A Review of Virtual Reality Applications in Education for Children with Autism Spectrum Disorders: A 2013-2022 Analysis

Mai Thi Phuong[1], Ngo Thuy Dung[2], Tran Thu Giang[3]

[1]phuong.mt@vnies.edu.vn, [2]dungnt@vnies.edu.vn, [3]giangtt@vnies.edu.vn,
The Vietnam National Institute of Educational Sciences (Vietnam)

ABSTRACT

Scientific technology is increasingly developing, and the application of virtual reality in education for children with disabilities generally and children with autism spectrum disorders particularly is also increasing enormously. By reviewing 18 studies that have been published in prestigious international journals between 2013 and 2022, it is found that 1) most of the studies bring good results, users are satisfied and well adapted to virtual reality software; 2) studies aimed at supporting social skills education for children with autism spectrum disorders are focused more than ones in other fields; 3) several studies have shown that the application of virtual reality should also be applied together with other therapies for optimal effectiveness; 4) in order to confirm the effectiveness clearly, studies on large samples and longer duration are needed. Then, the paper proposes that there should be studies on building or applying existing virtual reality software in the education of children with autism spectrum disorders in Vietnam.

KEYWORDS: *virtual reality, autism spectrum disorders, cognitive skills, social skills, communication skills*

1. Introduction

Autism spectrum disorder (ASD) has been increasing at a speedy rate worldwide and in Vietnam. According to statistics from the US Centers for Disease Control (CDC), from 2000 to 2016, ASD has been rising rapidly; in 2000, there was 01 in 150 children, and by 2016, there was 01 in 54 children. Another UK study also found that ASD rates are on the rise. Previous estimates of autism prevalence in the UK by the University of Cambridge, and based on a school survey, found that 01 in 64 children (1.57%) has autism. By 2021, this rate has reached 1.76%, meaning 01 in 57 children (Roman-Urrestarazu et al., 2021). In the study of Nguyen et al. (2014), based on the synthesis of qualitative and quantitative studies, the research team made a forecast that the number of children with ASD in Vietnam will continue to increase rapidly in the coming years as public awareness and criteria for autism are expanded. In the study by Tran et al. (2017), the rate of children with ASD in Vietnam ranges from 0.5 to 1%.

Since "autism" was officially named until now, there have been many studies on methods and measures for this disability because they have many defects. The most typical aspects are social interactions and stereotyped, rigid behaviours and hobbies (APA, 2013). Today, when science and technology are developing more and more,

scientists have also applied technology to education for this subject, that is, using Virtual Reality (VR) technology. The advantage of VR is that Virtual Environments are the ideal place to impart the skills needed for independence before encouraging children with ASD to practice these skills in the real world and gain real-world experience (Parsons et al., 2004; Cai et al., 2017), strengthen skills and improve quality of life for children with disabilities (McComas, Pivik, & Laflamme, 1998), and teach skills living independently (Strickland et al., 1996; Mitchell et al., 2007).

This paper aims to review studies using VR technology to educate children with ASD in the period from 2013 to 2022, thereby seeing the benefits that VR brings. This will be one of the foundations for conducting research on developing software or applying VR technology for children with ASD in Vietnam.

2. Research methods

This paper uses the method of literature review and analysis. First, the authors conducted a synthesis of studies at Google scholar with the phrases: "virtual reality", "children with autism spectrum disorders", "using virtual reality to educate autistic children", and "technology 4.0 in educating children with autism". Results of the search strategy are presented in Fig. 1. The keyword database search identified 48 potentially relevant studies. After removing duplicates, 32 studies were retrieved for full text review. Selected data are studies that meet the following criteria: time of publication (from 2013 to 2022), research target group (children with ASD under 18 years old), and research subjects (communication skills, Cognitive skills, and social skills). In total, 30 studies were excluded, leaving 18 studies in the review.

