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The Auxiliary Role of Virtual Reality Games in Education of Children with Autism

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Abstract: *Virtual-Reality (VR) games are a type of gaming method developed based on the Internet and computer technology, with characteristics such as visualization, interactivity, and scenicity. Compared with traditional educational intervention methods, it is more suitable for the psychological and behavioral characteristics of children with autism, and more conducive to their knowledge acquisition and skill mastery. This article uses the literature search method to systematically review empirical research literature on the application of virtual game in intervention for children with autism at home and abroad, clarify its theoretical basis, analyze its research status and existing problems, and point out its development direction.*
Key words: *Autism Spectrum Disorder, Children, VirtualReality, Virtual-Reality-Based Computer Game, Educational Intervention*

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I. Introduction

Children with autism spectrum disorder (ASD) often have characteristics such as social interaction disorders, repetitive and stereotyped behavior, and fixed and narrow interests. Regular education and training have various limitations for them. Virtual games are a general term for gaming methods developed based on the Internet and computer technology, including interactive video games, virtual environments, etc. [1]. They can not only be used as entertainment tools, but also as educational intervention aids for children with ASD. Previous studies have shown that moderate virtual games can alleviate loneliness in patients with autism [2]. In recent years, in order to improve the application effectiveness of virtual games in ASD children's education, scholars have designed virtual game frameworks based on the psychological and behavioral characteristics of ASD children. On this basis, extensive research has been conducted on the impact of virtual games based on different technologies on ASD children's education.

II. The Technical Foundation and Functional Methods of VR Games Supporting ASD Children's Education

The key technologies used to support VR games for ASD children's education include visualization technology, virtual proxy technology, and emerging technologies. Visualization technology displays human body and facial emotions in the form of 3D animation, which can promote the development of emotional understanding and recognition abilities in children with ASD; Virtual proxy technology helps ASD children interact with other objects through avatars, which can enhance their social skills; Building an interactive virtual reality environment through emerging technologies can enhance ASD children's understanding of causal relationships and their ability to experience independent travel.

2.1 Visualization Technology Enhances Emotional Understanding and Recognition Abilities

Visualization technology can improve the emotional understanding and recognition abilities of children with ASD through 3D animated character simulation and 3D animated scene creation.

2.1.1 Character Simulation

ASD children have significant difficulties in recognizing, understanding, and giving feedback to others' facial expressions, voice intonation, body posture, and expressing their emotions [3]. Three-dimension animation highlights the actions and expressions of virtual characters, especially facial and body movements, by simulating real objects in a natural and realistic manner. It helps ASD children observe and feel the behavior and emotions of virtual characters, and provides support for emotional intervention. For example, the "Junior Detective Training Program" [4] is a virtual educational game that aims to enhance the emotional recognition

ability of ASD children. It guides them to experience the process of case detection through strategies such as 3D animation appreciation and role-playing, helping them learn to recognize complex emotions such as embarrassment and guilt. After completing a series of learning tasks, researchers conducted a 5-month follow-up and found that the social skills and emotional management abilities of the intervention group were significantly improved.

2.1.2 Scene Creation

Interventions based on facial expressions are based on the theory of emotional cognition in autism. Baron-Cohen et al. [5] proposed the "Empathizing Systemization Theory(E-S)", which suggests that the brain of children with ASD is highly systematic. They have obstacles in understanding others' mental state, eye interaction, language communication, and other empathy mechanisms, but have advantages in observing details, processing highly structured information, and understanding rigorous physical structures. Therefore, immersive and unsupervised 3D scene technology can create virtual scenes that are suitable for the cognitive characteristics of ASD children. For example, the emotional cognition animation "The Transporters" [6] transplanted anthropomorphic faces expressing emotions onto six virtual vehicles: trams, cable cars, sprockets, long-distance buses, cable railways, and tractors, and contextualized the entertainment interactions between virtual vehicles. Due to the highly structured features of the story presented in this game, and the embedding of facial expressions into physical structures such as transportation rather than body language or emotional sounds, it meets the cognitive needs of ASD children's highly systematic brains. This enables ASD children to effectively utilize their advantageous abilities and compensate for their social cognitive barriers [7]. The experimental results indicate that this series of games can significantly improve ASD children's understanding and recognition of the 15 key emotions presented in the virtual games.

