Current Research in Behavioral Sciences 2 (2021) 100013

Contents lists available at ScienceDirect

Current Research in Behavioral Sciences

journal homepage: www.elsevier.com/locate/crbeha

Effect of cognitive training based on virtual reality on the children with autism spectrum disorder

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ARTICLE INFO

Keywords:
Autism spectrum disorder
Children
Cognitive training
Virtual reality
Intervention

ABSTRACT

Virtual reality (VR) is an artificial environment which is experienced through sensory stimuli provided by a computer. The capability of VR to simulate reality could greatly increase access to psychological therapies. The model of early intervention training and partial intelligent feedback was established to analyze the effect of cognitive training based on VA on children with autism spectrum disorder (ASD). The Autism Behavior Checklist (ABC), Childhood Autism Rating Scale (CARS) and Clancy Autism Behavior Scale (CABS) were used to assist the severity of symptoms and treatment effectiveness of cognitive training based on VA on children with ASD. The results showed that the cognitive training based on VA was very attractive to children with ASD; cognitive training based on VA significantly improved the typical symptoms (the social communication disorder, speech retardation, narrow interest and rigid behavior) of children with ASD and perfected the Autism Behavior Checklist (ABC), Childhood Autism Rating Scale (CARS) and Autism Behavior Scale (CABS) during 4 weeks after treatment. The data suggested that cognitive training based on VA might be a good method to treat children with ASD.

1. Introduction

Autism spectrum disorder (ASD) is a term used to describe a constellation of early-appearing social communication deficits and repetitive sensory-motor behaviors associated with a strong genetic component as well as other causes (Lord et al., 2018). ASD is characterized by difficulty with social communication and restricted, repetitive patterns of behavior, interest, or activities (Sanchack and Thomas, 2016).

The Diagnostic and Statistical Manual of Mental Disorders, 5th ed., created an umbrella diagnosis that includes several previously separate conditions: autistic disorder, Asperger syndrome, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified. Since the documented observations of Kanner in 1943, there has been great debate about the diagnoses, the sub-types, and the diagnostic threshold that relates to what is now known as ASD. Reflecting this complicated history, there has been continual refinement from DSM-III with 'Infantile Autism' to the current DSM-V diagnosis. The disorder is now widely accepted as a complex, pervasive, heterogeneous condition with multiple etiologies, sub-types, and developmental trajectories (Masi et al., 2017). There is insufficient evidence to recommend screening for autism spectrum disorder in children 18 to 30 months of age in whom the disorder is not suspected; however, there is a growing body of evidence that early intensive behavioral intervention based on applied behavior analysis improves cognitive ability, language, and adaptive skills. Therefore, early identification of ASD is important, and experts recommend the use of a validated screening tool at 18- and 24-month well-child visits (Sanchack and Thomas, 2016).

ASD starts in early childhood, and the incidence rate of boys is five times higher than that of girls (Sacrey et al., 2015). According to the China Autism Education and Rehabilitation Industry Development Report 3 in 2019, the incidence of ASD has been increasing year by year, reaching 0.7%, and there are more than 10 million people with ASD, including more than 2 million in children (0-14 years old), with an annual growth rate of nearly 200,000 in China. Genetics and neuroscience have

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https://doi.org/10.1016/j.crbeha.2020.100013
Received 14 December 2020; Received in revised form 16 December 2020; Accepted 18 December 2020

identified intriguing patterns of risk, but without much practical benefit yet. Considerable work is still needed to understand how and when behavioral and medical treatments can be effective, and for which children, including those with substantial comorbidities (Lord et al., 2018). Medications can be used as adjunctive treatment for maladaptive behaviors and comorbid psychiatric conditions, but there is no single medical therapy that is effective for all symptoms of ASD (Masi et al., 2017).

Virtual reality (VR) is an artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment. Mental health problems are inseparable from the environment. With VR, computer-generated interactive environments, individuals can repeatedly experience their problematic situations and be taught, via evidence-based psychological treatments, how to overcome difficulties. The capability of VR to simulate reality could greatly increase access to psychological therapies, while treatment outcomes could be enhanced by the technology's ability to create new realities (Freeman et al., 2017; Maskey et al., 2019; Bell et al., 2020). This capability is central to recent interest in how VR might be harnessed in both treatment and assessment of mental health conditions including ASD. The study was designed to investigate the effect of cognitive training based on VA on the children with ASD in China.