The final data has 18 studies that meet the criteria according to the following contents: (1) Using VR technology in cognitive skills education for children with ASD; (2) Using VR technology in social skills education for children with ASD; (3) Using VR technology in communication development for children with ASD.

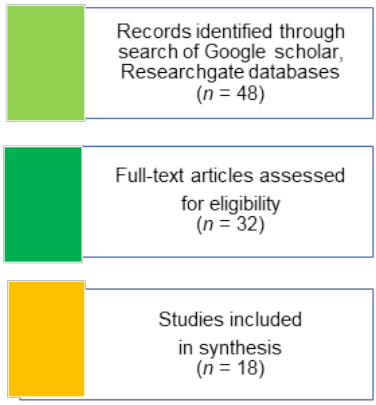

Figure 1. Flow chart of the search strategy

3. Research results

The aim of this systematic review was to investigate: (1) How are the effects of VR interventions on the cognitive, communication and social skills of children with ASD?; (2) Whether the feasibility of using VR with children with ASD in Vietnam?

3.1. The basic concepts

Autism spectrum disorders

According to the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5), ASD is defined as a form of neurodevelopmental disorder. ASD is characterised by two core impairments, limited interaction and social interaction, and the emergence of restricted, irregular, and repetitive behaviours and hobbies. These impairments cause limitations in the child's performance of daily functional activities and are not better explained by other disorders (APA, 2013).

Virtual Reality

VR is a term used to describe a range of technologies developed since the 1960s, including virtual worlds (VWs), massively multiplayer online role-playing games (MMORPG), virtual environments, and head-mounted displays (HMD) (Newbutt et al., 2017; Newbutt, Bradley & Conley, 2020). VR is a blend of natural and simulated environment settings. VR environments are computer-based, multi-sensory, simulated environments that are navigated using various technology (Mesa-Gresa et al., 2018). VR environments can be a way to create an analogue of the physical environment, which can be helpful for generalisation. Hale and Stanney (2014) refer that VR is a model of reality with which humans can interact, extract information from the model using common human senses such as sight, sound, and touch, or manipulate the model by typical human actions. Thus, VR is a reality model that people can similarly interact with in real life through devices such as computers, VR glasses and consoles by using the human senses.

3.2. Using VR in cognitive skills education for children with ASD

The review of the found documents shows that VR software is useful in improving and educating the cognitive skills for children with ASD. The typical studies are as follows.

Cai et al. (2017) designed the virtual pink dolphin game to improve learning and communication ability. De Luca et al. (2019) studied to apply VR to a 16-year-old ASD child at level three. According to experimental results, the use of VR along with cognitive behavioural therapy (CBT) can be a valuable and hopeful tool for improving cognitive function in people severely affected by ASD because the results displayed improvement in children's attentional processes and spatial cognitive skills.

Patsadu, Muchchimwong and Narudkun (2019) propose a VR game to develop cognitive skills for children with ASD and show satisfaction rating the game. The game is aimed at developing cognitive skills, especially in the case of developing listening skills and cognitive skills (memory) of autistic children aged 8-11 years old, with three sequential parts. Part I, designed for listening to and memorising traffic

rules, animals and virtual environments. The purpose of VR is to add a sense of reality that appeals to the user. Part II is a game that tests cognitive skills and learns rules based on a game. Finally, Part III is a report created for parents, carers and doctors so that they have the information for the trackable intelligence of child development perception found in Part I and II. The study had 15 participants (05 children with ASD and 10 caregivers). The results show that satisfaction with the game is at a good level as assessed by children with ASD and caregivers.

Ramadhani et al. (2021) conducted a review study aimed at analysing VR-based assistive technology to help students with ASD understand the school environment during the Covid-19 pandemic. As a result, VR-based assistive technology can help them understand the actual learning environment. In addition, this medium can also help them improve their cognitive, communication and social skills with funny situations.