2.2 Virtual Agent Technology Enhances Adaptability and Social Skills

Virtual agent technology is gradually developing towards personalization and strong interactivity. The avatar images of virtual agents have evolved from 2D animation to 3D animation, the technical features have also shifted from simple audio or video interaction to interaction in virtual reality learning environments, and educational applications are reflected in intelligent mentors and intelligent companions.

2.2.1 Avatar Technology

Avatar technology can simulate human physiological functions, giving virtual agents humanoid appearance, posture, behavior, and emotions. In the application process, avatar technology can be represented in forms such as images, videos, and animations. Avatar technology can help ASD children simulate real-life and social scenes. For example, theproject "Autism Games" in Australia [8] utilizes technologies such as audio and video, 2D animation, etc. to allow children with moderate and severe autism to interact with avatars, helping them to accept and respond to changes in daily life (such as weather changes and unexpected events), and improving their resilience. The intelligent proxy game "SHARE-IT" [9] in an immersive learning environment is guided by practical problems in real-life situations, integrating technologies such as avatars and audio and video, allowing ASD children to enhance their perception of external multi-channel information and enhance their adaptability to the environment through multidimensional interaction with virtual characters.

2.2.2 Collaborative Virtual Environment

The vast majority of virtual reality serious games use pre-programming or correlation technology, which lacks the flexibility of social and communication compared to the dynamic real world [10]. To this end, building a collection of computer supported distributed virtual scenes, namely Collaborative Virtual Environment (CVE), promotes multiple players to interact with virtual objects simultaneously, and can improve the limitations of interaction in the virtual environment [11]. CVE relies on advantages such as scene setting, interactive special effects, human-machine interaction, and intelligent algorithms to create a scene interaction system that integrates gamified display, learning content interaction, and learning experience, providing support for the training of ASD children. For example, the game "Virtual Cafe" based on CVE [12] can stimulate the social motivation of ASD children by enhancing communication (i.e.the gameasking players questions), interaction (i.e. players interacting with the game with the mouse), and navigation (i.e. players using joysticks to move in the direction indicated in the virtual environment), enhance their social intensity, enhance their social skills, and promote the development of their empathy ability [13].

2.3 Emerging Technologies Strengthen the Understanding of the Causal Relationship and the Experience of Independent Travel

Emerging technologies represented by touch interaction, motion capture, and wearable technologies are accelerating their integration with technologies such as 5G and artificial intelligence, and have spawned new

application scenarios. Among them, the creation and evaluation of immersive scenes has received the most attention from the academic community. The application research of emerging technologies in virtual games mostly focuses on natural interaction technology and multimodal learning analysis.

2.3.1 Touch Interaction Technology

VR games can place the thinking development of ASD children in real problem situations, and through the organic integration of multimedia technology and touch interaction technology, improve ASD children's perception and experience ability of the virtual learning environment through feedback on click, touch, and other operational behaviors, enabling them to understand the causal relationship between interactive behavior. For example, in the game "Virtual Garden" [14], ASD children can change the shape of various objects in the garden through operations such as single touch, multi touch, multi finger drag, and superimposed drag, achieving the goal of gradually "planting" flowers into corresponding flower pots. The one-to-one correspondence between touch operation behavior and the state changes of the controlled object can help ASD children understand the reasons for the changes in the controlled object and understand the causal relationship of changes in things in the game. In addition, the integration of touch interaction technology with wearable devices and big data technology can innovate human-computer interaction methods, thereby enhancing the learning experience of ASD children.

2.3.2 Wearable Technology and Motion Capture Technology

Wearable devices have the characteristics of mobility, portability, and strong interactivity, which can provide ASD children with rich visual, auditory, and tactile experiences, enhancing their perception and interaction abilities in virtual environments. Action capture technology sets up trackers in key parts of the human body, and the system captures the position of the tracker. After calculation and processing, spatial coordinate data is obtained, enabling the game process to more accurately obtain body data such as postures and movements. The combination of motion capture technology and wearable technology can help train ASD children for independent travel. Yang et al. [15] developed a VR training system for ASD children's autonomous travel scenarios, including recognizing road signs, safely crossing the road, taking buses and subways, and taking walks in parking lots, aiming to train ASD children's various independent travel skills. This training system utilizes wearable devices based on Kinect and IMU to capture the rotational motion of joints, estimate the motion trajectory of the joints, uses Microsoft Face tracking tools to obtain data on head posture, control the virtual environment view in first person view mode, and recognize the posture behavior patterns of ASD children. The virtual reality travel training system enhances the authenticity of interaction between vehicles and pedestrians by combining motion capture technology, natural interaction technology, and wearable technology. It can help ASD children practice essential skills for travel in an unsupervised and safe environment. Meanwhile, natural human-computer interaction based on gestures and intuitive virtual environment navigation can also enhance the virtual travel experience.

