Immersive Visualizations in a VR Cave Environment for the Training and Enhancement of Social Skills for Children with Autism

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Abstract: Autism is a complex developmental disorder characterized by severe impairment in social, communicative, cognitive and behavioral functioning. Several studies investigated the use of technology and Virtual Reality for social skills training for people with autism with promising and encouraging results (D. Strickland, 1997; Parsons S. & Cobb S., 2011). In addition, it has been demonstrated that Virtual Reality technologies can be used effectively by some people with autism, and that it had helped or could help them in the real world; (S. Parsons, A. Leonard, P. Mitchell, 2006; S. Parsons, P. Mitchell, 2002). The goal of this research is to design and develop an immersive visualization application in a VR CAVE environment for educating children with autism. The main goal of the project is to help children with autism learn and enhance their social skills and behaviours. Specifically, we will investigate whether a VR CAVE environment can be used in an effective way by children with mild autism, and whether children can benefit from that and apply the knowledge in their real life.

1 INTRODUCTION

The goal of the project is to design and develop an immersive visualization application in a VR CAVE environment for educating and treating children with mild autism. The main goal of the project is to help children with autism enhance and improve their social skills and behaviors. We address the following research questions:

- Can virtual reality technologies, and in particular the aforementioned application, be effectively involved in enhancing the social skills and behaviors of children?
- Can the immersive visualization application be considered as a new and innovative method of treatment?

Autism is a complex developmental disorder characterized by severe impairment in social, communicative, cognitive and behavioral functioning. It belongs to a group of disorders known as Autism Spectrum Disorder (ASD) and a broader category of pervasive developmental disorders (D. Strickland, 1997).

Autism Spectrum Disorder (ASD) is characterized by impairments in social interaction, social communication and imagination, stereotyped and repetitive behaviors and a resistance to change in routine. Intellectual disability is present in a large proportion of individuals (B. Robins, K. Dautenhahn, R. te Boekhorst, 2005; G. Dawson, 2010; K. Dautenhahn, 2000). Some basic characteristics of people with autism are reduced emotional attachment, absence or abnormal speech, ritualistic behaviors, aggression and self-harm. Typical is also the lack of eye contact (Matson J.L., Matson M.L., Rivet T.T., 2007; C. Lord, 2000), attention deficit, motor incoordination, symptoms of anxiety and depression (E. L. Hill and U. Frith, 2003). In addition some other characteristics are the reduced repertoire of activities and interests, and a tendency of fixation to stable environments (K. Dautenhahn, 2000).

Recent research investigated the use of virtual environments for social skills training, as an augmentation to existing methods and approaches. People with ASDs had the ability to use Virtual Environments (VEs) successfully, and learn simple social skills using the technology. VR technologies provide safe, realistic-looking 3-D scenarios that can be built to depict everyday social scenarios. The possibility of exploring these scenarios in real-time makes them an attractive tool for teaching social

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skills to people with ASDs (S. Parsons, A. Leonard, P. Mitchell, 2006).

Based on information provided by the Cyprus Autistic Association (2009), an interesting treatment method of enhancing social skills are 'social stories'. Social stories is an educational strategy developed by Carol Gray (The Gray Center) which aims to teach people with autism how to carry out some social processes to their daily life through story telling. A social story is presented with the help of pictures in a specific order and shows the performance of an action.

A study (K S. Thiemann and H. Goldstein, 2001) that investigated the effects of social stories, on the social communication of 5 students with autism and social deficits, showed increases in targeted social communication skills when the treatment was implemented. (K S. Thiemann and H. Goldstein, 2001).

In this work, we present the design and development of an immersive visualization application for the treatment of social skills for children with autism which unifies the advantages of the 'social story' teaching method and state-of-the-art technologies and in particular a VR CAVE.

The goal is to develop virtual social stories in an immersive VR CAVE environment which will be used to educate children about some specific social skills. The training will focus on real-life situations which are difficult or impossible to explain to children with the traditional way - pictorial cuing.

For example, consider an unsafe situation or a situation where the child must have an experience of it in order to learn how to act e.g. crossing the road or avoiding cars.

This research is conducted in collaboration/cooperation and support of Cyprus Autistic Association.

The paper is organized as follows: Section 2 presents a brief overview of the state-of-the-art in the area of teaching with the use of virtual environments. Section 3 describes our methodology and in Section 4 the design and development of the application is presented.

2 RELATED WORK

A plethora of work has been conducted in the area. Below we provide a brief overview of the state-of-the-art.

