The Application of Virtual Reality to Enhance the Learning Experience of Children with Disabilities

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ABSTRACT
Early education for children is critical in the development of life skills, moral and ethical perceptions, and increased knowledge. This is influenced by learning what is taught to them. Essential skills such as walking, hearing, speech and cognitive processes are skills that children with disabilities find extremely difficult without aids. Virtual environments have provided these children with the ability to learn and develop these skills without their disabilities limiting them. It enables the children to practise and rehearse to ensure that they can keep up and in some cases, overtake the learning of children without disabilities. Virtual environments are a safe and secure way for children to learn these new skills. There are many arguments that suggest virtual reality technologies are not ethical and pose weaknesses and threats upon the children; however the strengths and opportunities outweigh these concerns. Without virtual environments, children with disabilities would be at a disadvantage.

Keywords - Virtual reality, virtual environments, children, disabilities, education, rehabilitation, technologies.

1. INTRODUCTION
Applications of virtual reality were introduced by VPL and Autodesk on June 6th, 1989. It came with the potential to contribute to societal infrastructures such as education. The key characteristics include spatial interaction, inclusion [1], presence and autonomy [2]. The main element of the design focuses on ensuring that every technology meets the needs of all individuals [1].

Virtual reality (VR) and virtual environments (VE) provide personalised worlds and programmable environments that effectively enable a complex reproduction of accurate audio, visual, tactile and motion [1].

The application of virtual reality is extremely important to enhance the way that children with various disabilities learn. The interactive simulations pose as real life environments to allow users to engage in activities that will develop vital educational skills, without being limited by the effects of their disability. “Virtual reality provides enormous potential for disabled individuals, with the freedom to explore and interact with virtual worlds by carefully exploiting their existing skills” [1].

Traditional educational resources cannot compete in any way with the exceptional virtual reality technologies that are on offer to improve and accommodate children with language, literacy, physical and cognitive disabilities [3]. Virtual reality is a fairly new and upcoming technology that is being used in the rehabilitation for children with disabilities; therefore many studies have been conducted to test how effective these technologies are.

Explored in this paper are various examples of successful studies that investigate innovative virtual reality technologies that enhanced the education of children with disabilities. The benefits of these technologies will be discussed in this section, focussing on the following disabilities in particular: cerebral palsy, autism, attention deficit hyperactivity disorder (ADHD), visual impairments, speech and hearing impairments and physical disabilities such as a child in a wheelchair. To follow, a S.W.O.T analysis will be performed and ethical issues that arise with the VR technologies previously examined will be discussed. Concluded in this paper will be the investigation of the future of virtual reality technologies and the need for them in the educational sector.

2. VIRTUAL REALITY IN EDUCATION FOR CHILDREN WITH DISABILITIES
Virtual reality is considered a valuable tool for education and rehabilitation for children with disabilities. The technology could be used further in distance learning, distributed training and e-learning [4]. Computers have a sufficient computational capacity from the hardware that displays virtual environments of tomorrow; this includes Takacs’ tutor agent. The ever-growing technology will produce many new opportunities in the future for the use of virtual reality for children with disabilities [5].

The long term need for these technologies will ensure that human-computer interfaces for education and rehabilitation will be continually improved to aid and enhance the complexity of learning. Emotions are a catalyst that will motivate the transformation of information into knowledge thus introducing emotions into computer use [6].

2.1 Cerebral palsy
In order to establish how effective virtual reality is in enhancing the education of children who have cerebral palsy, the following must be analysed: the development of their skills, creation of friendships, learn-ability, performance of activities, achievements of self satisfaction and a sense of competence. This shows that virtual reality is only successful if it satisfies emotional well-being as well as educational skill development [7,8].

Children with cerebral palsy suffer with neuromuscular impairments that affect motor systems such as sensation, perception, cognition and behaviour [9]. These can limit the ability to communicate and participate in many activities; therefore this can be a barrier to developing educational skills. Sharipo et al. [10] conducted an experiment that investigated the
effects of a sensory adaptive virtual environment. The results concluded that if special lighting effects, relaxing music, vibration and aromas were present, then they would have a calming effect on the children with cerebral palsy thus allowing educational lessons to be more effective [11].

2.1.1 Lokomat
Lokomat is an example of a virtual reality technology that enhances the learning of children with cerebral palsy that is currently available. Lokomat was researched and designed by the Spinal Cord Injury Centre in Switzerland [12]. Lokomat is an automated treadmill training machine for children aged 4 and above, who suffer with cerebral palsy; the virtual environment that works in conjunction with the Lokomat provides motivating training that can also be used in real life situations. It has been shown that there has been an increase in active participation and therefore an increase in a new educational skill set learnt by the children [13]. At the same time as learning, the children are able to increase the use of their hips and knees to enable increased extension and flexibility [12].