The diagnosis of ASD depends on atypical responses to sensory inputs such as touch, sound, temperature, and vision [16]. For children with ASD, sensory responses exhibit high individual differences. Therefore, monitoring and analyzing the visual, auditory, and tactile signals fed back by wearable devices is a prerequisite for determining whether ASD children can safely use wearable devices. However, most of the educational research on VR technology supporting ASD children is based on smartphones and tablet applications [17], lacking research on the safety of head worn devices.

In summary, the key technologies of virtual games supporting ASD children's education are becoming increasingly diverse and personalized, with two aspects worth paying special attention to. First, as mentioned earlier, some studies have achieved the use of multiple data collection technologies to obtain and analyze multimodal data of ASD children, thereby calculating their behavior patterns and providing accurate educational feedback and services. In this application process, multimodal learning analysis makes it possible to detect nonverbal signals in children with ASD, and is also an important entry point for innovative multivariate evaluation methods. Second, with the rapid development of new technologies such as AR/XR technology and wearable devices, risks are also increasing, such as security issues, privacy breaches, algorithm discrimination. These are all issues that need to be addressed in the governance of science and technology ethics in the field of special education in China.

III. The Application Path of VR Games in ASD Children's Education

The application of VRgames in ASD children's education mainly focuses on two aspects: cognitive tools for learning and supportive tools for teaching and learning.

3.1 As a Cognitive Toolfor Learning

With the development of VR, cognitive tools based on VR games have increasingly become effective means for adaptive cognitive development in children with ASD, including avatars and gestures.

Avatar technology can provide an intuitive interactive medium for ASD children, creating a realistic visual experience. For example, Bosseler et al. [18] designed a virtual game called "Language Wizard/Player", which utilizes virtual teachers to teach vocabulary and grammar knowledge, providing an effective cognitive platform for ASD children to independently learn vocabulary. In the process of gamified teaching, virtual teacher Baldi issues voice commands, and After the ASD child responds, the screen will display a positive or negative feedback expression, therefore enhancing the cognitive effect. After 30 days of intervention, the vocabulary learning effect of ASD children was significantly improved, and the word memory rate remained at about 91%.

Gestures play an important role in knowledge acquisition, complex motor, fine motor, and cognitive development in children with ASD. Gesture based virtual games are a kind of highly potential cognitive tool that can help ASD children better interact with computers and receive immediate feedback, continuously improving their precise motor skills and cognitive abilities [19]. The Game “Pink Dolphin” [20] provides ASD child dolphin trainers with a role-playing experience through immersive interaction based on virtual reality technology, enabling them to point out the correct path for dolphins through gestures according to game instructions, thereby cultivating ASD children's understanding of the functions and meanings of different gestures, improving their ability to follow directions, psychological movements, and hand eye coordination. In addition, the game can also help ASD children master arithmetic, color and shape recognition skills through different game scenarios and level settings.

In summary, through avatars and gestures, virtual games present learning content in immersive, experiential, customized, and entertaining forms, providing cognitive development support for ASD children and continuously improving their cognitive abilities.

