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CURRENT USES OF VIRTUAL REALITY FOR CHILDREN WITH DISABILITIES

JOAN MCCOMAS, JAYNE PIVIK, MARC LAFLAMME

Rehabilitation Sciences Virtual Reality Lab,
University of Ottawa, Ottawa, Ontario, Canada

Abstract. Technological advances, including the use of virtual reality, have contributed enormously to improving the treatment, training, and quality of life of children with disabilities. This paper describes the advantages of VR for children with disabilities, how VR can minimize the effects of a disability, the role of VR in training and skills enhancement, and how social participation and the child's quality of life may be improved through the use of VR.
Examples from published literature and Internet sites are given of current and completed projects which focus on improving the lives of children with disabilities. The research describing the efficacy of knowledge and skills transfer from a virtual environment to the real world are examined in relation to children with disabilities. Finally, the current limitations and future directions of VR for children with disabilities are considered.

1. Introduction

Virtual reality (VR) has the potential for improving the lives of children with disabilities. Applications have been developed which could minimize the effects of a disability, improve quality of life, enhance social participation, and improve life skills, mobility and cognitive abilities, while providing a motivating and interesting experience for children with disabilities.

Virtual environments (VE) can be built to accommodate the needs of children with varying literacy, physical, language and cognitive levels. Even children with severe disabilities can explore or create new environments or manipulate objects without being limited by their disability, provided the correct interface is chosen or designed. The freedom of movement allowed by VR empowers children by giving them a sense of control over their environment [1]. In fact, unlike many real world environments, VEs can be custom-designed to enhance the strengths of an individual rather than allow a disability to limit their interactive capabilities [2]. With VR, children with disabilities can actively participate, focus on their abilities, and realize a sense of control and mastery [1].

This chapter will provide an overview of the current uses of VR for children with disabilities by reviewing VR projects reported in journals and on the Internet. We will synthesize the benefits of VR for children with disabilities and examine how VEs can be customized to meet their needs. The role of VR in training and skills enhancement, social participation, and quality of life will be addressed. Finally, the evidence for the effectiveness of VR for children with disabilities and whether VR can minimize the effects of disability will be considered.

2. The benefits of VR for children with disabilities

Benefits of VR have been reported for training and skills enhancement of children with disabilities. Children with disabilities have the opportunity to learn and practice new skills in VEs such as crossing streets [3, 4], or going shopping [5] without the worry of potential injury or fear of embarrassment [6,7]. VEs can also be designed to meet the specific training needs of each child. For example, the number of stimuli presented to a child who has autism can be controlled [8], or virtual wheelchair training for children with severe physical disabilities can be moderated [3]. Benefits have also been noted for the use of VR in rehabilitation, such as for applications for cognitive assessment [6,9], physical assessment [2], and training in motor [3,10] or cognitive functioning [6].

Social benefits for children with disabilities have also been attributed to the use of VR. Along with a sense of self-control and mastery, VR has allowed children to communicate with other children sharing similar disabilities or diseases [12,13]. Alternatively, through the use of an avatar (a persona that the user chooses to adopt in a virtual world), the child can focus on their sense of self and not their disability. VR may also offer a new perspective for children and the opportunity to experience different points of view or assume different identities [14].

The anonymity associated with communicating with other networked users within a VE puts the child on an equal footing and provides a social outlet for children who might otherwise be isolated from their peers [6]. However, Wilson and his colleagues [10] suggest that the very sense of freedom and well-being felt in VEs may in fact cause the user to withdraw from real-life social situations, a result of quasi-addiction to this artificial reality.

3. Customizing VR to meet the needs of children with disabilities

The properties of VR, in particular its malleability, make it a versatile medium for the development of applications that can be customized to meet the needs of children with disabilities. The characteristics of the VE can be modified to include or exclude certain categories of stimuli depending on the goal of the program [9]. This adaptability helps promote an optimal interaction for children with disabilities. VR allows children with sensory impairments to experience what would normally be difficult or impossible for them by transposing information from the affected sensory modality into information that can be perceived by the senses which are intact.