It is essential for children with cerebral palsy to perform repetitive rehabilitation exercises to learn every day skills such as walking. Lokomat was developed and tested to increase performance and participation levels. These are motivating and engaging and have been found to allow children to actively participate in sport lessons and learn the rules of how to play various sports in which they are interested [12].

Figure 1 represents how the user of Lokomat and the virtual reality perceives themselves in a real life situation, i.e. a football game.

Figure 1. Lokomat virtual reality aiding the learning of sports.

The presence of a virtual environment that aids the education of children with cerebral palsy produced higher participation and learning results compared to the absence of the visual stimulus [12].

2.2 Autism
Autism is a severe disorder that affects the individuals’ independence, satisfying work, and friendships. It also stunts their social, emotional, communicative, behavioural and cognitive development [5].

Virtual reality has many strengths which are beneficial to children with autism. “Virtual environments can be simplified to the level on input stimuli tolerable by the user and minimal modification across similar scenes may allow generalisation and decreased rigidity. It provides a safer learning environment that is based upon visual and auditory responses. Trackers are used which can be monitored thoroughly to eradicate various weaknesses” [14].

2.2.1 Habilitation tools
The ability to recognise emotions and improve social interactions are skills that children with autism lack. Studies using desktop virtual environments as habilitation tools have been investigated by Mitchell [15] and Herrera [16] to teach autistic children how to behave in social environments and to understand these social conventions. A virtual scenario is created that teaches social skills. Repetition of the task improved these skills as well as their understanding of social skills. Skills were then further taught in a virtual scenario that presented physical, functional and symbolic use of objects exercises; the performance of the users also improved and they were able to effectively use these skills in a real scenario [15,16].

2.2.2 Street safety
An average individual would not think twice about how to cross a road. However, for a child with autism, it is virtually an impossible task to do safely on their own. Strickland et al. [17] developed a virtual environment that involved a head-mounted display, body tracker, and three-dimensional hand controls. This is shown in figure 2 with a head-mounted display on a boy participant ages 9.

Figure 2. Head-mounted display on boy participant aged 9.

There were two participants involved; a girl aged 7 and a boy aged 9. They were placed in this environment to learn to stop at a stop sign and to track moving cars before crossing a street. Both children had very limited verbal and language skills therefore it was a visual-based task. The familiarisation of the scenario enabled the participants to grow in confidence with crossing a street safely and taught the step-by-step processes needed in order to complete the task successfully in the virtual world. This was not tested in a real life situation; however the girls’ parents indicated that she continually put her previous experiences into practice when crossing a road in real life [17].
2.3 ADHD
Children that suffer from attention deficit hyperactivity disorder (ADHD) have learning difficulties due to behavioural symptoms that involve inattentiveness, hyperactivity and impulsiveness [18].

2.3.1 Virtual realities and ADHD
Rizzo conducted research into ADHD and virtual realities [19]; this consisted of a replica of an ordinary classroom as a virtual environment. This study explored the attentiveness of the children while exposed to distractors i.e. ambient noise, pupil motions and outside events. The measurement used for this study was reaction time and performance using a wide variety of adjustable attention challenges from simple to complex. This was tested on children with and without ADHD. The results showed that children with ADHD had more irrational body movements and made more errors as well as being easily distracted by things going on around them, whereas the children without ADHD were more attentive and made fewer errors [19].

2.4 Visual impairments
It is imperative that technology is integrated into education for children with visual impairments to enhance their learning skills. Interactive software is currently used for learning and entertainment purposes; however at the moment, interfaces are not appropriate for children with visual impairments and 3D acoustic virtual worlds have been introduced [20].

2.4.1 AudioDoom
Lumbreras and Sánchez conducted research that investigated usability and cognitive issues in a purely aural environment [4]. Children that have visual impairments have cognitive difficulty when representing spatial environments; the use of interactive virtual environments such as AudioDoom, reduce this difficulty due to acoustic stimuli in the software [21].

AudioDoom is an interactive game that is used for learning and enjoyment purposes that allows the visually impaired user to navigate through corridors, where they obtain and interact with virtual objects and characters, and encounter various challenges. The target audience for this research was blind children between the ages of 8 and 12. “AudioDoom tests the hypothesis that claims that an interactive 3D sound that is a navigable aural environment, can create visual mental images in the absence of direct sensory stimuli from the eyes” [20].

The user interacts with AudioDoom by acting on voxels which operates the game through the surrounding space. “The voxel concept determines a discreteness of the space, simplifying the surrounding positions of interaction and creating a concrete repository for an entity” [20]. Figure 3 represents this.

