

Virtual Reality Street-Crossing Training for Children with Autism in Arabic Language

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Abstract— Unintentional injuries poses a serious and life-threatening risk to children with Autism Spectrum Disorder (ASD) so providing them with safety training is essential, and while providing this training in a natural environment can put lives at risk, virtual reality offers a safe alternative. This paper presents the design and application of a Head Mounted Display (HMD) immersive virtual reality system that improves the street-crossing skills of children with ASD. To create the most suitable learning environment, both qualitative and quantitative research methods are used for data collection. A structured questionnaire is employed for all stakeholders, including teachers, specialists and parents being involved in the design process. Semi-structured interviews are used to obtain information from specialists who identify various design principles. These design principles are then assessed and discussed to provide insight into how they might be used in future research.

Keywords— virtual reality, gamification, street crossing, safety skills, autism, ASD

I. INTRODUCTION

According to Centers for Disease Control and Prevention [1], the primary cause of death in children between 1 and 14 years old is unintentional injury. The demographic most vulnerable population to these accidents is children with special needs. A previous study conducted in the United States indicates that children with disabilities are nearly three times as likely to die as a result of road accidents compared to children without any disabilities [2]. The study of [3] indicated that children diagnosed with autism, especially those under the age of 15, appear to be at high risk of dying from unintentional injury. Children with Autism Spectrum Disorder (ASD) have an evolutionary and neurodevelopmental impairment that highly influences their verbal and nonverbal communication, behaviors and social interaction. They are, in other words, often unable to understand others [4]. In addition to these difficulties, one of the most common challenges faced by autistic children is their inability to concentrate and listen for extended periods, with individuals having difficulty directing attention correctly [5]. This presents obvious barriers to daily routines; for example the use of public transport, meeting friends or even buying groceries from the supermarket [6].

To limit unsafe behavior, families with an autistic child often resort to modifying the child's environment [7]. This may be effective for younger children through regular

monitoring and supervision, but it limits their freedom and independence as a price for safety. For older children, however, this strategy is difficult or even impossible, with direct supervision having a negatively effect on their quality of life. The adoption of such strategies may, moreover, reduce their chances of gaining independence and participating in character-forming activities that seem central to their quality of life. It is therefore evident that there is an increasing demand for active interventions and teaching methods that ensure safety while encouraging independence.

Several attempts have been made to teach social skills to children with autism, and most of these attempts have used traditional methods like peer-mediations intervention, video modelling, social stories, cognitive behavioral therapy and others. All these depend on converting knowledge into visual information to enable children with ASD to grasp certain concepts and apply them in the real world. For example, video modelling is utilized for teaching conversation skills to three children with autism in [8], and social stories are used to teach social skills in [9,10,11,12]. These methods help reduce the number of instructions that may be misunderstood by formulating social situations and providing direct information, then following up with appropriate responses. These stories are usually written on paper or through video recordings, but not all social situations can be presented and not all social stories translate into real life. For example, a teacher cannot cross traffic lights in a real-life situation and show children the correct responses [13]. However, these situations can be presented in virtual environments, which provide a safe and manageable setting that can be duplicated and repeated until the children understand the concepts involved.

Computer simulation as an alternative solution to developing pedestrian safety programs has piqued the interest of researchers and therapists. The use of Virtual Reality (VR) as a learning tool for children with autism goes back to [14], an early study that attempts to identify innovative-intervention solutions using computer technology. Researchers have developed a virtual world that simulates the street environment and gives each vehicle a different color. Two children participated in this study, and they asked to report the color of each vehicle by saying it out loud. The results show that both children were able to successfully perform the task, which can be considered a promising start for VR in developing advanced interventions for treating and educating mental disorders.