An example is a VE that uses auditory and/or tactile cues for children who are blind [15].VEs can also be adapted to suit different learning styles. For instance, auditory information can be provided in a greater proportion for the “acoustic learner” [14] as opposed to more visual information for the “visual learner” [4]. VEs developed for autistic children limit the number of stimuli presented, to encourage children to concentrate on a particular task [8]. The number of simultaneous stimuli can gradually be increased as the child’s time on task progresses, until the child can function at a level that mimics real-world settings. Similarly, learning experiences can be structured for children with learning difficulties to break down complex tasks into more simple components until the child masters the necessary skills [4,9].

Another advantage of VR described by Wilson, Foreman & Stanton [10] is that the need for semantics, symbols or language is virtually eliminated, due to the experiential nature of the learning process. This means that VR is more accessible to different categories of users who may benefit from learning a task in VR without the restrictions of traditional teaching methods.

VEs may be modeled on a familiar or novel location depending on whether the goal is identification within the environment or generalization of experiences to the real world [16]. A familiar setting may favor accommodation, whereas a novel setting may require longer accommodation times [14], but provide improved generalization of learning. VR also provides immediate feedback on the learner's actions in a VE and allows training to be paused at any time for discussion and correction of performance [9]. The gaming aspect that can easily be incorporated into VR may also contribute to motivation for maintaining time on task [9,17]. Once the environment has been customized to suit the child's needs, various tasks can be presented within the VE in order to promote interaction and learning. Cueing stimuli or selective emphasis can be used to foster errorless learning by guiding the child through the performance of various learning tasks [9].

4. VR for minimizing the effects of a disability

Virtual reality can be viewed as an assistive technology, due to its potential to minimize the effects of disability. Lewis [18] conceptualized assistive technology as having two purposes: to improve a person's strengths in order to offset the effects of disability, or as an alternative way to accomplish a task that compensates for a disability. VR can serve as an assistive technology in both ways. For example, it is possible to translate gestures into speech [19], thereby taking advantage of good motor skills when speech is lacking. Alternatively, it allows a child to move within a VE even though in real-life this is physically impossible.

VR technology also provides children with disabilities, greater access to many experiences. For instance, Nemire and Crane [39] designed a VE that allowed students with cerebral palsy to access a virtual science laboratory using a specially adapted interface technology to target objects in 3-dimensional space. Other changes are occurring in VR technology to provide access to users who are blind via audio navigation. Max and Gonzalez [15] are testing a system that they developed to convert models from the Internet into objects that can be felt using a haptic interface and localized using 3-D audio. They reported that a four-year-old girl who was blind was able to use the system to successfully localize sounds and recall the 3-dimensional scene over a course of several weeks. This type of technology may eventually open up the World Wide Web to individuals with visual impairments and supports the premise of VR as a tool for increasing access for children with disabilities.

5. Role of VR in Skills Enhancement and Training

A lot of the work being done in VR for children with disabilities focuses on providing a simulated world which allows the child to train, practice or enhance their skills. The goal of this training can either be external, in order to practice skills which can be transferred to the real world, or internal, such as restoring or improving cognitive function through repetition and training [6,21]. Currently, the applications which focus on using virtual reality for enhancing skills and training for children with disabilities can be categorized as those which improve life skills, those which provide opportunities for mobility training, and finally, applications focusing on improving cognitive skills.