2. Materials and methods

2.1. Diagnosis of child ASD

The children with ASD were diagnosed depending on the disease onset before the age of 3-years old, three typical symptoms (social communication disorder, speech retardation, narrow interest and rigid behavior), who excluded diagnosis of childhood schizophrenia, mental retardation and other pervasive developmental disorders.

2.2. Participants

One hundred and twenty children with ASD including 88 boys and 32 girls, 2–7 years old, average 4.8 ± 2.3 years old, who suffered with ASD, were asked to participate in the study between September 2016 and August 2020. The patients, which ASD history was 1–3 years, average 2.1 ± 1.1 years, did not accepted any treatments before the study.

The children with ASD were randomly divided into Experimental group (60 children with ASD) and Control group (60 children with ASD). There was no significant difference between the two groups in age, sex, sick time and disease severity degree (all $p>0.05$).

2.3. Application methods of VA

2.3.1. Building the model for cognitive training based on VA

Import the Maya model into ZBRUSH software to make the model level details (Fig. 1), and use UNLAYOUT software in Unreal 4 to make low-mode display (Fig. 1). The high mold and low mold were matched and baked by XNORMAL software. The color position map was backed by 3DMAX, then the model, normal and color position map were imported through Photoshop and Substance Painter for the production of the overall map, and finally put into the VR engine (Fig. 2).

The scene models by the camera sensor device capture target motion data of the object, including parts of the body posture, bearing and other information, and to transmit the data through data transmission equipment to data processing equipment, after correction, data processing, eventually establish a three-dimensional model, and makes the 3D model with moving objects, real natural movement.

2.3.2. Visual interaction

The content scene interaction with data input/output image processing, collect the camera in the scene with interaction with server processing good motion data, output action by data to render content to the VR glasses scene, at the same time will locate track after partial capture data or whole body move data to the server, motion drive mapping in the application of VR model, realizes the display and the combination of virtual and interactive (Fig. 3).

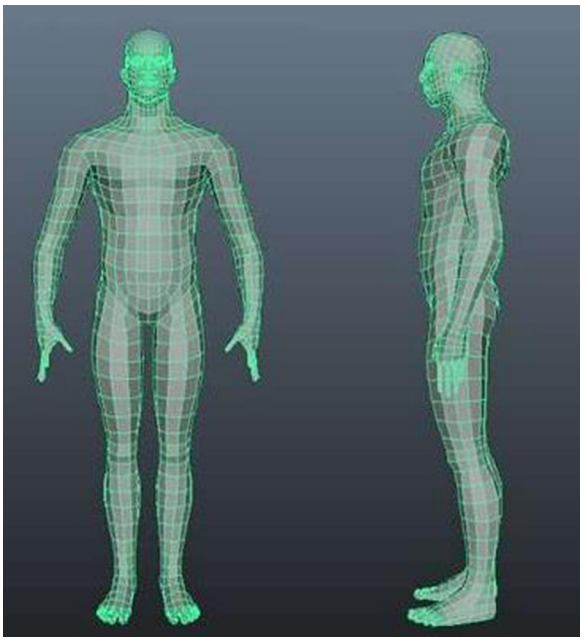

Fig. 1. The model diagram built by ZBRSH software.

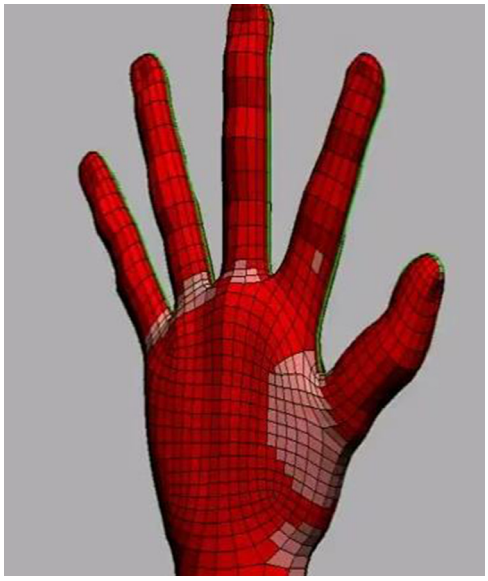

Fig. 2. A surgical hand made by UVLAYOUT software.

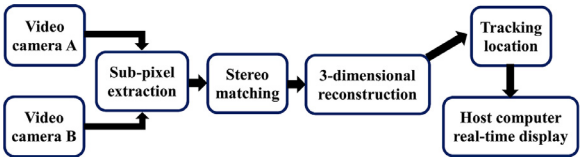

Fig. 3. The principle of motion capture technology process.

