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Application of Virtual Reality Technology in Pediatric Clinical Practice

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[Abstract] *the concept of Virtual Reality Technology (VR) was formally put forward in 1989. At the beginning of the 21st century, VR have developed together with children's education. Up to now, VR has made great achievements, especially with the breakthrough progress of 5G technology, which provides a strong technical support for the application of VR in children's education. Over the past 20 years, more and more medical staff have applied VR to pediatric clinical practice, which has significantly improved the effect of pediatric treatment and nursing, and effectively promoted the rehabilitation of children.*

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I. Introduction

Compared with adults, children's physiological and psychological functions are immature, the side effects of drugs are more obvious and lasting, and it is easier to have a negative impact on children's growth and development. At the same time, because children are highly suggestive and have poor self-control ability, they are easy to be affected by drugs or treatment, resulting in strong negative emotions and resistance behaviors, which affect treatment compliance.

VR [1] is a technology created by high-speed computer system, which is immersive and can get interactive experience with the virtual environment [1]. VR has the following four main characteristics: ① multi-channel perception. In addition to the visual perception of general computers, VR also has the perception characteristics of hearing, touch, motion, and even taste and smell. The ideal VR should have all the perceptual functions that human beings have. ② Presence, also known as immersion, refers to the degree to which users feel that they exist as protagonists in the simulated environment, that is, the virtual situation makes it difficult for users to distinguish between true and false. ③ Interaction, which refers to the operability of participants to objects in the virtual environment and the natural degree of feedback from the environment (including real-time). For example, he can directly grasp an object in the virtual environment with his hand. At this time, his hand has the feeling of holding the same real object, and he can feel the weight of the object. The captured object in the field of view immediately moves with the movement of his hand. ④ Autonomy, which refers to the degree of autonomous movement of objects in the virtual environment according to the requirements of operators and their own motion models and rules. For example, when pushed by an external force, the object will move in the direction of the force, or overturn, or roll from the desktop to the ground, and so on.

With the development of computer and human-computer interaction, VR is gradually infiltrating into various professional fields, such as aerospace, military, communication, medicine, education, art, entertainment, architecture and commerce. Over the past 20 years, more and more medical staff have applied VR to pediatric clinical practice and achieved good results, reducing discomfort and improving treatment compliance.

II. Application of VR in pediatric clinical practice

2.1 Application of VR in the of functional diseases in children

Amblyopia refers to those who have no organic lesions in eye examination and have corrected visual acuity ≤ 0.8 after cycloplegia examination [2]. The harm of amblyopia is not only that monocular vision can not be corrected to the normal level, but also that amblyopia affects the establishment of binocular vision, and the lack of perfect stereopsis leads to stereopsis blindness.

Traditional amblyopia training methods include covering method, fine eyesight training, CAM, red light flashing, etc., which have certain therapeutic effects, but the training process is relatively boring and single, and children's compliance with training is poor, which directly affects the therapeutic effect. "Visual Enhancement" is a intelligent multimedia visual enhancement training software for amblyopia which integrates the above methods, adopts early neural intervention theory and cognitive psychology theory and methods,

combines computer technology with VR to stimulate the brain nervous system, and makes full use of binocular fusion, stereopsis and the coordination training of hand, eye and brain under the condition of secondary projection to stimulate children's interest and potential.

Ren Xiaojun et al. [3] collected clinical data of 248 eyes of 172 children with amblyopia aged 5 ~ 8 who received "Visual Enhancement" training, including 97 boys and 75 girls. Statistical analysis was carried out according to the etiology, degree and fixation nature of amblyopia. The two parts of visual stimulation and fine visual of the "Visual Enhancement" were used for training for 6Mo. The results showed that the overall cure rate was 68.1%, the improvement rate was 23.8%, and the ineffective rate was 8.1%; the total effective rates of ametropia, anisometropia and strabismus amblyopia were 96.7%, 87.7% and 77.4% respectively; the total effective rates of mild, moderate and severe amblyopia were 98.2%, 86.2% and 61.9%, respectively.

2.2 Application of VR in the treatment of pediatric psychosomatic diseases

Psychosomatic diseases refer to those somatic organic diseases and somatic functional disorders in which psychosocial factors play an important role in the occurrence, development and prognosis of diseases. They are a category of diseases between somatic diseases and neurosis. There are many kinds of psychosomatic diseases, which can occur in various systems and organs of the human body, especially those dominated by autonomic nerves, such as pain, asthma, ulcer disease, ulcerative colitis, cancer and so on.

VR-assisted treatment of psychosomatic diseases mainly uses the principle of distraction to transfer the patient's attention from uncomfortable feeling or its accompanying bad mood to other stimuli. People can only focus on one thing at a time. If we shift the attention from the patient's uncomfortable feeling or bad mood to a task of interest, or engage in a job that can focus their attention, we can block the connection between conditional stimuli (such as disease) and responses (such as pain) and reduce the uncomfortable feeling. This is not to say that patients passively shift their attention from the feeling of discomfort to other things to cover up the still existing feeling of discomfort, but a process of active regulation, which can really reduce the response of neurons to harmful stimuli [4-5].

