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Virtual reality technology to support the independent living of children with autism

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ABSTRACT

Many designed systems have shown the potential of virtual reality (VR) to greatly transform autism treatment studies. Indeed, the literature shows that treatment via VR is appropriate for effective and repeatable training, without the intense anxiety, allowing trainees to recognize and modulate errors as they occur. This study evaluates the effectiveness of a new VR-based learning environment designed to safely practice and rehearse the daily activities related to the school world in children affected with autism. A total of nine children with autism actively enrolled in the study to learn and test their street crossing skills and social attention. Incremental change of difficulty levels has been added to the designed environment to generalize real-world situations, this includes overlaid distraction audio and increased vehicles intensity and speed. In order to enhance the learning experience, the real-time feedback is given according to the participant's behavior, additionally, post processing profile is given for analysis purpose, where the participant's behavior can be reviewed by parents and therapist to determine whether the participant's mistakes are in decision making or focusing attention. The Wilcoxon signed-rank test for a single sample was used to test the change in the skills of participants with autism after using the educationally and therapeutically VR technology compared to a baseline. As a result, significant effects were found on the behavioral measures indicating that the VR-based learning environment is promoting a positive and informative learning environment.

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1. INTRODUCTION

Autism spectrum disorder (ASD) includes conditions that were previously thought to be separate illnesses, these conditions include: autism, Asperger's syndrome, childhood disintegrative disorder and unspecified form of pervasive development disorder [1]. According to the American Psychiatric Association (APA) ASD refer to a group of neurodevelopmental disorders that involve a delay in the development of many basic skills and functions [2]. This is not just a single disorder but, in fact, a group of closely related disorders that have a common core set of symptoms. Social issues are one of the most common symptoms throughout all the different types of ASD, as every individual on the autism spectrum has some degree of predominant difficulty with social interaction, communication, empathy and flexible behavior.

The prevalence of ASD is estimated to affect about 62.2 million globally as of 2015. Although ASD begins in early childhood, when symptoms usually are seen by the age of two years, eventually these symptoms last throughout an individual's lifetime. For individual with ASD, the impairments can make life very challenging to how conduct crucial activities of daily living. Yet, there is no cure for this disorder, but early intensive therapy can significantly improve the lives of many children. The goal of treatment is to develop the ability of the child to function by reducing symptoms and supporting learning and development. Treatment options contain therapy such as communication and behavioral therapy, family therapy, speech therapy and educational therapy. Overall, the type of therapy depends on the child's need [3]–[5].

In recent years, different studies have stated that the virtual reality (VR) intervention can be used across different applications in order to improve social skills in children with ASD. The review in [6] has carried out an evidence-based systematic review about the effectiveness of VR for children with ASD. The review has addressed thirty-one research papers contribute to the improvement of activities in daily life and communication for children with ASD, these activities include: social, emotional, daily living, communication, attention, physical and phobia.

The term VR applies to "computer technologies that use interactive software to generate realistic images, sounds and other experiences that mimic a real-world context" [7]. In a broader sense, VR is a trending term that revolutionizes the present and the future by creating new interactive experience. VR has emerged as an innovative new approach in different areas such as healthcare field for rehabilitation and treatment [8], [9], education field for learning and teaching [10], [11], also in business field for employee training and product development [12].

Specifically, VR-based therapy is being used to develop the skills of autistic children for independent living. Comparatively, VR intervention offers several benefits compared to traditional intervention [13]. First, it can provide safe environment to practice a number of social scenarios in an iterative manner [14]. Second, it can provide supportive environment to make social mistakes in challenging interaction scenarios in a less-anxiety feelings [15]. Finally, it can provide stimulating and rewarding environment to satisfy the individual's needs [16], [17].

In recent few years, since 2015, different solutions have been used to train safe street crossing skills through the use of VR among children with autism. In this paper, we develop such a fully immersive environment that will generalize to real-world situations, where autistic children become accustomed to safely practice and rehearse their daily activities related to the school world. In this environment, the autistic children will be actively involved to learn and test their street crossing skills and social attention, and real-time feedback is given accordingly to enhance the learning experience.

This paper is organized as follows. Section 2 presents the background of existing safe street crossing training approaches in virtual environment. Section 3 is the development of the VR learning and testing environment. Section 4 discusses about the application evaluation and results. Section 5 summarizes how the research objectives being achieved, its contribution and future works.

2. RELATED WORKS

Lately, some VR-based studies are oriented toward the safe independent living for autistic children, such as cross street safely [18], as most of serious injury and death may be caused by traffic accidents, due to pedestrian limitations of traffic knowledge, perceptual, and conscious. Therefore, in this section, a number of related works, which are based on different technology for planning pedestrian safety, are reviewed in general.