The benefits of using virtual environments as remedial learning environments for children with autism are many. The features of virtual environments which make them suitable as learning tools for children with autism are:

Controlled and safe learning environments: In virtual environments input stimuli can be controlled and the behavior of the child can be monitored. Environments can be customized to account for individual differences. Children can be guided through learning experiences and explore new behavioral opportunities by themselves. Virtual learning environments can provide safe environments, a less dangerous and more forgiving environment for developing skills associated with activities of daily living. In addition, mistakes are less catastrophic compared with the real world (D. Strickland, 1997; K. Dautenhahn, 2000). Tina R. Goldsmith and Linda A. LeBlanc (2004) indicate that some of the most notable benefits of virtual reality are the incomparable control over the environment, and that it may offer highly realistic but safe environment in which to teach skills that are associated with some level of danger when taught in the natural environment (T. Goldsmith, L. LeBlanc, 2004).

Generalization: An important issue and problem of all therapeutic approaches to autism is generalization. It is difficult to the child to generalize the learning experiences and applying the skills to non-classroom situations, even if the child shows improved performance in the classroom. Virtual environments have the benefit to change dynamically, create alternative scenarios or variations, and increase the complexity of scenario very easy (K. Dautenhahn, 2000; S. Parsons, P. Mitchell, 2002). Few modifications across similar scenes may allow generalization. A child with autism who learns how to cross a virtual street, in one scene might generalize to another street scene if the differences are reduced until the similarities are recognizable. (D. Strickland, 1997).

A primarily visual/auditory world: Virtual environments highlight visual and auditory responses rather than other senses such as touch. Such responses effectively involved in teaching abstract concepts to people with autism. Individuals with autism indicate their thought patters are primarily visual (D. Strickland, 1997).

Individualized Treatment: Individuals with autism vary widely in their abilities, strengths and weaknesses. Each individual may even demonstrate wide variation in skills and behavior between different days. Taking this into account, an individualized approach of treatment and training based on a careful, personalized assessment is essential. Virtual environments deemed appropriate considering the ability to change dynamically and be customized based on each individual separately (D. Strickland, 1997; S. Parsons, P. Mitchell, 2002).

Preferred Computer Interactions: The complexity of social interaction can interfere when teaching individuals with social disorders. Human interaction can be so difficult and disruptive that learning is not possible. Children with autism characterized by proactive behavior, they prefer a predictable, structured and in this way 'safe' environment. They prefer to be in 'control' of the interaction and they respond well to structure, explicit, consistent expectations, and challenge provided by computers. Virtual environments are stable, familiar, predictable, and allow children to learn basic social interactions in consistent and accepting way (D. Strickland, 1997; K. Dautenhahn, 2000; S. Parsons, P. Mitchell, 2002).

Embodied Interaction: Virtual environments devices (e.g. VR helmets, hand controls), might be unacceptable for many autistic children, but for others might be appropriate. Approaches which support interactions involving the whole body seem highly promising; set ups where the child can freely move and is not constrained to sitting at a desk and is not required to wear special devices. The use of body and head trackers provides other advantages and possibilities. The movements and actions of an individual can be controlled in a virtual environment, allowing the system to adjust to a patient's actions. A large proportion of individuals with autism never learn to communicate, this allows interactions in virtual scenes without verbal training from a teacher or other controllers (D. Strickland, 1997; K. Dautenhahn, 2000).

Immersion: The sense of immersion refers to the feeling of being part of, or engaged in one virtual scene. Feeling like you are really inside the virtual environment (Parsons S. & Cobb S., 2011). Parsons and Cobb (2011) report that in a research of Mineo (2009) have been compared responses of 42 children with autism to three different electronic media conditions. The thrird condition in which the child engaged directly in activities within an immersive VR, was classified as the most immersive media condition. Children were more engaged with this technology – they spent more time looking at the screen. As the author points out, a further investigation needs to be done, in order to check whether this aspect of VR can be translated into effective instruction and learning. Parsons and Cobb (2011) indicate another study of Wallace (2010), which explored the responses of adolescents with autism to an immersive 'Blue Room' (animations projected onto the walls, no headsets needed). Participants experienced scenes from a street, playground and a school and asked to rate their feeling of 'presence'. Results show positive experiences and that immersive VR has the advantage of allowing realistic and accessible scenes that could form the basis of important social role-play (S. Parsons, S. Cobb, 2011).

A study of Strickland, Marcus, Mesibov and Hogan (1996), showed that children with autism were able and willing to accept and interact within virtual reality worlds. Also demonstrated that children respond to the virtual world in a meaningful way, and tolerated wearing virtual reality equipment. Max and Burke at 1997 demonstrated that the virtual environment improved children's attention and performance across sessions (T. Goldsmith, L. LeBlanc, 2004). S. Parsons and P. Mitchell (2002), conclude that virtual environment is an exciting tool that can extend the existing teaching practices and methods for social skills treatment for people with ASDs. Moreover, it provides a safe and supportive learning environment that succeeds to transfer knowledge between virtual and real world (S. Parsons, P. Mitchell, 2002).