The study of Shahab et al. (2022) using social virtual reality robots (V2R) to educate children with high-functioning ASD is a new study to evaluate the feasibility of implementing virtual music education programs with an automated assessment system for children with ASD at treatment/ research centres. The results indicated small improvements in cognitive skills over the course of therapy for children.

3.3. Using VR in social skills education for children with ASD

According to a systematic review based on empirical studies by Patricia Mesa-Gresa et al. (2018), out of 31 studies, up to 45% of the studies used VR to educate social skills for children and adolescents with ASD. Studies about using VR to educate social skills refer to a number of specific skills such as buying things, earning money, crossing the street, flying by plane, etc., skills of recognition, expression of emotions, skills to identify and become familiar with the school environment through VR.

Dixon et al. (2020) use VR technology through physical activities (e.g., walking, stopping, turning) using head-mounted displays, body trackers and three-way hand control. The VR environment shows streets, stop signs, and moving cars. The training is done in about 20 sessions of 3 to 5 minutes over a period of 5 weeks. Participants learned new behaviours: tracking cars and locating stop signs in an immersive VR environment. The results showed that all three children participating met the criteria of mastering both VR and natural environments in terms of safety skills to cross the road. Miller et al. (2020) performed a VR-based-air-travel functional communication activity on five children diagnosed with ASD. The researchers did VR interventions once a week for three weeks for each child. The results revealed that all children improved their air travelling skills as observed by the researchers and their parents, and all children headed to real-world airports with their own abilities. Another skill that Junaidi et al. (2020) have developed was VR content to improve social skills in children with ASD, namely food purchasing skills training in the school canteen for children. This product was said by teachers to be quite effective.

Yuan & Ip (2018) used VR to train social and emotional skills in children with ASD. The results presented that children from the trained group scored higher on

emotional expression and control than before the training, and higher scores on social interaction and adaptation. A VR support program that enhances social and emotional adaptation skills for children with ASD has taken place on a relatively large scale. Six unique learning scenarios, one of which focuses on emotion management and relaxation strategies, four that simulate different social situations, and one that reinforces and generalises. The results exhibited significant improvements in the expression and control of emotions in children, as well as social-emotional reciprocity.

Zhao et al. (2018) studied the combination of the CVE Augmented Reality Environment System with Communication Enhancement, allowing two children to play a series of interactive games in a VR environment using simple gestures of fingers to point to the virtual movement of objects that are tracked in real-time through the camera. Furthermore, these games are designed to promote natural communication and cooperation among users through the presented Communication Enhancement mode that allows users to share information and discuss game strategies using eye contact and voice-based communication. The results of a feasibility study with 12 children with ASD and 12 peers showed that the system was adopted by both children with and without ASD, improving children's cooperation in playing games, and demonstrating the potential for fostering children's communication and cooperation skills.

Sait et al. (2019) discussed the architectural design of a virtual environment for children with ASD based on ABA therapy. This software helps children immerse themselves in the classroom environment, can adapt to the classroom interface, and identify characters, including students and teachers in that environment. As a result, 8/9 of children are satisfied and accept VR, and 5/9 of children remember what they saw in the school environment. This result exposed the potential of VR in training ASD students in a school environment, thereby helping them adapt to new and unfamiliar things, improving their abilities and social skills, and helping children get used to the environment.

Adjorlu et al. (2018) conducted a study to investigate the feasibility of using HMDs-based VR applications to teach social skills to children with ASD through the use of social stories. The results suggest that there is potential for use in teaching appropriate social behaviours. Moon and Sokolikj (2020) studied to use VR called Open Simulator. Research results on a group of seven children with ASD 10-14 years old in 20 hours of intervention have shown the initial effectiveness in improving social skills for this group of children.

3.4. Using VR in communication development education for children with ASD

A number of studies on using VR to develop non-verbal and verbal language for children with ASD were carried out. Kurniawan's study (2018) was conducted to examine the use of the PECS (Picture Exchange Support System) method based on multimedia augmented reality as an alternative learning method in communication training of children with ASD. Research results revealed that the average level of communication ability before and after therapy is 47%, while the average level of treatment is 65%. There was an improvement after the intervention period with a mean of 76%.