Fostering independence, full participation and access, and a sense of control and mastery, are the main rehabilitative goals for children with disabilities. Much of the work being done for children with disabilities in VR has focused on these goals in concrete ways, such as training to shop independently, ride public transportation, and safely cross streets. VR's ability to adapt to the differing levels of a child's functioning and to different types of disabilities, makes it a useful tool for enhancing and training in life skills. However, to date, most of the VR applications developed for improving life skills have been designed for children with developmental disabilities. Researchers at the University of Nottingham's Virtual Reality Applications Research Team (VIRART) [22, see also Brown *et al.* in this book], are building VEs to assist students with developmental disabilities, by providing the opportunity to train and enhance their skills in areas such as visiting a post office, supermarket or bakery; moving within a virtual house; driving in a virtual city that includes traffic, pedestrian crossings, and other cars; learning tenant's rights and responsibilities; and skiing on virtual hills. Successful transfer of skills learned while shopping in the VE when compared to actual performance have been noted [5]. Learning to ride public transportation is another skill that would give children with disabilities more independence and greater self confidence. To that end, researchers at the University of Dayton Research Institute and the Miami Valley Regional Transit Authority have developed simulated bus rides for children with developmental disabilities to teach them to independently ride public transportation. Within a virtual environment, the children learn to recognize landmarks and emergency situations [23].

Learning to safely cross streets is an important task for all children, but particularly for children with disabilities. Dr. Dorothy Strickland and her colleagues at the University of North Carolina developed a VE to determine whether two autistic children were able to adapt to the virtual reality equipment and practice pedestrian safety in a VE. The two children were taught to use a virtual reality helmet and were introduced to a VE which involved a sidewalk, buildings, and a moving car. After 5 weeks of training, the children showed acclimatization to the virtual reality equipment and response to the virtual environment. Further research is advised to examine the effects of virtual environments on the perceptual processes of children with autism [4]. VR training in street crossing has also been developed for children with severe orthopaedic impairments. Inman, Loge and Leavens developed a virtual intersection as part of their mobility training to teach children with cerebral palsy how to use a motorized wheelchair [24].

Similarly, two projects, one at the University of Washington [25], and another at the University of Ottawa [26], both currently in the development phase, are using VR as a skills training medium to prevent disabilities in children. These projects focus on teaching children pedestrian safety skills to combat one of the leading causes of disablement and death in children [25,27]. With the goal of using VR to provide simulated opportunities to enhance skills in street crossing, we, at the University of Ottawa's Rehabilitation Sciences Virtual Reality (RSVR) Lab, are using desktop VR, while Rusch and colleagues at the University of Illinois [28] are using an immersive CAVE system. Both projects will be utilizing a controlled study to examine the learning effect of crossing streets in a VE using different scenarios with varying degrees of difficulty, and will be examining how well learning in the VE transfers to real world behavior.

Mobility training for children with physical disabilities not only assists with improved perceptual-motor skills and cognitive-spatial abilities, but also gives the child a sense of independence, increased competence, and personal control [3,29]. To date, mobility skills training using VR for children with disabilities has focused on simulating environments which aid in self-locomotion. The advantages of using a VR simulator for self-locomotion are accelerated learning of navigation, as well as a decreased risk of injury throughout the learning process [3,24]. Inman and colleagues at the Oregon Research Institute (ORI) Virtual Reality Lab are developing VEs which provide self-locomotion training using a motorized wheelchair. These VEs give children with severe physical disabilities, the opportunity to: learn perceptual-motor skills; provides the child with a safe environment in which to train, experience movement, explore different environments; and, provides an opportunity to assess the suitability of acquiring an electric wheelchair [24].

The areas of cognitive training using VR that are currently being examined for children with disabilities include attention, memory and spatial skills. Researchers at VIRART are involved in creating an interactive audio-visual virtual environment for children who have autism. Labeled the AVATAR house, this virtual environment consists of familiar objects which emit sounds when activated. This cause and effect format gives the child the opportunity to practice skills and transfer knowledge to the real world. The researchers are currently examining the effect of this program on levels of concentration, attention span, and confidence [30, see also Brown *et al*. in this book]. Wilson, Foreman and Tlauka used desk-top VR to successfully train and enhance spatial skills in physically disabled children [31, see also Stanton *et al*. in this book], while researchers at the University of London are examining the potential for using VR for procedural memory, attention and spatial skills training [6, see also Rose *et al*. in this book].