2.3.3. Force feedback

The source of force is determined by magnetic marker, and the position change of the sensor is obtained through the preset magnet and

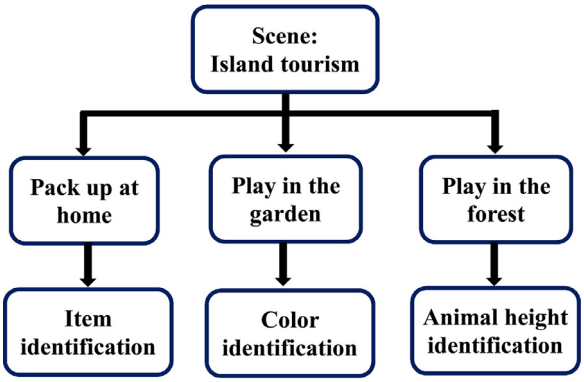

Fig. 4. The model of early intervention training for children with autism spectrum disorder.

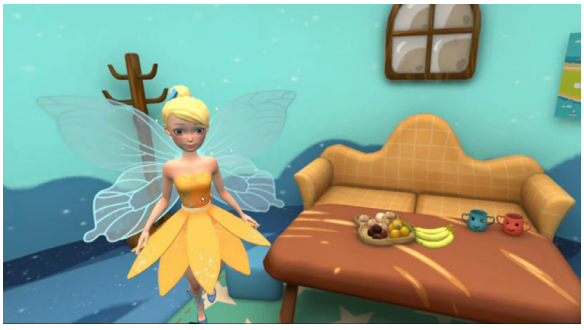

Fig. 5. Cognitive training based on virtual reality for the item identification.

Fig. 6. Cognitive training based on virtual reality for the flower color.

the motion change information of the permanent magnet is obtained by the magnetic sensor. When the force feedback signal is not received by the force feedback device, the fingers can stretch and bend freely in the device, realizing the visualization of six-dimensional space. When a feedback signal is received by the force feedback receiver, the electromagnet provides a feedback force, the magnitude of which can be changed by adjusting the current in the electromagnet.

2.4. Cognitive training based on VA

According to "Application methods of VA", the model of early intervention training was built for children with ASD (Fig. 4), and then the model of partial intelligent feedback was established. These models were used to analyze the effect of cognitive training based on VA on children with ASD, and the control training was to watch the island tourism animation, which plot and scene were similar to the cognitive training (Figs. 5–7).

Fig. 7. Cognitive training based on virtual reality for the animal height.

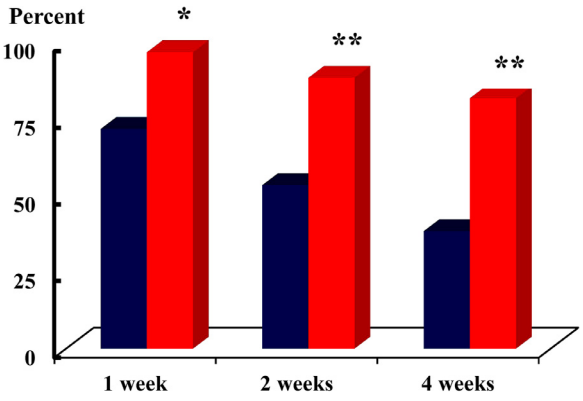

Fig. 8. Attraction of cognitive training based on virtual reality for children with autism spectrum disorder. ■ Control group (n=30) ■ Experimental group (n=30); $^{*}p<0.05$, $^{**}p<0.01$.

2.5. Treating assessment for the children with ASD

The clinical rating scales, which included Autism Behavior Checklist (ABC), Childhood Autism Rating Scale (CARS) and Clancy Autism Behavior Scale (CABS), were used to assist in diagnosis, to understand the severity of symptoms, and to assess treatment effectiveness.

2.6. Statistical analysis

Data were expressed as mean ± standard error of the mean (SEM) and performed with the SPSS 18.0 statistical package, with two-way analysis of variance (ANOVA) followed by the Bonferroni test and multisampling analysis of difference followed by the χ^2 test. Significance was accepted at $p<0.05$.