VR can be defined as an interactive simulation that can be created using computer hardware and software with the aim of providing users with a feeling of immersion in the virtual scene that appears completely similar to the real environment [15]. There is a significant difference between the most common kinds of VR, immersive VR and non-immersive VR. Although they have characteristics that may appear similar, they have different advantages and disadvantages that can be utilized to help children with autism. Immersive VR technologies provide a fully immersive user experience with greater realism and interaction with computer-generated environments [16,17]. On the other hand, the interaction between end-user and computer program in non-immersive virtual reality remains limited to the computer screen. The greater sense of immersion and realism is not available in non-immersive virtual environments, which may not allow attunement to the sensory needs of children with ASD or reduce the chances of transferring experiences to real world [18].

To date, many studies have shown the advantages of VR as an intervention tool for treating and educating autism children. Some studies focus on addressing social aspects [19,20,21], while some studies addressed the emotional side of children with ASD [22,16]. Certain studies indicate that this technology is beneficial for individuals who suffer from behavioral disorders or cognitive disabilities, including autism. In [23], the authors point out that VR is a useful intervention method for children who suffer from impairment in communication and have inadequate verbal skills. Moreover, a study of [24] emphasizes VR's value, highlighting strengths in the provision of motivational learning environments, control and consistency, independence of practice, flexibility, and, in particular, safe and comfortable settings.

The apparent disorders in communication, behavioral and cognitive in autistic children promote researchers, clinicians, and caregivers to recognize the need for effective interventions that improve safety and encourage independence. In Saudi Arabia, for example, services available for children with autism do not meet a high standard, promoting many families to travel to neighboring countries such as Jordan or overseas countries like the United States to access the support they need [25]. The authors in this study [26] suggest an alternative for assisting families with autistic children and this can be identified through the use of technology. The claimed limitation in that study is considered as the motivation that led to conduct this study. This research supports the idea that individuals with autism are at increased risk of accidental death. **Therefore, the main goal of this study is to design and develop of a head-mounted display (HMD) based VR application through gamification to teach children with autism how to cross the street independently.** This kind of environment in which people will be immersed in an interactive experience that is similar to their daily life can teach children diagnosed with ASD social and living skills in a safe and cost-effective environment.

II. RELATED WORK

Children diagnosed with ASD may struggle in imagine how to cross the street when taught via verbal instructions [27]. This has been proven to be especially true for children with ASD [28]. However, emerging computer-assisted technologies such as VR has gained a great deal of attention in a number of studies as an alternative to traditional training

such as disaster awareness [29], emotional and social skills [13], cognitive skills [30], conversation skills [31], and the reduction of disruptive classroom behavior [32]. Such technology allows instructors and therapists to easily change or adjust intervention settings to accommodate children's characteristics.

VR has been recently addressed specifically in teaching safety skills. The authors in [33], designed a virtual road for six children with ASD to test their ability to cross the road safely. Their findings show significant improvement in their ability to cross safely during the experiment. Different study implemented by [34] on 86 children diagnosed with ASD with different age groups, emphasized the potential of virtual environment to improve pedestrian behavior. In [35], VR desktop was developed to simulate a street environment. Six children diagnosed with autism aged between eight and sixteen participated in this study, with a control group of the same age and gender who typically develop. Participants showed improvement in street-crossing skills in both virtually and in real life. In [21], the feasibility of non-immersive VR systems was investigated, where the interaction with the virtual environment is through the screen using the Microsoft Kinect system. The study conducted on seven adults with autism and their caregivers recorded a significant improvement in their street-crossing skills after using the VR platform. To assess the impact of monitoring peer on the behavior of child pedestrians, [36] developed virtual immersive pedestrian environment and around 55 children aged from eight to ten are asked to participate. Their behaviors before and after the experiment are evaluated and the results do not show a sufficient variation in the first evaluation while crossing the street with their peers. However, the child who observed their peers crossing the road in risky fashion subsequently crossed into more serious gaps between vehicles than those in the control group.