A study [19] was conducted to evaluate several methods which could enhance learning environment. These methods are varied from demonstrating educational videos and board game, basically, applying classroom activities which are based on street intersections model and a doll to demonstrate the actual reality, and providing some real practices in a protected street-environment. The study concluded that the most factors that could affect the teaching procedure are reinforcement, prompting, and role-playing.

Other studies were conducted to evaluate the effect of interactive multimedia programs to educate children on how to distinguish the dangerous situations when crossing the street. The main idea of these programs is to demonstrate real life situation to the children in a safe way by teaching them some of the critical skills that are necessary to cross the street safely. The results of these studies indicated that these kinds of programs may increase the efficiency of educating children the proper way to cross the street under several circumstances. They also suggested integrating the behavioral-intervention strategies along with awareness training to enhance the effectiveness of these kinds of the programs [20], [21].

Moreover, the study in [22] was discussed the VR effects of teaching persons with ASD some pedestrian skills by providing them a path with signs to guide them on how to cross the street using the shortest path. Other studies have discussed the effect of VR on educating persons with ASD these skills by using VR learning facilities. These facilities supposed to educate persons with ASD on how to cross the street by demonstrating a protected real-life environment [23]–[25]. The main conclusion of these studies indicated that VR may play a significant role in educating persons with ASD the way of how they should cross the street safely.

In a recent study [26], some VR facilities have been applied on the experiment to teach three children with ASD how to cross the street safely. The results of the experiment showed that VR plays an important role on teaching how to cross the street in efficient way. Additionally, the study suggested that VR facilities need to be improved to provide more effective tool for teaching these children the proper way of how to safely cross the street, along to other safety skills.

One more study [27] was also conducted to evaluate the role of VR in how to educate children with ages ranging from 5 to 14 years old, on how to safely cross the street. The study applied an experiment on these children starting with observing those crossing real streets, then educating those using VR facilities to analyze the effectiveness of VR teaching on them. After involving these children in VR cross-street education course, they observed them again while they were crossing real streets. They compared the results of the tow observation and they concluded that, VR course enhances the abilities for the children to cross the street safely with a variety of enhancement related to the children ages. Based on the above-mentioned related works in this area, our contribution in this work is developing together a VR-based training and a VR-based testing environment, with a sufficient sample of participants conducted the study of using the developed system. Besides, post processing profile of participants will be available for analysis purpose.

3. RESEARCH METHOD

We conducted a study of nine children with ASD using the developed system to test our hypothesis. The developed system involved multiple phases. The phases including VR-based learning practice, VR-based test practice, and finally, VR-based tour practice.

3.1. Participants

Nine children with ASD ranging in age from 8 to 11 years (Mean 10.3 years, standard deviation 1.15) involved in this study. The group included 3 females and 6 males. All children had similar initial levels of daily life skills and their parents confirmed that they are totally dependent children and in need of supervision.

3.2. Settings and materials

We developed the virtual city environment based on unity platform [28], which is one of the most widely used technologies that are created for games and VR development purpose in the first place. It can help developers create three-dimensional graphics as well as animations that offer visual and functional effect. In this paper, the developed virtual city environment was designed with vast array of buildings, streets, transportation, people, trees, flowers, and rocks to add variety into scenes and to create more native feel to the environment. Picture from this environment is presented in Figure 1.

The developed VR training and testing environment viewed on a 15-inch LCD monitor. The child behavior was tracked using Google Cardboard. Head motion-capture technology was incorporated using Google cardboard to capture and project the child’s head and movements into the virtual environment. All nine participants were required to use a device like a thick pair of goggles called Google VR headset (Gvr headset) to access positional tracking features alongside a pair of headphones to enhance their simulated experience of being in another world. In this technology, two pointers were used, one called Google VR reticle pointer (Gvr reticle pointer) which is used for the pointer and reticle to follow the user’s gaze (using for interaction with the environment), and second one called Google VR base pointer (Gvr base pointer) which provides methods called on pointer interaction with in-game objects and user interface (UI), trigger events, and “BaseInputModule” class state changes. In this paper, smooth workflow was conducted in multiple phases; each phase is discussed in turn.

3.2.1. VR-based learning practice

A conceptualization video was produced to depict a rendition of the street beyond the school world. This video tends to be primarily educational material to educate the viewer on specific instructions to cross the street accompanied by traffic lights as pre-activity demonstration. Traffic lights are positioned at road intersections and pedestrian crossings to be integrated into the 3D modelling for simulating flow of traffic and pedestrians. Different situations to cross the street were shown either safe or unsafe situation. Also, additional distraction audio was laid over the video to serve as arousal level control and barrier of attention.