2.2.1 Application of VR in pain treatment

Pain is a complex physiological and psychological reaction. The nature, degree, temporal and spatial characteristics, discrimination and reaction degree of pain are restricted by a variety of psychological and social factors, which has an extremely strong subjective color. Pain signals can be regulated by psychological factors at any transmission level and link. Psychological factors such as attention, suggestion and emotion can change the pain response. Distraction, benign suggestion and joy can reduce pain response. Among the many factors affecting pain experience, attention to pain is particularly important. Therefore, distraction has become an effective means to reduce pain [4]. Ren Haixia et al. [6] randomly divided 160 5-8-year-old children with deep caries who needed to undergo pulpotomy treatment and accompanied by children's dental fear (CDF) (120 were mild CDF and 40 were moderate CDF) into mild fear VR group (group 1, 60 cases), mild fear notification demonstration operation (TSD) group (group 2, 60 cases), moderate fear VR group (group 3, 20 cases) and moderate fear TSD group (group 4, 20 cases). Group 1 and group 3 were operated on with VR glasses (VR groups), group 2 and group 4 were operated on with TSD behavior guidance (TSD groups). The results showed that the heart rateand pain grade of VR groups were lower than those of TSD groups, and the score difference of anxiety and treatment compliance before and after treatment were higher than those of TSD groups; All children in the VR groups said their eyes were completely free from fatigue, 95% said they were very comfortable and VR games were very interesting.

Wu Yujie [7] used the convenient sampling method to select 96 children with infected wounds who were treated in the wound clinic of a Grade A Class Three children's Hospital in Chongqing from November 2019 to January 2020 as the research objects. According to the treatment order, they were divided into the control group and observation group, with 48 cases in each group. During the dressing change process, they were given mobile video intervention and virtual video intervention respectively. The pain scores of the two groups before the intervention and on the first to third day of the intervention were evaluated and heart rate, dressing change time and adverse reactions were compared. The results showed that there was no significant difference in baseline data between the two groups before intervention; On the first to third day of intervention, the pain score, debridement heart-rate and dressing change time in the observation group were significantly lower than those in the control group.

2.2.2 Application of VR in cancer treatment

Cancer and its treatment are a strong stress for patients' physiology and psychology. Physically, it can cause fatigue, pain, vomiting, nausea, hair loss and other discomfort, and emotionally, it has adverse reactions such as depression, anxiety, anger, hostility, guilt and so on.

Many physical symptoms (such as pain, fatigue and vomiting) of patients with advanced cancer are

often unpredictable, long-lasting and difficult to alleviate which not only make patients have "anticipatory anxiety" about the occurrence of symptoms, but also brings inconvenience to the implementation of traditional psychotherapy with clear time limit. VR can effectively divert patients' negative attention to diseases, and is more suitable for cancer patients because of its flexibility in operation time.

Li et al. [8] divided 122 cancer children hospitalized in the oncology department into the control group (70 cases) and experimental group (52 cases) by using the experimental model of pre-post test and unequal group control. The control group received routine nursing, and the experimental group received 7 days of nursing assisted by VR game. Compared with routine nursing, the depressive symptoms of children in the experimental group on the 7th day were significantly less than those in the control group, but there was no significant difference in anxiety symptoms between the two groups. Schneider et al. [9] asked 11 children with cancer (aged 7-15) to experience one of the three scenes of "Magic Carpet Story of One Thousand and One Nights", "Legend of Sherlock Holmes" and "Seventh Guest" through VR system when they received chemotherapy. The symptom pain scale and state anxiety scale were used to evaluate the degree of symptom-related pain. The results of one-way repeated measurement (ANOVA) showed that VR could reduce the pain of patients receiving chemotherapy, but the effect was not lasting; The level of state anxiety was high at the first chemotherapy, but decreased at subsequent chemotherapy.

2.3 Application of VR in rehabilitation of special children

Special children (children with physical impairment, intellectual impairment, autism and other disabilities) have different degrees of physical or psychological disorders, and can not effectively perceive the exterior world through various information channels like normal children, resulting in unpredictable difficulties and even dangers in teaching and training. Compared with normal children, they are more sensitive, suspicious, inferior, introverted and unwilling to cooperate with training. VR simulation environment can improve the safety of teaching and training. Its immersion and closeness can reduce the interference with the real world, reduce the source of children's anxiety, and make them learn more easily and confidently, so as to achieve better results and greatly reduce the physical and mental burden of teachers and parents.