Finding of previous studies highlight the potential of VR in helping autism children cross street in real world. One of these studies [32], was performed on three children who met nine criteria, the most important of which is the child's ability to wear HMD. Three of the participants aged between four and ten have high-functioning ASD. To evaluate the performance, three steps should be completed: the first is to respond by moving the head in both direction, while the second and third involve asking questions about nearby traffic and the safety of proposed crossing. The results indicate that participants mastered street crossing in both VR and real world.

Based on these results, VR has been shown to have a positive impact on autistic children's ability to acquire street-crossing skills without danger of injury. In [37], the authors emphasized that more research on the efficiency of VR as a training tool is necessary: since autism is a widespread disorder, each case will have unique characteristics and it is therefore important not to generalize such that other perspectives on VR requirements for children with ASD are ignored. The involvement of teachers, parents and caregivers in the VR's design would be a step in the right direction.

Another limitation lies in the simple design of the VR environments, with those used in the aforementioned studies failing to express the variability and dynamism of the real world. In this paper, we attempt to provide a 'best practices' guide for a better application design by taking multiple stakeholders' views into account and creating a more dynamic environment. Most of the previous studies implemented the

VR street-crossing environment in the English language; our contribution will be beneficial to autistic children in the Arabic-speaking world.

III. METHODOLOGY

To better understand the research problem and discovering the real situation of autism children in Saudi Arabia, this study adopts a mixed method approach where both quantitative and qualitative methods are used. Based on a literature review of the previous VR studies that targeting individuals with ASD, we identify different factors that were considered as the common design specification. Moreover, a structured questionnaire is used as a primary source to collect information from the target sample included specialists, teachers, and parents of autism children across Saudi Arabia to identify skills autistic children tend to lack. The secondary source comprises semi-structured interviews devised to establish the main requirements for the design process.

A. Questionnaire

The questionnaire was distributed electronically at the beginning of the study to ensure it reached a significant section of the target sample. This section comprises 122 participants in total. 66.7% of those are parents with autistic children and 23.4% are teachers of autistic children, with the balance constituting specialists. One of the questions asks, ‘Do you see that children with autism in Saudi Arabia receive proper care?’. 62.5 % responded negatively to this, with 31.9% being neutral and 19.3% responding positively. When parents were asked about the methods and technology they used for their children at home, a number of them referred to educational games like puzzles, watch exercises and tutorials on YouTube.

Moreover, specialists, teachers and parents have been asked about specific tasks for which they believe autistic children need VR training. ‘Practice safety rules when traveling, such as crossing the road’ was the most popular choice with 79.3%. ‘The child needs training to encourage him greeting others’ was supported by 67.5% and 65.6% agreed with ‘The child needs training to perform some tasks such as arranging the bed and dining table’. ‘The child needs training on how to deal nicely with others such as asking for help and giving thanks’ was the least popular, as shown in Fig. 1.

To support the research and view the issue from the participants' perspective, the following question was asked: ‘Do you think a virtual environment that simulates real-life is useful to train autism children?’. The responses showed that 78.8% support this idea but that 14.8% think the impact of VR would not be significant. 6.6% do not agree.

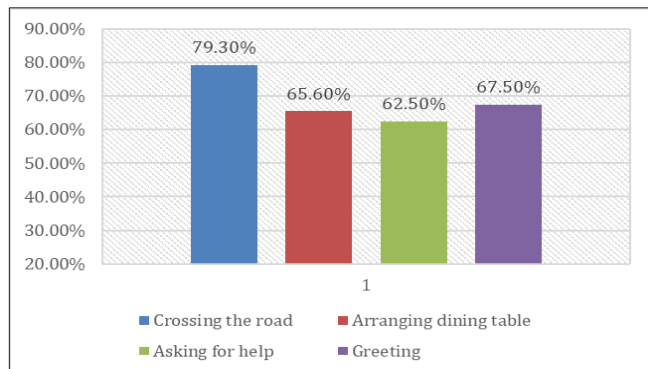


Fig. 1. Tasks need to be training through VR.