Figure 3. Visually impaired user interacting with AudioDoom.

2.4.2 AudioBattleship
Following this, Sánchez conducted further research called AudioBattleship [22]. It investigated the development of abstract memory through spatial reference whilst using sound-based virtual environments. “It focused on the cognitive integration of both spatial and haptic references. The results illustrated that it was very useful in forming mental images of space, haptic perception, abstract memory and spatial abstraction” [4].

2.4.3 AudioMath
The research conducted using AudioMath targeted registered blind children; this consisted of 5 girls and 5 boys between the ages of 8 and 15.

AudioMath was developed to enhance the memory of blind children to increase their reading and writing skills that are used in our everyday lives. AudioMath allows blind children to repeat, practise and rehearse the tasks to improve their short-term memory which exercises audio/oral, audio/graphic and visual/graphic memory. By integrating mathematics that was based on the National Curriculum into the audio-based virtual environment, the children were able to practise simple equations such as adding, multiplying, division and subtraction [23]. Figure 4 shows the interfaces of AudioMath.

Figure 4. Interfaces of AudioMath
The results evidenced that sound can be an effective interface to develop and enhance memory as well as the education of mathematics based on the National Curriculum [4].

2.5 Hearing and speech impairments
It is vital that different cognitive and language abilities are enhanced for children with hearing and speech impairments [24]. The following studies prove how virtual environments aid learning and enhance the education of children with these impairments.

2.5.1 Time sequence
“Time is a central and essential dimension of our lives” [24]. The study carried out by Eden aimed to see whether representation modality has any effect on children with hearing impairments as well as their perceptions on time sequence, as it was suggested that they find temporal order a difficult task [24].
Five different modes of representation were used: pictorial, textual, aural, signed and immersive 3D virtual reality. This study was carried out on children with and without hearing impairments. The children were given four different episodes of a script that were scrambled. Each child was then asked to arrange the episodes in order. The results illustrated that practising this task with virtual reality 3D spatial rotations, improved the children’s response with hearing impairments inductive thinking, compared with 2D spatial rotations [24].

2.5.2 Spatial rotation
Passig and Eden further researched this with a study that looked at the influence of an intervention program; practising 3D spatial rotation has an effect on the children’s inductive thinking. [25]

The target audience of this study was a group of 44 children with hearing impairments aged 8-11 and 10 without hearing impairments. “Each subject in the experimental group was given 15 minutes once a week over a period of three months to play unguided, a VR 3D Tetris game; involving the rotation of objects in space” [25]. Three 3D games were used: Tetris, Puzzle and Centre-Fill; these all presented challenges that involved control over 3D blocks.

The children with hearing impairments improved their structural inductive processes and flexible thinking ability due to the virtual environment. So much so, that the results were as good as the children without hearing impairments [25].

2.5.3 SPECO Project
SPECO Project was created and is a “multilingual, multimodal speech teaching and training system” [26] that was developed for 5-10 year olds that had speech impairments.

The children that participated in the study were shown speech pictures and told to listen to the sound of it at the same time, using visual and auditory feedback. The opinions from speech therapists were collected and summarised whilst an objective evaluation was performed to analyse the efficiency of the systems. The results indicated that the system used in the SPECO Project was a very valuable and effective teaching aid for children with speech impairments [26].

2.6 Physical disabilities
Children with a physical disability i.e. in a wheelchair, experience spatial problems, as they have limited movement. Limited access means that they are reliant on assistance for other optional routes and therefore find it difficult to effectively form spatial maps [27].

2.6.1 Powered wheelchairs
A study investigated and developed a simulation system for powered wheelchairs in France [28]. The system consisted of a fixed base platform and a simulator that matched the locomotive disability to the given user. Spatial navigation is a vital skill that is learnt very early on in life to assist mobility. However, physical disabilities such as being in a wheelchair, act as a barrier to this; therefore a virtual environment was created that did not limit the user as it was flexible and personal to any individual. As further research, a remote monitoring architecture was created to train powered wheelchair users. A DX-joystick (controller used to navigate wheel chairs) interface was used for exploration and navigation to aid the users. This can lead to an increase in performance of spatial awareness and navigation [28]. Figure 5 shows the virtual environment and the powered wheelchair simulator.

![Figure 5. Features the virtual environment and the powered wheelchair simulator.](image)

3. DISCUSSION
In the following discussion, I will explore the strengths, weaknesses, opportunities and threats that are related to virtual reality in education, the ethical issues that arise, and the future of virtual reality technologies.