3.2 As Supporting Tools for Teaching and Learning

3.2.1 Integrating Multiple Sensory Channels to Promote Vocabulary Learning

Vocabulary plays a bridging role in social meaning construction in daily language communication. It is not only an indispensable component of reading comprehension, but also a "catalyst" for language use. However, for ASD children, vocabulary learning is a highly challenging task. Compared with ordinary children, ASD children have certain barriers in pragmatic ability and emotional cognition [21]. Children with normal development can speak their first word at 8-14 months after birth, while ASD children cannot speak their first word until at least 38 months after birth and cannot follow the order of speech pronunciation in normal children [22]. In general, combining real life situations and using virtual games to carry out vocabulary teaching for ASD children can improve learning effectiveness. Khowaja et al. [23] designed a game framework for vocabulary learning for ASD children and developed a vocabulary learning software called "Vocab Bilder" based on this, aiming to present daily life items through audio-visual teaching media and assist ASD children in learning different types of words. During the game, ASD children can freely choose an object to browse, and can also choose different sounds to play the corresponding word pronunciation. The experimental results indicate that with the help of this software, ASD children's vocabulary learning ability has been improved, manifested as being able to recognize corresponding objects by simply listening to their names, and being able to recall them correctly for a period of time. It can be seen that combining the text of vocabulary learning with the visual images and sounds it represents can help ASD children remember and acquire target vocabulary, as well as improve their language comprehension ability.

3.2.2 SupportingDigital Reading with Immersive Virtual Scenes

Virtual games effectively integrate various media information such as sound, video, and reading text, providing support for ASD children's digital reading through immersive virtual teaching scenarios. Research has found that ASD children face various difficulties in reading and understanding the meaning of the text [24]. Digital reading is a hypertext reading method based on terminal reading devices. In the process of digital reading, virtual games are used to shift the attention of ASD children to digital reading scenes, and matching virtual game resources are set up to help them easily access reading content and understand the meaning of the text. Based on the consideration of reading disorders in ASD children, strategies such as "one minute classroom" can be adopted to help them obtain key information, and tools such as "reading bookmarks" and "social calendars" can be used to assist them in understanding virtual reading situations, or guide them to focus on clues such as the voice, intonation, or facial expressions of characters [21], in order to solve the differentiated reading difficulties caused by the "digital usage gap" for ASD children to the greatest extent possible. It can be seen that digital reading for ASD children, using virtual games as a carrier and integrating technologies such as images, sounds, videos, animations, and VR/AR, tends to present vivid and concise content, significantly improving the text comprehension ability of ASD children.

3.2.3 Supporting ASD children's programming education through diverse interactions

The integration of virtual games and programming education provides new possibilities for the development of computational thinking in ASD children. Research has shown that ASD children have a natural tendency towards digital tools, so computer programming is considered a more suitable job for autism patients [25]. When virtual games are applied to programming education, their intelligent visualization, collaborative interaction, and other characteristics have a significant positive impact on the social skills, computational thinking, and cognitive development of ASD children. For example, the virtual game "Virtuoso" [26], which combines the meanings of "virtual" and "social", utilizes "virtual programmable robots" to help 11 to 14 year old ASD children solve entry-level computer programming problems. During this process, ASD children utilize virtual learning materials to engage in collaborative learning in a virtual learning space, which can improve their social skills in a targeted manner. Overall, computing tools integrated with virtual games can not only enhance the social skills of ASD children, but also enhance their computational thinking.

In summary, as a supportive tool for teaching and learning for ASD children, virtual games have a positive impact on vocabulary learning, digital reading, and programming learning for ASD children. There are two aspects that need to be focused on: first, there is already a game design framework specifically designed for ASD children's learning internationally, and it has passed the effectiveness and applicability tests. However, there is still insufficient emphasis on the research of virtual game design frameworks in China, and there is still a lack of evaluation of game usability [27]. Second, existing research has shown that international ASD children's education based on virtual games is increasingly tending towards comprehensive cultivation of digital literacy and skills, which coincides with the requirements of the "Accessibility Transformation and Enhancement Project for Digital Society" in China's "Action Plan to Enhance National Digital Literacy and Skills". Taking multiple measures to enhance the digital awareness, computational thinking, and lifelong learning abilities of ASD children is the key and experience for China to accelerate the inclusive service of bridging the digital divide [28].

IV. Research Inspiration

Through the analysis of the research on virtual game assisted education, the following four suggestions can be summarized.