3.2.2. VR-based test practice

In reflecting upon the learning and training outcome followed in the previous phase, it is clear that there is need to bring gaining training ideas to practice in a context beyond the school world. Therefore, in this phase, the children will be actively involved in fully immersive VR environment that simulates the world of outer school. The child was represented by an avatar being to examine the street crossing, and the behaviors that are being recorded are: i) what is the standing point on the sidewalk and distance from the crosswalk; ii) whether the participant is looking left and right; iii) how the child responded to the traffic light; and iv) how long it takes for the user to respond and cross the street.

After first round of crossing the street, incremental change of difficulty was then added to determine the child behavior to cross one more intersection as a second round. This round included overlaid distraction audio, as sounds of pets, lawn mowers and vehicles trumpet. In addition to increase in pedestrians and cars intensity, also higher cars speed. These two rounds allowed us to get anecdotal data pertaining to the participants' reactions to the different situations.

3.2.3. VR-based tour practice

In this phase, the participant rides the virtual school bus, and the behaviors that are being recorded are: i) social interaction, ii) the right seat selection, and iii) using the bus stop signal. As a sequence of aforementioned phases as shown in Figures 2 to 4, after the training in the first phase, the participant will be simply asked to login to the model in order to record the responses outcome of the remaining two phases.

Figure 1. Screenshot of the virtual environment used in the study

Figure 2. Screenshot of the virtual learning environment

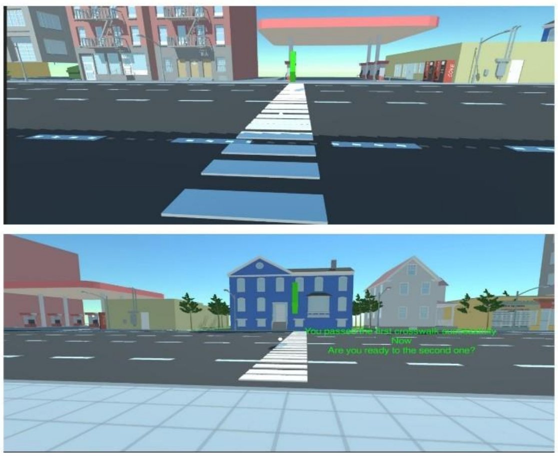

Figure 3. Screenshot of the virtual street crossing environment

Figure 4. Screenshot of the virtual tour

It is worth to mention that the user's access history is archived in the database. So that, it can be used as post processing profile for analysis purpose, where the information can be reviewed and analyzed by the child, parent, and professionals. Children may also be able to see their own success and weaknesses whether it is in decision making or focusing attention. The user's progress can be followed over time to see which skills have improved and which skills still need develop. Parents and therapists can review the behavior with the child and point out more appropriate responses and/or behaviors, promoting a positive and informative learning environment.

4. RESULTS

All nine participants with ASD completed the designated VR-based daily living tasks. The performance of all participants is reported in Table 1, in which we compare the baseline score and the post intervention score. The Wilcoxon signed-rank test [29] for a single sample was used to test the change in the skills of participants with ASD after using the educationally and therapeutically VR technology compared to a baseline. The Wilcoxon signed-rank test uses the sum of the signed ranks as the test statistic W.

$$W = \sum_{i=1}^{N} [sgn(x2, i - x1, i). Ri] \quad (1)$$

Table 1. Differences within the participants before and after VR

Participant number	Baseline score	Post intervention score	Difference (Before-After)	Difference|	Rank	Negative signed rank	Positive signed rank
1	16	15	-1	1	1.5	1.5	-
2	17	20	3	3	3	-	3
3	7	14	7	7	7.5	-	7.5
4	8	15	7	7	7.5	-	7.5
5	13	14	1	1	1.5	-	1.5
6	12	17	5	5	5.5	-	5.5
7	5	10	5	5	5.5	-	5.5
8	7	7	0	0	-	-	-
9	10	14	4	4	4	-	4
						W1=1.5	W2=34.5

Based on the results which are tabulated in Table 1, we find that W- is 1.5 and W+ is 34.5, and so the smaller of these values is the test statistics T. Here we use α (the significance level)=.05 and N=8 (the nine subjects excluding the subject number eight where the difference value is zero), hence from the Wilcoxon signed-ranks table shown in Table 2, the critical value Tcrit for the T statistic is 3. Since T statistic=1.5 is less than Tcrit=3, clearly, this is sufficient evidence to suggest that there is a difference between the two measurements scores in terms of daily living tasks improvement. For this test we use the following hypotheses:

- *H0*: There is no difference between the following baseline and the post intervention.
- *H1*: There is a difference (the median change was non-zero).