Strickland (1997) investigated the use of Virtual Worlds as a learning tool for children with autism. Two autism children (a seven year old girl and a nine year old boy) took part in the study which consisted of over forty virtual exposures (each less than five minutes). The goal of the research was to help children with autism, cross a road safely. The first part of exposures was to train the child to recognize and track a moving car within a street scene. The second phase was to train the child to find an object and the color of it in the environment, walk to it, and stop. Finally, with the learned skills the child should have the ability to cross a street alone. They used VR helmets for the immersion in the 3D environment, and the results proved that children are able to use them. In addition, the results have demonstrated that children immersed themselves in the virtual scene, were able to track the moving cars and verbally labeled objects and their colors. Also children tracked moving objects with eyes, head and body turning and located objects (signs) and walked towards them. Because of the small number of participants the results cannot be generalized. (D. Strickland, 1997).

S. Parsons, A. Leonard, P. Mitchell (2006), investigated the use of virtual environment for social skills training with two adolescents boys (14 and 17 years old) with ASDs. There are two types of VEs - a bus and a café – both of which were presented to participants on a laptop. Feedback and instructions provided through textual, picture and audible prompts from the program. In both VE scenarios, the user's aim is to find an appropriate place to sit in an empty or busy café/bus and to ask appropriate questions when needed (e.g. if he can sit next to one stranger). Participants take a number of sessions and one session after 3 months, to check whether any new knowledge from the VE had been maintained over the summer school break. Results showed that they had remembered social knowledge gained during their VE sessions, they have a good understanding of the purpose of the VEs and were able to offer examples of how it had helped them now, and could help them in the future. Also, participants seemed to enjoy the VE sessions and showed that they can learn about social 'errors' in a safe way, without any stress (S. Parsons, A. Leonard, P. Mitchell, 2006).

Strickland, McAllister, Coles, Osborne (2007), investigated whether children with ASD would use VR equipment and whether they could learn in a virtual environment. The VR system consisted from a head-mounted display, body trackers, and three-dimensional hand controls. Participants were two children (a girl and a boy, 7 and 9 years old) and were placed in a street crossing virtual scene to learn two basic steps of stopping at a stop sign and tracking moving cars before crossing a street. Before exposure, neither child displayed awareness of street boundaries or demonstrated normal safety actions. While in the virtual environment both children immersed themselves in the scenes, verbally labeled objects and colors of objects, moved their bodies when tracking a moving car, and located a stop sign. The parents of the girl indicated that she did track moving cars in the real world with her head after VR training (D. Strickland, D. McAllister, C. Coles, S. Osborne, 2007).

Parsons and Cobb (2011) refer to studies which suggest that children can learn information from VR and some can transfer this knowledge to the real world. Strickland (2007) developed desktop VEs to teach fire safety skills, like how to recognize the fire danger and how to respond. Eleven out of the 14 children who took part completed the VE session without error. An animated character named Buddy demonstrated proper actions and continually interacted with the child (D. Strickland, D. McAllister, C. Coles, S. Osborne, 2007). Self (2007) developed a fire safety and tornado safety VR training application. Children were able to use the program successfully, but the responses of children varied widely and there was limited evidence of generalization of understanding to real fire and tornado situations. Furthermore, Josman (2008) tested VR as a tool for teaching children with autism to cross the road safely. The results showed that children could use the VE successfully and improve their skills to cross a virtual street during the study. Some of them were able to transfer this learned knowledge to a real street. The authors emphasized that programs need to be carefully targeted according to the individual needs of children (S. Parsons, S. Cobb, 2011).

Parsons and Cobb (2011) stated that nevertheless, the overall scale of the research about VR for educational purposes generally (and supporting social skills specifically), is undeniably limited. Because of the limited scale of research the results characterized as equivocal. The challenge is to translate the VR applications into flexible, workable, useful and realistic tools for everyday classrooms. The authors refer to an interesting find that the more realistic a virtual environment, the more generalization will be achieved. (S. Parsons, S. Cobb, 2011).

3 METHODOLOGY

3.1 Method

This work is conducted in collaboration/cooperation and support of Cyprus Autistic Association. The evaluation is ongoing and preliminary results are promising. The evaluation proceed as follows: a number of children with ASDs took a session using the application in a VR CAVE environment for the training of specific social skills. The engagement and the use of the application by children during the sessions will be measured/ determined which will provide an insight on the effectiveness of the application.

The goal of this research is to design and develop an immersive application in a VR CAVE environment for educating/treating children with autism. The training focuced in situations of real life which are difficult or impossible to explain to children with the known methods of treatment. For example, an unsafe situation or a situation where the child must have an experience of it in order to learn how to act e.g. crossing the road or avoiding moving cars.