Research by Parsons (2015) designed multi-user VR games for social collaboration and communication support for children with ASD. This design has been shown to be a helpful technology in supporting children with ASD to support and cooperate with each other, thereby developing communication for children. Similarly, Zhang et al. (2018) also designed a collaborative virtual environment that allows natural communication between two or more individuals in a shared virtual environment. The results showed that the participants' game performance and communication tendencies improved over time.

ECHOES Intelligence Tools is a serious game built to help children with ASD acquire social skills. It showed encouraging improvements for some children (Bernardini, 2013).

Y et al. (2013) designed and developed a virtual dolphinarium for children with ASD that allows children to act as dolphin trainers by the pool and learn (non-verbal) communication through gestures with the virtual dolphin. The results show the potential of the application for children's communication development.

Table 1. List of articles from 2013 - 2022

No.	Author(s), year of publication	Research method(s)	Field	VR software	Number of children
1	Shahab et al. (2022)	Applied research	Cognitive skills: Music	social virtual reality robot (V2R)	5
2	De Luca et al. (2021)	Case study	Cognitive skills		1
3	Dixon et al. (2020)	Applied research	Social skills: know if it is safe to cross the street		3
4	Junaidi et al. (2020)	Applied research	Social skills: food purchasing in canteen		7
5	Miller et al. (2020)	Applied research	Social skills: air travel training		5
6	Ke et al. (2020)	Case study	Social skills	OpenSimulator	7
7	Patsadu et al. (2019)	Applied research	Cognitive skills		5

No.	Author(s), year of publication	Research method(s)	Field	VR software	Number of children
8	Sait et al. (2019)	Applied research	Social skills: help children identify and adapt to elements in the classroom environment	Unity3d	9
9	Adjorlu & Serafin (2018)	Applied research	Social skills: appropriate social behaviours		5
10	Ip et al. (2018)	Applied research	Social skills		94
11	Kurniawan et al. (2018)	Applied research	Communication	PECS based on VR	12
12	Yuan & Ip (2018)	Applied research	Social skills: adaptation skill of emotion and society		72
13	Zang et al. (2018)	Applied research	Communication	Collaborative virtual reality environment (CVE)	14
14	Zhao et al. (2018)	Applied research	Social skills	CVE augmented reality environment software & Communication Enhancement	12 children with ASD; 12 normal children
15	Cai et al. (2013)	Basic research	Cognitive skills Communication	Virtual pink dolphin game	
16	Parsons (2015)	Applied research	Communication	Collaborative virtual reality environment (CVE)	8
17	Bernardini et al. (2013)	Basic research	Cognitive skills		
18	Cai et al. (2013)	Basic research	Cognitive skills Communication	Virtual pink dolphin game	

4. Discussion

4.1. The advantages of using VR in educating children with ASD

According to Bailey, Bryant, and Hemsley (2021), with a review of 69 articles on VR for children with neurodevelopmental disorders and communication difficulties, it is found that these technologies can be used to create safe and authentic communicative learning experiences for the majority of children, adolescents, and adults with ASD, intellectual disability, and communication disorders. VR allows simulation of everyday life situations so that scheduled training can be conducted in a safe and therapist-controlled environment. Studies also show that VR has a high ecological value and that learning can be transferred to real life. Another advantage is that VR has the ability to modify and personalise the tasks, measures, difficulties, situations and stimuli present in the environment. In addition, the use of structured commands helps children with ASD feel in control of media use, which can provide a sensory experience for students, and keeps the eyes focused, and the child needs to use the whole body to use that device (De Luca et al., 2021).