From statistically standpoint, as we have statistically significant evidence at α=0.05, we can reject the null hypothesis H0 and accept the research hypothesis H1, and so conclude the VR-based training efficacy in developing the daily life skills among autism's children.

Table 2. Critical values of T for a two-tailed test

N	Two-Tailed Test	
	α=0.05	α=0.01
5	--	--
6	0	--
7	2	--
8	**3**	0
9	5	1
10	8	3

4. CONCLUSION

This paper presents VR-based learning environment, which provides opportunities for children with autism to develop necessary daily living skills in a safe and controlled environment. We effectively demonstrated fully immersive VR environment that simulates the world of outer school. In this regard, three phases sequentially were demonstrated; including: VR-based learning practice, VR-based test practice, and VR-based tour practice. Future studies will explore the effectiveness of VR technology through a larger sample and to children with autism younger than 8 years, also, VR intervention could be extended to more general skills, such as conversational and physical skills.

REFERENCES

[1] O. Ousley and T. Cermak, "Autism spectrum disorder: defining dimensions and subgroups," *Current Developmental Disorders Reports*, vol. 1, no. 1, pp. 20–28, Mar. 2014, doi: 10.1007/s40474-013-0003-1.

[2] American Psychiatric Association, *Diagnostic and statistical manual of mental disorders*. American Psychiatric Association, 2013.

[3] J. Baio *et al.*, "Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States, 2014," *MMWR. Surveillance Summaries*, vol. 67, no. 6, pp. 1–23, Apr. 2018, doi: 10.15585/mmwr.ss6706a1.

[4] C. Colombi and M. Ghaziuddin, "Neuropsychological characteristics of children with mixed autism and ADHD," *Autism Research and Treatment*, vol. 2017, pp. 1–5, 2017, doi: 10.1155/2017/5781781.

[5] J. A. Walsh, S. E. Creighton, and M. D. Rutherford, "Emotion perception or social cognitive complexity: what drives face processing deficits in autism spectrum disorder?," *Journal of Autism and Developmental Disorders*, vol. 46, no. 2, pp. 615–623, Feb. 2016, doi: 10.1007/s10803-015-2606-3.

[6] P. Mesa-Gresa, H. Gil-Gómez, J.-A. Lozano-Quilis, and J.-A. Gil-Gómez, "Effectiveness of virtual reality for children and adolescents with autism spectrum disorder: an evidence-based systematic review," *Sensors*, vol. 18, no. 8, pp. 1-15, Aug. 2018, doi: 10.3390/s18082486.

[7] Myeung-Sook Yoh, "The reality of virtual reality," in *Proceedings Seventh International Conference on Virtual Systems and Multimedia*, pp. 666–674, doi: 10.1109/VSMM.2001.969726.

[8] M.-L. Bird *et al.*, "A randomized controlled trial investigating the efficacy of virtual reality in inpatient stroke rehabilitation," *Archives of Physical Medicine and Rehabilitation*, vol. 98, no. 10, p. e27, Oct. 2017, doi: 10.1016/j.apmr.2017.08.084.

[9] S. Albiol-Pérez, J.-A. Gil-Gómez, M.-T. Muñoz-Tomás, H. Gil-Gómez, R. Vial-Escolano, and J.-A. Lozano-Quilis, "The effect of balance training on postural control in patients with parkinson's disease using a virtual rehabilitation system," *Methods of Information in Medicine*, vol. 56, no. 02, pp. 138–144, Jan. 2017, doi: 10.3414/ME16-02-0004.

[10] Y. Slavova and M. Mu, "A comparative study of the learning outcomes and experience of VR in education," in *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, Mar. 2018, pp. 685–686, doi: 10.1109/VR.2018.8446486.

[11] G. Taxén and A. Naeve, "A system for exploring open issues in VR-based education," *Computers & Graphics*, vol. 26, no. 4, pp. 593–598, Aug. 2002, doi: 10.1016/S0097-8493(02)00112-7.

[12] D. Andone and M. Frydenberg, "Creating virtual reality in a business and technology educational context," in *Augmented Reality and Virtual Reality*, Springer International Publishing, 2019, pp. 147–159.

[13] N. Didehbani, T. Allen, M. Kandalaft, D. Krawczyk, and S. Chapman, "Virtual reality social cognition training for children with high functioning autism," *Computers in Human Behavior*, vol. 62, pp. 703–711, Sep. 2016, doi: 10.1016/j.chb.2016.04.033.