3. Results

3.1. Attraction of cognitive training based on VA for children with ASD

Cognitive training based on VA was very attractive to children with ASD. Cognitive training was practiced for 30 min every time, twice a day. Compared with the Control group (watching the animation of island tourism), which attracted 71.67% patients in 1 week, 53.33% patients in 2 weeks and 38.33% patients in 4 weeks to complete the training, the Experimental group (cognitive training) attracted 96.67% patients in 1 week, 88.33% patients in 2 weeks and 81.67% patients in 4 weeks to complete the training (all $p<0.05$ or 0.01, Fig. 8).

3.2. Improve typical symptoms after cognitive training based on VA in children with ASD

Cognitive training based on VA significantly improved the typical symptoms (the social communication disorder, speech retardation,

Table 1
Change of Autism Behavior Checklist after cognitive training based on virtual reality in children with autism spectrum disorder.

Therapeutic schedule	Treatment time	*n*	Autism Behavior Checklist (ABC)				*p*
			≤31	32-52	53-66	≥67	
Cognitive training based on virtual reality	Before	30	28 (93.3%)	2 (6.7%)	0 (0)	0 (0)	>0.05
	1 week		24 (80.0%)	5 (16.7%)	1 (3.3%)	0 (0)	<0.05
	2 weeks		20 (66.7%)	8 (26.6%)	2 (6.7%)	0 (0)	<0.01
	4 weeks		17 (56.7%)	9 (30.0%)	3 (10.0%)	1 (3.3%)	<0.01
Control treatment	Before	30	29 (96.7%)	1 (3.3%)	0	0 (0)	–
	1 week		29 (96.7%)	1 (3.3%)	0	0 (0)	–
	2 weeks		28 (93.3%)	2 (6.7%)	0	0 (0)	–
	4 weeks		24 (93.3%)	5 (16.7%)	1 (3.3%)	0 (0)	–

Table 2
Change of Childhood Autism Rating Scale after cognitive training based on virtual reality in children with autism spectrum disorder.

Therapeutic schedule	Treatment time	*n*	Childhood Autism Rating Scale (CARS)			*p*
			≤30	31–36	37–60	
Cognitive training based on virtual reality	Before	30	30 (100.0%)	0 (0)	0 (0)	>0.05
	1 week		28 (93.3%)	2 (6.7%)	0 (0)	>0.05
	2 weeks		25 (83.3%)	5 (16.7%)	0 (0)	<0.01
	4 weeks		22 (73.4%)	7 (23.3%)	1 (3.3%)	<0.01
Control treatment	Before	30	30 (100.0%)	0 (0)	0 (0)	–
	1 week		30 (100.0%)	0 (0)	0 (0)	–
	2 weeks		29 (96.7%)	1 (3.3%)	0 (0)	–
	4 weeks		28 (93.3%)	2 (6.7%)	0 (0)	–

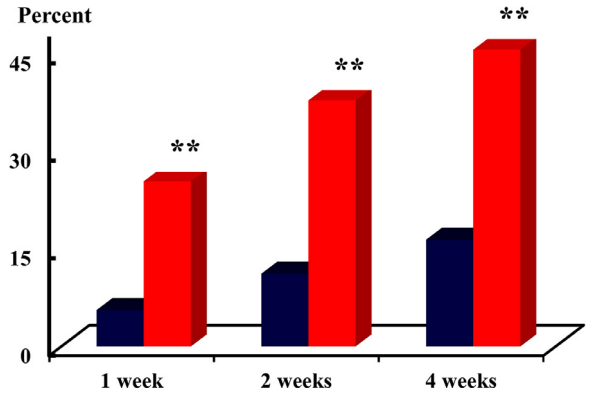

Fig. 9. Improvement of typical symptoms after cognitive training based on virtual reality for children with autism spectrum disorder. ■ Control group (*n*=30) ■ Experimental group (*n*=30); $^{**}p<0.01$.

narrow interest and rigid behavior) of children with ASD. Compared with the Control group (watching the animation of island tourism), which only improved 5.61% of the typical symptoms in 1 week, 11.21% in 2 weeks and 16.45% in 4 weeks, the Experimental group (cognitive training) improved 25.42% of the symptoms in 1 week, 37.89% in 2 weeks and 45.68% in 4 weeks (all $p<0.01$, Fig. 9).

3.3. Changes of the clinical rating scales after cognitive training based on VA in children with ASD

Cognitive training based on VA significantly perfected the clinical rating scales including Autism Behavior Checklist (ABC) (Table 1), Childhood Autism Rating Scale (CARS) (Table 2) and Autism Behavior Scale (CABS) (Table 3).