The treatment focused on situations where the child will be alone and helpless in an unknown place. Specifically, we developed a scenario where the child wonders off in the city alone ("Lost in city”). He/she should be prepared to stay calm and act accordingly. The child should learn, under the guidance of educator, how to cross the road safely. The training on the scenario splited in various parts so that the child builds step by step the knowledge which is necessary in order to cope with the next part of the treatment. In this way the new knowledge “digested” better and easier and the learned skills could lead to new abilities.

The parts of the training at the scenario, “Lost in city”, executed as follows:

- The child trained to recognize, track, and avoid the moving cars within the virtual street scene
- The child trained to recognize and find the crossing button, walk to it, stop, and press it
- The child learned to recognize the lights and to interprets them
- The child trained to recognize the crossing and walk to it if he can – according to the lights and cars
- The final phase was the most difficult; the child had to cross the street alone without any help.

Figure 2 (a) shows the user in the VR CAVE with the scenario (“Lost in city”). The user can navigate and interact within the virtual environment.

For the evaluation of the application we consider the degree of involvement and use of the application by children during the session. Behaviours, fillings, difficulties, problems, actions or activities of the children recorded and analysed. Also examined whether children were able to accept and use the equipment of the application in the VR CAVE environment.

In addition, taken into account whether children were able to successfully complete the session and whether they succeeded to transfer knowledge from the virtual to the real world. Furthermore educator and parents completed questionnaires. Educator was one of the users during the session. Also, as an expert with children with autism he was able to provided informations that we have not noticed or thought. Parents will be present at sessions, and as knows their children well, so are the most appropriate people to mention things that they observed to their child and they considered as an important.

During the development process of the application a first formative evaluation was conducted with the help of one of the educators of the Cyprus Autistic Association. This evaluation provide guiding feedback for the proper completion of the application. Also we have the opportunity for a second empirical evaluation that was made

Figure 2: (a) User in the VR CAVE, (b) A scene of the crossing learning environment.

a second empirical evaluation that was made towards the end of the development phase with the participation of twelve children (9-10 years old) without autism. This evaluation helped us to evaluate the application as a learning tool for children, and to understand important features which must identified a session in order the training be correct, complete and effective. These features have taken into account in the training of children with Autism.

The results from this evaluation are encouraging. Children learned easily to used and interact with the system and devices without important difficulties or problems. Also, completed the sessions with signs of improvement between the different trials. Children showed samples of excitement, they laugh and smile during and after the completion of the session and gave us to understand that they enjoy the whole experience.

3.2 Equipment

The equipment that we used is the EON REALITY iCube VR CAVE environment where the application run and the 3D virtual world present, the 3D glasses which the participant wears, and the xbox controller that participant or educator uses for the interaction and the navigation in the virtual environment. The participant be in the VR CAVE and interact with the virtual environment through the 3D glasses and the xbox controller. Both 3D glasses and xbox controller have markers on them so that the position and direction of them detect. In this way the virtual environment adjust according to participant’s head movements. For example, if the participant moves his head to see beyond a wall then the virtual environment will be adjusted properly. Also, with the 3D glasses, the participant will be able to see in three dimensions the virtual world. The xbox controller needed for the navigation and interaction in the 3D virtual environment (e.g. navigate and select objects in the scene). The VR CAVE consists of four HD screens, four projectors and cameras.

Figure 3: VR CAVE, glasses, xbox controller.

The screens are placed in such a way that creates a box without a roof and front part (See Figure 3). The participant when use the VR CAVE is within this and with the help of the glasses see the virtual world in three dimensions, all that make user to fully immerse in the virtual environment.

4 DESIGN & DEVELOPMENT

For the design and development of the immersive application in the VR CAVE environment we used the EON Studio Professional for the implementation, Autodesk Maya and 3ds Max for the 3D modelling and animation production. At the implemented scenario ('Lost in City') a crossing learning environment has been developed. At this implementation there is a crossing, with the crossing button and lights and cars that commute in a street of a city (Figure 2 (b)). The child has the opportunity to navigate and interact with the virtual world. The child can press the button at the crossing, wait until cars stop and lights change from red to green and then cross the street.

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6 CONCLUSIONS

The goal of this research is to design and develop an immersive visualization application in a VR CAVE environment for educating children with autism. The training regards on how to cross the street safely.

Can the immersive visualization application in the VR CAVE environment be effectively involved in enhancing the social skills and behaviors of children? Furthermore, it will be examined whether children were able to accept and use the equipment of the application. And, whether children interact in a meaningful way with the environment, and succeeded to transfer knowledge from the virtual to the real world.

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