4.1 Use Multimodal Learning Analysis to Expand Teaching Evaluation Methods

The rapid development of multimodal learning analysis has brought new opportunities for the teaching evaluation of ASD children. From the perspective of social symbol systems, the interpretation of multimodality is more inclined towards the perception mode or information channel of the external environment of the machine [29], including information perception channels such as body posture and facial expressions, as well as data collection methods based on multiple sensing devices in teaching contexts [30]. Compared with single modal data, multimodal data fusion can not only improve the accuracy and comprehensiveness of evaluation, but also enhance the rationality of problem interpretation through verification of multi-channel data [31]. Multimodal learning analysis can enrich the effectiveness evaluation methods of virtual game education applications and provide data support for verifying the learning effectiveness of ASD children. In the process of supporting ASD children's learning in virtual games, multiple data acquisition devices (such as ultra-high definition cameras, eye movement devices, and heart rate sensors) can be used to collect multimodal learning behavior data of teachers and students in a companion manner. Multiple analysis techniques can be used to unify, integrate, and model the data, providing teaching support and services for stakeholders such as teachers and students [32]. Therefore, it is recommended to construct a hybrid and systematic virtual game education application evaluation plan to comprehensively examine the training effectiveness of ASD children in emotion recognition, adaptation to changes, social collaboration, and computational thinking.

4.2 Pay Attention to Ethical Risks, and Build a Diversified Co-governance Mechanism of "Government, Enterprise and School" Collaborative Linkage

As an effective and reliable auxiliary tool for ASD children's education, virtual games still face many technological and ethical challenges in the application process. For example, due to the high differences in sensory responses among children with ASD, wearable devices may have excessive stimulation in their sensory feedback, making them unable to cope with changes brought about by virtual environments; The prolonged use of virtual games by ASD children may lead to a risk of addiction; There is a risk of privacy data such as voiceprints and facial features of ASD children being leaked and stolen. In response to the above technological ethics issues, it is necessary to strengthen the collaborative linkage between "government, enterprise and school", establish a differentiated and fully covered multi-party joint accountability mechanism, formulate and implement supervision and prevention measures, and continuously improve the governance capacity of technological ethics [33]. The diversified co-governance mechanism of "government, enterprise and school"

collaboration is led by the government, establishing ethical norms and risk warning mechanisms for the application of virtual games in special education, and clarifying the responsibilities and rights of enterprises and schools. Enterprises should comply with market norms and ensure that their products do not violate technological ethics. For example, when designing games, it is important to adhere to educational ethics, standardize user data collection methods, and establish data protection mechanisms. As the main application subject of virtual games, schools should strengthen the daily management of technology ethics and proactively assess relevant ethical risks. For example, schools should strictly incorporate virtual games into the entrance of school teaching activities and standardize their application methods.

4.3 Build a Design Framework for Virtual Games Guided by Learning Needs

Due to the late start of research and practice in special education in China, there is still a lack of a virtual game design framework that meets the learning needs of ASD children and is suitable for China's national conditions. To develop such a framework, it is firstly necessary to fully follow the cognitive mechanism and psychological development laws of ASD children, and master the psychological and behavioral characteristics, interests, and learning styles of them. This is the starting point for building a virtual game design framework. Secondly, the designing framework of virtual games should have multiple branching paths, with differentiated settings for game motivation strategies, learning content presentation methods, progress arrangements, etc. for each branch, and each branch needs to provide learning content and test questions of different difficulty levels. Specifically, the setting of difficulty levels should not only be matched with ASD children of different ability levels, but also match the learning needs of children in a differential order to continuously stimulate their participation motivation and learning interest. Once again, due to the differences in digital cultural experiences, avatars in virtual games should use national or ethnic character images to help ASD children better receive knowledge learning and emotional training. Finally, with the support of technologies such as big data and artificial intelligence, virtual game design can incorporate the ability to perceive and collect personalized features and needs of ASD children, thereby recommending appropriate learning resources and learning activity sequences, forming an self-adaptive learning path recommendation mechanism, and providing real-time data analysis and visual presentation functions, providing intelligent learning paths for the cognitive development and social skills improvement of ASD children.

4.4 Utilize VR Games to Cultivate ASD Children's Digital Literacy and Skills, and Promote Their Vocational Training and Employment

The information society has put forward new requirements for the digital literacy of every citizen. Currently, the employment rate of young people with autism in China is less than 10%, and the vast majority of parents believe that the vocational training and employment support needs of autistic children have not been met [34]. We should utilize ASD children's natural tendency towards digital tools and consciously and systematically use virtual reality games from primary school to cultivate their digital literacy. Starting from the middle school stage, vocational transition training [35] is initiated to develop the professional skills and digital literacy and skills of ASD children. At the same time, provide appropriate opportunities for them to explore their careers, help them clarify their personal work preferences, and determine their career direction.

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