VR can also be used in cognitive assessment [6,9, see also Riva in this book], and as a physical assessment tool [2,32]. This medium allows for the controlled evaluation of cognitive or motor function within a VE that adequately simulates activities of daily living in a safe, non-restrictive environment [6]. The results of such evaluations are quantitative and objective, and can be stored for future reference or analysis [2,9]. VR can also be modified to enhance certain sensations in order to overcome partial sensory loss, since the tester has full control over the stimulus presented [9]. Rose, Attree & Johnson [6, see also Rose *et al*. in this book] suggest that VR could be used to stimulate patients in a persistent vegetative state, where traditional methods fail to evoke a response, by providing different combinations of stimuli. It was also suggested that VR can be used to promote interaction of the patient with the environment, thereby potentially increasing neuroplasticity and preventing future damage due to lack of stimulation and interaction. A major advantage of using VR to promote interaction, stated by Rose, et al., is that it increases the time spent in therapeutic activities, without the need for a therapist to be constantly present. As well, the VE can be tailored to the motor skills of the child and modified to allow sensory manipulation of virtual objects for practice of a motor task.

6. Virtual reality to enhance social participation and improve quality of life

Although VR can be used to simulate physical environments, it also has potential to simulate social environments. This suggests possible advantages for children with disabilities or for children who are hospitalized. Social advantages of the use of VR for children with disabilities include: providing the opportunity to develop prosocial skills in a non-threatening environment, increasing communication opportunities, and giving the child a sense of control and empowerment. It has been suggested that VR could be an excellent tool to help develop prosocial skills in children with behavioral problems. Muscott and Gifford [33] reviewed the possible applications for virtual reality in social skills training, and suggested its use to help teach social skills. One example, is to have a teacher and students working on the same project through networked computers, requiring collaboration for the project to be completed. A second example is to have virtual reality scenarios that model complex social situations such as responding to peer pressure, to bullying or to a fight breaking out. These situations could be modified to emphasize aspects that need improvement and the interactions could be saved and later reviewed by other members of a group to discuss alternative strategies. Since movements and actions in VR occur in real-time, social interactions are possible between avatars or among users of networked

VEs. Scenarios can be modified to teach new social skills and allow practice in a non-threatening environment. Based on an Apple Computer project that randomly assigned high school students to a technology-enhanced curriculum or not, Casey [7] has suggested that computer technology may help students to show more social awareness and self-confidence, communicate more effectively and see themselves as collaborators and experts.

Several authors have described the use of virtual reality to enhance the well-being and quality of life of children who are hospitalized. Hirose, Tanigucchi, Nakagaki, and Nihei [12, see also Hirose in this book] developed a system that included computers and video conferencing which allows hospitalized children in Japan to interactively visit places from their hospital room. The children were able to communicate with their families in remote locations and play games interactively with other children in similar situations. The authors stated that their system provided a way to improve the hospitalized child's environment and was welcomed by the children, but as yet, there is no concrete evidence of the effectiveness of the system in measurably improving well-being or quality of life. The "Starbright" project (http://www.starbright.org) has received much publicity for developing a computer network for hospitalized children in the USA [13]. This project uses powerful computers, 3-D software and video-conferencing to link four children's hospitals. Using this system, a child can explore virtual worlds and interact with other hospitalized children either as an avatar or by using the video-conferencing facility to actually see and speak to other children. Studies are ongoing to assess whether participation in the project enhances well-being, shortens recovery time and decreases the amount of pain medication needed by the participants.