3.1.1 SWOT analysis
The following SWOT analysis compares and analyses the strengths, weaknesses, opportunities and threats of virtual reality in education [29].

| Table 1. SWOT analysis of virtual reality in education [29] |
|---|---|---|---|
| **Strengths** | Side effects | Innovative creations can be developed |
| Real-time feedback | Unknown long term effects | Aids |
| Increased ecological validity | Designers may not ethically think about the virtual reality technologies | Rehabilitation |
| Virtual environments can be duplicated and distributed | Front-end flexibility | Drives the gaming industry forward |
| Safe testing and training |Platform capabilities | Appeals to the public |
| Allows naturalistic performance | Hardware may be uncomfortable | Academic and professional acceptance |
| Enhances motivation to learn | | Real-time data intelligence |
| Individual to each disability | | Integration of VR with physiological monitoring and brain imaging |
| Independent practice | | Tele-rehabilitation |
| Self-guided exploration | | Work more closely with the medical scientists and clinical community |
| Low cost environment | | |
| **Weaknesses** | **Opportunities** | **Threats** |
| Hardware may be uncomfortable | Ethical issues | Legal issues |
| Side effects | Morality issues | Too few cost/benefit proofs could impact virtual reality rehabilitation adoptions |
| Unknown long term effects | Perception that VR will eliminate the need for clinicians | |
| Designers may not ethically think about the virtual reality technologies | | Limited awareness |
| Front-end flexibility | | Unrealistic expectations |
| Platform capabilities | | |
| Hardware may be uncomfortable | | |
The strengths and opportunities outweigh the weaknesses and threats for the use of virtual reality in the enhancement of the education of children with disabilities. Weaknesses such as the hardware being uncomfortable and the ethical issues not being considered during the development stages of the technologies can be easily overcome.

After more research is carried out and the long term effects of these technologies can be analysed, then they will not be as much of a threat as they are already academically and professionally accepted by scientists and the public to aid the rehabilitation of many individuals. The use of these technologies is extremely important and life changing for children with disabilities.

3.1.2 Ethical issues
There are various ethical issues that arise when using virtual realities as tools for enhancing education for children with disabilities.

Misrepresentation and biased representations are ethical issues that are a concern for many individuals as they pose a risk to the children. Therefore, the values and interests of the target audience need to be accounted for during the designing phases [30].

Behaviour in the virtual environment is another ethical issue that is raised. The environments must pose as a realistic idea of what real life is like so that users are not given false practice [30].

The amount of distress that the virtual realities may impose on a user is an ethical issue that must be considered. A parent or guardian will need to agree to the use of the technologies. These are important issues to which developers should morally adhere.

3.1.3 Future of virtual realities
Virtual reality has emerged as an extremely effective and vital tool in the education of children with disabilities, and overall as a form of therapy and rehabilitation [31].

Further developments in to ensuring virtual realities are fully immersive and utilise all senses including smell, touch, sight, hearing and taste are to be carried out to improve the technologies. Sight and hearing are currently being used; however, touch is also being incorporated in to the technologies so that the user feels that the objects are real [32]. The use of smell is also being researched by Eric and Woodrow [33]. Benefits of this have been voiced in this investigation to immerse users in the virtual reality more effectively.

It is necessary for further research into virtual realities to ensure that innovative technologies are being developed to enhance the education of children with disabilities and to ensure that they are reliable, motivational, effective and of benefit to the users. The virtual environments must inspire the children to take on new challenges and experience new things. This will ensure that they are emotionally satisfied and seeking new goals.

The next step for the virtual reality technologies is to make them available for everyone. They must be effective, at an appropriate price and be accessible for all users. It is imperative that educational alliances can use these technologies to enhance the learning of children with disabilities.

4. CONCLUSION
Virtual reality technologies are continually improving and emerging into the public for children and adults to use. Virtual environments are used for enjoyment purposes as well as benefiting individuals with disabilities that otherwise could not perform activities that the virtual environments provide. Virtual environments have the ability to meet the needs of each individual that has a different disability. This is extremely beneficial for the software and hardware industries of virtual realities as well as the children that use these technologies.

The studies that are discussed in this paper reflect the effectiveness of virtual realities, in improving the lives of children with disabilities. They are extremely effective in enhancing and aiding the education, rehabilitation and therapy processes. It is however evident that further research must be carried out to ensure validity of the technologies.

However, questions will arise as virtual environments improve such as: Are they dangerous? Has there been enough testing of the technologies? What is the limit of use of the technologies and how do we know about the long term effects? These questions will eventually get answered once the public, academics, scientists and professionals are confident in the technologies and agree that they are of benefit to users.

Overall, the use of virtual realities in enhancing the education of children with disabilities is evidently successful as illustrated in research shown in this paper. It is an established method that allows users to become entirely absorbed, to create a sense of feeling that they are alleviated from their disability.

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6. REFERENCES


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