4.2. Limitations of using VR in educating children with ASD

Limitations to the use of VR in autism therapy include limited evidence of its effectiveness of VR therapy. Many of the studies analysed did not include control groups, which means the ASD group that received other traditional therapies, to compare the effects of VR use. Considering this problem, some of the study results are preliminary and limited to clinical practice. Another limitation of the studies is the number of subjects in the samples. The studies reviewed had small samples, so it is difficult to extrapolate the results to the number of children with ASD affected by this disorder. In addition, some studies have been performed on high-functioning children, so the results should only be considered for this sample and not representative of the rest of the children with ASD (Bozgeyikli et al., 2018; Bailey et al., 2021).

5. Conclusion

An overview of previous studies in the period from 2013 to 2022 on the use of VR in education for children with ASD shows that most of the studies have brought good results, and users are satisfied and well-adapted to VR software. Studies aimed at supporting social skills education for children with ASD have been focused more on research than in other fields, perhaps because of impairments in social interaction as core and typical in this group of children. A number of studies have shown that the application of VR should also be applied together with other therapies for optimal effectiveness. In order to confirm the effectiveness clearly, studies on large samples and longer duration are needed. Educating children with disabilities in Vietnam also needs to conduct software design studies or apply VR to help support students and families in the process of educating children with disabilities in general and children with ASD in particular.

This study also has a limitation. Since only using keywords in English, this analysis only applies to articles published in English-language journals.

References

Adjorlu, A., & Serafin, S. (2018). Head-mounted display-based virtual reality as a tool to teach money skills to adolescents diagnosed with autism spectrum disorder. In *Interactivity, game creation, design, learning, and innovation* (pp. 450-461). Springer, Cham.

American Psychiatric Association. (2013). *Desk Reference to the Diagnostic Criteria from DSM-5,* American Psychiatric Publishing.

Bailey, B., Bryant, L., & Hemsley, B. (2021). Virtual reality and augmented reality for children, adolescents, and adults with communication disability and neurodevelopmental disorders: A systematic review. *Review Journal of Autism and Developmental Disorders*, 1-24.

Bernardini, S., Porayska-Pomsta, K., & Sampath, H. (2013, November). Designing an intelligent virtual agent for social communication in autism. In *Ninth Artificial Intelligence and Interactive Digital Entertainment Conference*.

Bozgeyikli, L., Raij, A., Katkoori, S., & Alqasemi, R. (2018). A survey on Virtual Reality for individuals with autism spectrum disorder: Design considerations. *IEEE Transactions on Learning Technologies, 11(*2), 133-151.

Cai, Y., Chia, N. K., Thalmann, D., Kee, N. K., Zheng, J., & Thalmann, N. M. (2013). Design and development of a virtual dolphinarium for children with autism. *IEEE transactions on neural systems and rehabilitation engineering*, *21*(2), 208-217.

Cai, Y., Chiew, R., Nay, Z. T., Indhumathi, C., & Huang, L. (2017). Design and development of VR learning environments for children with ASD. *Interactive Learning Environments, 25*(8), 1098-1109.

De Luca, R., Leonardi, S., Portaro, S., Le Cause, M., De Domenico, C., Colucci, P. V., ... & Calabrò, R. S. (2021). Innovative use of virtual reality in autism spectrum disorder: A case-study. *Applied Neuropsychology: Child*, *10*(1), 90-100.

Dixon, D. R., Miyake, C. J., Nohelty, K., Novack, M. N., & Granpeesheh, D. (2020). Evaluation of an immersive virtual reality safety training used to teach pedestrian skills to children with autism spectrum disorder. *Behavior Analysis in Practice*, *13*(3), 631-640.

Hale, K. S., & Stanney, K. M. (Eds.). (2014). *Handbook of virtual environments: Design, implementation, and applications*. CRC Press.

Ip, H. H., Wong, S. W., Chan, D. F., Byrne, J., Li, C., Yuan, V. S., ... & Wong, J. Y. (2018). Enhance emotional and social adaptation skills for children with autism spectrum disorder: A virtual reality enabled approach. *Computers*