Along with enhancing well-being, it has been suggested that VR could empower children with disabilities. Sims, for example, described a multimedia camp where children with various disabilities, using custom interfaces, could manipulate sounds, actions and images in a computer, thereby learning to control an environment [1]. However, it is not just the use of the technology by children with disabilities that may give them a chance to control environments or exercise control in situations where they have previously been powerless. At the RSVR Lab, we have involved children with disabilities as consultants to assist us in developing a VE focused on promoting disability awareness. Children with physical disabilities who are participating in our Disability Awareness Virtual Reality Project are advising our technology partner on the content of the virtual world and will be evaluating the finished VE. Their own experiences with the accessibility barriers that they have encountered will be used to construct the VR software that will provide disability awareness to children in schools. The VE that will be developed will simulate the barriers identified by the children with disabilities and allow the children using the program to identify and then manipulate the encountered barriers. For example, while navigating through the VE in a virtual wheelchair, children will experience obstacles such as stairs, curbs, doors that are difficult to open, objects that are too high to reach and attitudinal barriers such as inappropriate expectations and comments. Changes in attitudes toward persons with disabilities and knowledge of issues associated with being disabled will be assessed. Another important objective of the project is to assess changes in the self-esteem of the children who participate as consultants in the project.

7. Evidence of the effectiveness of VR for children with disabilities

Training in a simulated environment assumes that the experience impacts on skill level and that those skills then transfer to the real world. Although, there is a paucity of published literature examining the efficacy and impact of VR training for children, the transfer of spatial information from VEs to the real world has been reported for adults [34, 35, 36]. With regard to children with disabilities, Wilson, Foreman and Tlauka tested severely disabled children's knowledge of a real environment and found that spatial learning from VR to real space occurred [31]. Recently, we studied the transfer of learning of a spatial task from desktop VR to a real environment. Children without disabilities were asked to maneuver through a VE in a virtual wheelchair while trying to find puzzle pieces hidden throughout a virtual classroom. The children had to remember which locations had been visited previously. On a post-test of the same task in real space, we found that children who practiced in a VE performed as well as children having done the same number of practice trials in real space [29]. These studies suggest that VR has a role in providing children with opportunities to practice spatial skills and also that the learned skills can transfer to a real-world spatial task. Further, this suggests that VR can assist children with mobility difficulties by providing spatial experiences normally acquired through self-locomotion .

Inman, Loge and Leavens conducted a study using three virtual worlds of increasing difficulty to train wheelchair skills in children. They found that the children's driving skills improved with increased time spent in VR training. In particular, the children were better at turning, stopping and traveling in a straight line [24]. Another important transfer study, conducted by Standen and Cromby investigated the transfer of shopping skills from a virtual to a real environment in children with severe learning difficulties. The students were then observed during a shopping task in a real supermarket. Half of the students practiced shopping in a virtual supermarket while the other half had access to virtual environments but not to virtual shopping. They found that students who practiced in the virtual supermarket improved their real-world shopping skills [5]. These authors raise some important questions regarding the transfer of training from virtual to real environments. First, short-term and long-term maintenance of performance is an issue that should be investigated before VR technology can be used as an educational medium. Second, they recommend further studies to circumscribe those features of VEs which are most conducive to transfer. Third, how much control or how much freedom should be provided to the user in order to optimize transfer? And lastly, how much detail must be included in the VE to promote transfer and learning? Evidence is beginning to support the idea that children with disabilities can learn skills in VR that transfer to the real world but much more remains to be done in this area. The need for more rigorous examination of generalizability, validity and transfer of skills to real life has been recognized [37], and is being pursued [4,5,6,29].

8. Limitations

It is not yet possible to inexpensively deliver true real-time VR with highly realistic graphic images. If children find the VR application unrealistic, unresponsive or frustrating to use, the advantages of VR over traditional treatment methods are lost. Also, in order for any technology to be useful, it must be accessible. Children with disabilities will not receive benefits if their families or their local rehabilitation facility cannot afford the new VR technology. Although VR has the advantage of costing less than many real-world simulators, this new technology is still quite costly. As new products are developed through ongoing research, VR systems are becoming more affordable. However, to keep abreast of the latest hardware and software available, the maintenance of a VR system can prove to be quite costly. Internet shareware distribution of various products and prototypes may one day bridge the gap between research and application.