[14] M. R. Kandalaft, N. Didehbani, D. C. Krawczyk, T. T. Allen, and S. B. Chapman, "Virtual reality social cognition training for young adults with high-functioning autism," *Journal of Autism and Developmental Disorders*, vol. 43, no. 1, pp. 34–44, May 2012, doi: 10.1007/s10803-012-1544-6.

[15] M. Maskey, J. Lowry, J. Rodgers, H. McConachie, and J. R. Parr, "Reducing specific phobia/fear in young people with autism spectrum disorders (ASDs) through a virtual reality environment intervention," *PLos One*, vol. 9, no. 7, Jul. 2014, doi: 10.1371/journal.pone.0100374.

[16] S. Parsons and P. Mitchell, "The potential of virtual reality in social skills training for people with autistic spectrum disorders," *Journal of Intellectual Disability Research*, vol. 46, no. 5, pp. 430–443, May 2002, doi: 10.1046/j.1365-2788.2002.00425.x.

[17] C. A. da Silva, A. R. Fernandes, and A. P. Grohmann, "STAR: speech therapy with augmented reality for children with autism spectrum disorders," in *Enterprise Information Systems*, Springer International Publishing, 2015, pp. 379–396.

[18] J. D. Westwood *et al.*, Eds., *Medicine meets virtual reality 21*. IOS Press, 2014.

[19] D. R. Dixon, R. Bergstrom, M. N. Smith, and J. Tarbox, "A review of research on procedures for teaching safety skills to persons with developmental disabilities," *Research in Developmental Disabilities*, vol. 31, no. 5, pp. 985–994, Sep. 2010, doi: 10.1016/j.ridd.2010.03.007.

[20] A. Glang, J. Noell, D. Ary, and L. Swartz, "Using interactive multimedia to teach pedestrian safety: an exploratory study," *American Journal of Health Behavior*, vol. 29, no. 5, pp. 435–442, Sep. 2005, doi: 10.5993/AJHB.29.5.6.

[21] J. A. Miller, J. Austin, and D. Rohn, "Teaching pedestrian safety skills to children," *Environment and Behavior*, vol. 36, no. 3, pp. 368–385, May 2004, doi: 10.1177/0013916503260880.

[22] H. Mengue-Topio, Y. Courbois, E. K. Farran, and P. Sockeel, "Route learning and shortcut performance in adults with intellectual disability: A study with virtual environments," *Research in Developmental Disabilities*, vol. 32, no. 1, pp. 345–352, Jan. 2011, doi: 10.1016/j.ridd.2010.10.014.

[23] T. R. Goldsmith, "Using virtual reality enhanced behavioral skills training to teach street-crossing skills to children and adolescents with autism spectrum disorders," Western Michigan University, 2008.

[24] N. Josman, H. M. Ben-Chaim, S. Friedrich, and P. L. Weiss, "Effectiveness of virtual reality for teaching street-crossing skills to children and adolescents with autism," *International Journal on Disability and Human Development*, vol. 7, no. 1, Jan. 2008, doi: 10.1515/IJDHD.2008.7.1.49.

[25] M. Saiano *et al.*, "Natural interfaces and virtual environments for the acquisition of street crossing and path following skills in adults with autism spectrum disorders: a feasibility study," *Journal of NeuroEngineering and Rehabilitation*, vol. 12, no. 1, Dec. 2015, doi: 10.1186/s12984-015-0010-z.

[26] D. R. Dixon, C. J. Miyake, K. Nohelty, M. N. Novack, and D. Granpeesheh, "Evaluation of an immersive virtual reality safety training used to teach pedestrian skills to children with autism spectrum disorder," *Behavior Analysis in Practice*, vol. 13, no. 3, pp. 631–640, Sep. 2020, doi: 10.1007/s40617-019-00401-1.

[27] O. Bart, N. Katz, P. L. Tamar, W. W. Josman, and N. Josman, "Street crossing by typically developed children in real and virtual environments," in *2006 International Workshop on Virtual Rehabilitation*, 2006, pp. 42–46, doi: 10.1109/IWVR.2006.1707525.

[28] *Unity 2021.1b*. (2021). Unity. Accessed: January 10, 2021. [Online]. Available: https://unity3d.com/beta/2021.1b

[29] B. Rosner, R. J. Glynn, and M.-L. T. Lee, "The wilcoxon signed rank test for paired comparisons of clustered data," *Biometrics*, vol. 62, no. 1, pp. 185–192, Mar. 2006, doi: 10.1111/j.1541-0420.2005.00389.x.

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