B. Interview

In order to engaged specialists in the design process, several interviews were conducted with Jeddah Autism Center [38], a center for children diagnosed with ASD. Five specialists collaborated in this study, all of them familiar with the day-to-day lives of those children.

The authors presented different scenarios to improve social, behavioral and safety skills for autism children. **One of these scenarios intended to train children to cross the street by allowing them to imitate a virtual avatar while following instructions.** Based on the data gathered from participants, this is the scenario on which VR should most concentrate. As crossing the street is a significant part of a child's daily activity, the specialists affirmed that this would have a positive impact on the children’s independence and, by extension, their self-confidence and ability to interact with others. The specialists strongly supported the idea of training via a VR application and they were willing to use this kind of technology.

Wherefore, a variety of requirements for the design and implement the VR application were discussed. The specialists recommended a clear, simplified and straightforward environment that takes appropriate learning techniques into account. Various learning techniques have been used at the center. Each technique was briefly illustrated during the interview, an example being Applied Behavior Analysis (ABA) [39]. Another example is the Picture Exchange Communication System (PECS) [40]. Treatment and Education of Autism and Communication related handicapped Children (TEACCH) [41] is used, too.

Along with the design process, the specialists indicated that mental age (cognitive skills) is a measure that must be considered where autistic children are concerned. They also explained that children with ASD often have difficulty processing verbal instructions and that any such instructions must be concise, univocal and preferably include visual cues for clarification. Previous literature [42], addressed more than 20 guidelines, with consideration given to flexibility, simplicity, the highlighting of key words, the avoidance of distraction, the dividing of tasks, the giving of instructions, the provision of realistic stimuli and so on. These authors propose to further encourage the education of autistic children through gamified features. Based on previous literature and interviews with specialists, this study sets out an attractive scenario to develop VR street-crossing applications through gamification.

IV. STREET-CROSSING TRAINING IN VR ENVIRONMENTS

The training application was developed using a desktop platform, mobile device and Xiaomi VR HMD (see Fig. 2).

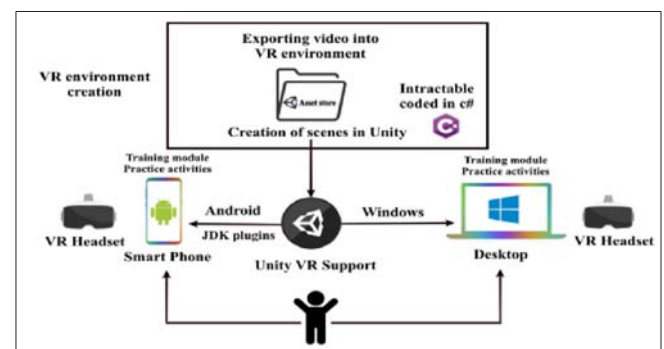


Fig. 2. The proposed VR environment.

The entire environment chooses to be compatible with Android smartphones. Tool and the controller, which acts as an assistive tool to control functioning, navigate and select objects in the scene, have been used. Unity 3D and C# scripts were designed to be compatible with Xiaomi VR HMD to allowing users to move through 3D a virtual environment.

The environment includes a street, a sidewalk and a crosswalk, all in an Arabian setting. A skyscraper can be seen in the background, as can some billboards and the child is represented by a 3D avatar that moves between them. According to the advice given by the specialists, all aspects of the virtual environment were made simple and clear. The child must stand on the sidewalk aligned with the crosswalk to press the start button (see Fig. 3).



Fig. 3. The street, sidewalk, crosswalk, buildings and start button.

Four visual instructions will be visible on the instructional box, including stop, wait, check for traffic and finally cross the street (see Fig. 4). This supports the significance of providing visual instruction, as highlighted by specialists.



Fig. 4. Instructional box of guidelines.