There have been some difficulties noted with the use of head-mounted displays (HMDs). They generally, offer low resolution, limited field of view and tend to restrict movement due to their size, weight and attachments [14,38, see also Rizzo *et al.* in this book]. At present, many of these devices are too heavy to be worn comfortably by most children with disabilities. In addition, Nemire, Burke and Jacoby indicated that some users with physical disabilities would be unable to manually adjust the HMD independently to fit their heads or to adjust other characteristics of the display [20]. These problems are important considerations, as children with disabilities should be able to access the technology as independently as possible.

Users of immersive VR, which make use of HMDs or immersive CAVEs, have reported experiencing signs and symptoms of motion sickness [6]. This is believed to be due to a discrepancy between the visual and vestibular inputs received by the brain as the visual system detects motion, while the vestibular system does not. To minimize "cybersickness" and to better simulate real-world interaction, Bricken suggests that users should not be allowed to defy the laws of physics by being allowed to fly or to go through walls or floors [14]. However, for a hospitalized child or a child who uses a wheelchair, such a fantasy experience may provide a sense of freedom and a necessary distraction. Due to these current limitations, many researchers have opted for the less immersive desk-top VR. Desk-top VR is accomplished through projection of the VE onto a screen or computer monitor, where the participant uses a joystick, mouse or keyboard to interact within the VE. Speakers may also be used to provide 3-D sound. The major limitation of desk-top VR is that users have a diminished sense of immersion, however, its advantages include cost-efficiency and absence of cybersickness.

9. Conclusion

As it stands, virtual reality is still in its infancy, with each new project often being the first of its kind. This emerging technology is providing children with developmental disabilities, the opportunity to practice life skills such as visiting a supermarket, bakery or post office; moving within a virtual house; or driving in a virtual city [22]. Other applications for improving life skills include VEs for practicing to cross streets safely [4], and riding public transportation [23]. Projects developed for children with physical disabilities allow the chance to participate in science education experiments [24,39], to train to use a motorized wheelchair under differing conditions [24], and, to enhance their physical and cognitive functioning [6,10,24]. VR systems are being developed and tested for children who are hospitalized, often with chronic or debilitating illnesses, to provide distraction and fun, to enhance social opportunities, and hopefully to reduce anxiety and stress [12,13]. As well, programs are being developed in VR for children to practice social skills such as dealing with a bully [33], or to provide an outlet for creativity and self mastery [1]. Finally, VR is moving into the awareness and prevention realm, where programs are being developed to raise understanding of issues concerning accessibility and full participation for children who are disabled [26], and to prevent disabilities by teaching all children pedestrian safety [26,28].

Based on the VR projects that are specific to children with disabilities, it is clear that there are distinct advantages to the use of this medium in training, skills enhancement, and augmenting social participation. Due to VR's plasticity, environments can be developed to meet the special needs of the child or the specific goals of practice or training. Children can have experiences never previously known such as skiing down a hill (VIRART), participating in a chemistry lab [24] or crossing a street independently [4,24]. The simulated world can provide the opportunity to repeatedly practice a skill without the fear of injury or embarrassment. The reported effects on the children include: gaining a new perspective [14], increasing participation and access [15,24], instilling a sense of confidence, competence, self control and mastery [1,14,24], having the opportunity to learn skills which increase independence [5,23], being able to practice communication skills [7,33], having fun, and providing an opportunity for distraction [12,13,40].

Further research is needed to document the effects of VR on children with disabilities, in order to ensure that the applications are valid and reliable, and to examine their generalizability. As well, the current trend toward testing the transfer of learning from the VE to the real world, needs to be continued to ensure that the goals of the applications are being met. Specific for children with disabilities, we recommend that researchers continue to focus on developing applications which enhance accessibility, full participation, and independence in the academic, vocational and life skills areas. And perhaps as important as the learning and training, is to provide opportunities for children with disabilities to play and have fun. So often, the lives of children with disabilities center around treatment, training, education and rehabilitation, with little time devoted to just being kids. Ideally, future VR applications for children with disabilities would combine the goals of training and rehabilitation with an experience that is enjoyable and empowering for the child.

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