4. Discussion

ASD is a neurodevelopmental disease that is specially characterized by impairments in social communication and social skills. ASD has a high prevalence in children, affecting 1 in 160 subjects. VR has emerged as an effective tool for intervention in the health field. VR can add many advantages to the treatment of ASD symptomatology (Mesa-Gresa et al., 2018), and provides a safe, controllable environment to practice skills repeatedly for children with ASD (Yuan and Ip, 2018). In clinical practice, ASDs have been usually treated with cognitive-behavioral approaches. VR has played an important role in neurorehabilitation, even for ASD cognitive treatment. A 16-year-old boy with severe ASD and his caregiver were enrolled in the study. The combined approach provided an improvement in attention processes and spatial cognition skills, with a significant reduction of ideomotor stereotypes. The use of VR in addition to CBT could be a useful and promising tool to improve cognitive function in individuals severely affected by ASD (De Luca et al., 2019). One study investigated the feasibility of an engaging VR Social Cognition Training intervention focused on enhancing social skills, social cognition, and social functioning. Eight young adults diagnosed with high-functioning ASD completed 10 sessions across 5 weeks. The VR platform is a promising tool for improving social skills, cognition, and functioning in ASD (Kandalaft et al., 2013). Our study showed that he cognitive training based on VA was very attractive to children with ASD; cognitive training based on VA significantly improved the typical symptoms (the social communication disorder, speech retardation, narrow interest and rigid behavior) of children with ASD and perfected the Autism Behavior Checklist (ABC), Childhood Autism Rating Scale (CARS) and Autism Behavior Scale (CABS) during 4 weeks after treatment. The results suggested that cognitive training based on VA might be a useful method to treat children with ASD.

Although social stories in a form of VR program can help children with ASD, developing them and identifying appropriate responses might be subjective and thus challenging. Using Delphi method, and guided by general case training, the project is the first study to develop and validate a library of 75 short socio-emotional stories that illustrate various types and intensities of emotion in three social contexts of home, school, and community as the content of a virtual reality program (Ghanouni et al., 2019).

In this study, the model of early intervention training and partial intelligent feedback was established to analyze the effect of cognitive training based on VA on children with autism spectrum disorder (ASD). We built the scene of tourism animation (cognitive training based on VA for the item identification, the flower color and the animal height) and

Table 3
Change of Autism Behavior Scale after cognitive training based on virtual reality in children with autism spectrum disorder.

Therapeutic schedule	Treatment time	*n*	Autism Behavior Scale (ABS)		*p*
			≥14	<14	
Cognitive training based on virtual reality	Before	30	30 (100.0%)	0 (0)	>0.05
	1 week		29 (96.7%)	1 (3.3%)	>0.05
	2 weeks		27 (90.0%)	3 (10.0%)	<0.05
	4 weeks		24 (80.0%)	6 (20.0%)	<0.01
Control treatment	Before	30	30 (100.0%)	0 (0)	–
	1 week		30 (100.0%)	0 (0)	–
	2 weeks		30 (100.0%)	0 (0)	–
	4 weeks		29 (96.7%)	1 (3.3%)	–

relative video as the control training. Cognitive training was practiced for 30 min every time, twice a day. Cognitive training based on VA was very attractive to children with ASD 4 weeks after the treatment. The results suggested that cognitive training based on VA might be a good method to treat children with ASD.

In fact, we have studied that not only the cognitive training based on VA, but also the verbal social, computational training, big muscle training and physical coordination training based on VA influenced the children with ASD. In this article, we only reported the results of cognitive training based on VA influencing the children with ASD. We will report the results of other factors influencing the children with ASD in future.

5. Conclusion

The cognitive training based on VA was very attractive to children with ASD; cognitive training based on VA significantly improved the typical symptoms (the social communication disorder, speech retardation, narrow interest and rigid behavior of children with ASD) and perfected the Autism Behavior Checklist (ABC), Childhood Autism Rating Scale (CARS) and Autism Behavior Scale (CABS) during 4 weeks after treatment. The data suggested that cognitive training based on VA might be a good method to treat children with ASD.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgment

This project has been partly funded by the Key Project of Henan Province Edition and Teaching Reform (2019SJGLX115), Key Project of Henan Province Educational Science “14th Five-Year Plan” (2021JKZD09), Training Plan for Young Key Teachers in Colleges and Universities in Henan Province (2017GGJS219) and Henan Province Science and Technology Project (2020).

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