest [7], such as 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 which may become chaotic or self-destructive. Fewer opportunities to engage in structured physical activity and increased social isolation, among other factors, promote sedentary lifestyles in children with autism [2], and its difficult to motivate them to engage in physical activity. Sedentary lifestyles 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 also provides 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 [4]. In addition, exercise has also been shown to decrease chaotic behavior associated with self-stimulation [5], which can foster an overall improvement in their quality of life.

In this paper, we present Astrojumper: a virtual reality exercise game, or exergame, which may help motivate children with autism to engage in physical activity. We will be using Astrojumper to measure the participant's psychological reactions to the game, such as enjoyment and motivation to engage in gameplay. We are also interested in studying physiological reactions including quality of workout and cognitive effects of exercise, such as increases in fluid memory and decreases in meltdown frequency. In addition to studying individuals with autism, we are also interested evaluating Astrojumper with neuro-typical users to compare the differences between these two populations to provide guidelines for the future design of similar applications. Finally, we will also measure changes in children's movement patterns and body control after extended exposure to Astrojumper, as immersive virtual reality technology has been shown to be effective for restoring balance in people with irregular movement patterns [3]. We believe that a virtual reality exergame may be a successful exercise motivator for children with autism, helping to reduce their meltdowns, improve coordination, and foster academic development.

2 ASTROJUMPER

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. The goal of Astrojumper is to jump over, duck under, and swerve around the

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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.

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/she could not appropriately contort their 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. To provide more diverse physical activity, the user must also reach out and tap certain objects for bonus points. 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, etc.

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 [9]. Virtual reality also provides strengths over physical environments by providing the opportunity for completely immersive interaction. People with autism are more easily distracted by outside stimuli than neuro-typical individuals [1], and virtual reality can subtract all environmental factors which are outside of the scope of the project's intentions. In addition, researchers can adjust the level of stimuli within the virtual environment to ensure the child is not either too bored or too distracted during participation [10]. 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 engaged in game play. Astrojumper addresses each of the previous considerations, leading us to believe that extended, regular exposure to the game may not just motivate children with autism to exercise, but to enhance body control and train coordination and balance.

3 Preliminary Evaluation

We have recently finished doing preliminary playtesting on Astrojumper 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. Participants were given a survey after playing Astrojumper, and the ratings on the 7-point Likert scale questions were extremely positive (M = 6.50, SD = .53). This number got even higher when we only looked at questions regarding the player's motivation and enjoyment, with almost all participants "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 exercise was and if participants thought they were getting a good workout, though 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 had 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 requested to play a second time and 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 three times a week responded that Astrojumper was a lot of fun, but more like a stress reliever than an intense workout. For future studies with a larger participant population, we're very interested in evaluating if there are significant differences between neuro-typical and autistic individuals with different exercise and gaming habits.

4 Conclusion and Future Work

Preliminary playtesting of Astrojumper with neuro-typical individuals has yielded promising results. In the future, we have plans to perform a thorough evaluation to investigate the different ways people with and without autism respond to this virtual reality exergame. The results of this study will provide insight on the exergame design requirements directed toward a population with ASD, and will help future researchers design therapeutic VR exercise tools. In addition, we plan to run a case study on three children with autism where they will play Astrojumper three times a week for a total of eight weeks. We will measure the changes in positive / negative affect, balance and coordination, and memory span to evaluate the effectiveness of extended exposure.

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