According to [43], Peer-mediated instruction and intervention strategies will be considered as successful way to engaging autism children in social communication. In this training, a 3D avatar of a child named Anas will be presented as a virtual pair in a virtual environment that will mimic the role of the pair in the real world. He will direct the child to follow the instructions until he finishes the tasks properly.

The child should follow the floating arrow and stand nearest to the avatar. The avatar will then look both left and right twice to check there are no cars approaching, as shown in Fig. 5.



Fig. 5. The avatar instructs the child to look to both sides and crosswalk light.

When the light goes green, an instructional box will notify the child that Anas is now crossing the street (see Fig. 6).



Fig. 6. Instructional box to notice the child.

The avatar will then cross the street along the crosswalk. Once it reaches the opposite sidewalk, the second scene will begin and the instructional box will notify the child that it is their turn to cross.

In accordance with learning theories, the authors have chosen the TEACCH technique considered as the best suited to the current training. TEACCH mainly a visually coordinated system designed to promote the ability of people with ASD to know what has to be completed first (or next) and understanding the relationship between steps and what the result should look like [44]. Consequently, the child should repeat what the avatar did before. Another instruction will be shaped with a visual representation as a floating arrow to allow a child to walk towards it (see Fig. 7).



Fig. 7. The visual arrow helping the child to follow instructions.

Once the child imitates an avatar perfectly and reaches the designated arrow, they will receive stars and hear clapping as a reward. If the child fails to cross streets safely, they will return to the starting point and make another attempt. This scenario aims to guide the child through street-crossing and repeat the experience until mastery is achieved.

V. CONCLUSION AND FUTURE WORK

Children with autism appear to be at greater risk of becoming victims of road accidents. Notably, 1 in 50 children is a diagnosis with ASD [45], which emphasizes the importance of developing training to teach them safe street-crossing behavior. This study therefore presents the use of the VR application to train and improve social skill deficits, particularly safety skills, seen in children with ASD.

In general, street crossing is a part of a child's day-to-day life. The authors in [46] point out that teaching autism children to cross streets safely would increase their ability to move independently and thus improve their self-confidence. This supports the suggestions highlighted by specialists in the current work. With the help of two disciplines, computer science and psychopedagogy, designing and developing a game as a learning tool for this group requires the involvement of experts. Previous studies corroborate this point: for example, [47] stated that stimulating use of VR facilities should be based on open dialogue between teachers, parents and students. In this study, the design process includes specialists, teachers and parents, all of whom agreed that virtual environments were an ideal tool for teaching safety skills to children with ASD. This is particularly true if the children have never practiced crossing streets in a real environment. Moreover, they made some suggestions and essential practices to must be taken into account, including:

1) *Encouragement*: Reward systems, like stars and clapping sounds, offer a motivation for individuals with ASD. Specialists state that children are not being encouraged to complete their tasks properly in real life. The inclusion of encouragement in these virtual environments may improve this situation.

2) *Clarity of the Instructions*: The instructions must be obvious to avoid varying interpretations by children with ASD. Moreover, the human voice must provide a better understanding of instructions than written or computer-generated voices. As the specialists have requested, we will move all instructions from written to vocal.

3) *Brief Prompts*: Autistic children struggle to follow directions and instructions properly. These instructions must therefore be short and divided into multiple tasks.

4) *Repetition*: Repetitive tasks will allow children to learn in an environment where mistakes can occur with no negative consequences. This tool has been designed to provide safe and valuable training.

5) *Realism*: The virtual environment should be designed in such a way that children feel immersed, and that it resembles the real-life environments they will later encounter.

In conclusion, the aforementioned practices will provide valuable insight for future research. Furthermore, this scenario needs to be tested in order to gain the results of users' experiences about the usability of street-crossing application.

ACKNOWLEDGMENT

The authors would like to thank all participants in the survey and the overall study; their feedback has greatly assisted the paper. They would also like to express their deep gratitude to Jeddah Autism Center, for their cooperation throughout this study.

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