2.3.1 Application of VR in the rehabilitation training of children with physical disability

(1) Application of VR in rehabilitation training for children with limb disorders

The purpose of rehabilitation training and treatment for children with limb disorders is to master certain knowledge and skills, improve activity ability and enhance social adaptability [10]. It is not easy for them to recover from boring and boring movements in traditional training. In addition, the existing rehabilitation equipment can not organically combine the three aspects of function evaluation, exercise therapy and psychotherapy, especially can not put psychotherapy throughout the therapeutic process. VR can well solve the above problems, provide evaluation, assistance, monitoring, training and other technologies, and make the training effect more remarkable [11]. Children can not only train and interact with the virtual environment, but also see the feedback information provided by the VR system and adjust the training plan in time. This novel model can not only provide children with personalized training programs and quantitative evaluation, but also increase the interest of training and stimulate children's enthusiasm for treatment. Relevant studies have shown that children with limb disabilities can not only learn motor skills in the virtual environment, but also transfer the acquired motor skills to the real world and improve their life skills [12].

Wann and Turnbull of the University of Edinburgh in the UK developed a real-time computer feedback system (RTF) to treat children with limb disabilities by controlling different virtual game scenes. The results showed that children trained with RTF had better motor performance than children trained with traditional treatment schemes [13]. Huang Jingyuan et al of Tsinghua University have developed a "virtual reality fitness bike for rehabilitation", which enables children to train and restore the damaged lower limb motor function by riding a relaxed and pleasant bicycle [14]. Zhang Lixun et al [15]of Harbin Engineering University developed the "virtual reality simulation robot system for lower limb rehabilitation", which remotely monitors the motion state of the rehabilitation robot through the network, adjusts the control parameters of the rehabilitation robot online, and carries out virtual simulation at the control end, so that the therapist can intuitively understand the training state of children at the control end, providing a platform for the therapist to remotely guide children in rehabilitation training.

(2) Application of VR in the correction of hearing impairment in children

Hearing impairment refers to people's permanent hearing impairment in both ears to varying degrees due to various reasons. They can't hear clearly or completely the sound of surrounding and speech, which affects their daily life and social participation [16], and then leads to the lagging of thinking ability (especially thinking flexibility). The traditional intervention methods for hearing impairment are boring, single and repetitive, which

are easy to cause fatigue and boredom of children, thus affecting the effect of intervention. Since the 1990s, VR has been applied to the rehabilitation of hearing-impaired children [17], which has good applicability. A large number of studies have shown that, especially in language training, due to the variety of pictures, many colors and representational problems provided by VR, it can effectively stimulate the interest of hearing-impaired children, improve their language understanding and narrative ability, and then improve their time sequence perception ability, reasoning ability, thinking flexibility and spatial rotation thinking [18-24].

David Passig and sigal Eden [20], two researchers from Bar Ilan University in Israel, carried out research on using VR to help hearing-impaired children cultivate flexible thinking as early as 2000. They divided 44 hearing-impaired children with hearing loss ranging from 55 to 120dB into experimental group and reference group, and 16 healthy hearing children also served as the reference group. The children with hearing impairment in the experimental group were provided with a set of three-dimensional virtual reality rotating games (tetris, puzzle and filling), which were integrated into the desktop virtual reality device. The same game was provided to the control group in the traditional two-dimensional form. The study lasted one year. Before and after the study, Torrence test was used to evaluate the abilities of each group, including the ability to observe the object from different angles and think flexibly. The results showed that after one year of VR game intervention, the scores of hearing-impaired children in the experimental group were significantly improved, while the scores of hearing-impaired children in the control group were almost unchanged. The scores of hearing-impaired children in the experimental group are still not as high as those of healthy children who did not participate in game teaching, but they are very close.

2.3.2 Application of VR in the treatment of mental retardation

Zhou Hairong et al. [25] randomly divided 90 children with mental retardation aged 3~8 years into routine group (n=30), repetitive transcranial magnetic stimulation (rTMS) group (n = 30) and research group (n = 30) according to the ratio of 1:1:1. The routine group received routine rehabilitation, rTMS group adopted routine rehabilitation + repetitive transcranial magnetic stimulation, and the research group adopted routine rehabilitation + repetitive transcranial magnetic stimulation + virtual reality training. Before treatment, there was no significant difference between the three groups in the scores of Gesell Development Scale, revised Chinese edition of Wechsler Infants and Children Intelligence Scale and Infants and Junior Middle School Students' Social Life Ability Examination Scale. After 3 months of treatment, the development quotient score of Gesell scale, the IQ score of Wechsler Intelligence Scale for Infants and Children and the social life ability scale of infants and junior middle school students in the three groups were improved, and the scores of the research group were significantly higher than those of the other two groups.

2.3.3 Application of VR in limb rehabilitation training for children with cerebral palsy

Yoo [26] trained and evaluated the upper limb motor function of 18 children with spastic cerebral palsy with biofeedback and VR, and measured the EMG feedback function of upper limbs. The results showed that combined with VR, the training made the activation of triceps brachii muscle of children more effective, improved muscle imbalance and abnormal limb coordination, and promoted the flexibility of fine activities of the children's upper limbs.

Through meta-analysis, Rathinam [27] found that with the adopting VR, the recovery degree of hand function of children with cerebral palsy is inversely proportional to the age of the children and is directly proportional to the daily training intensity, which may be due to the negative correlation between brain nerve plasticity and age of children with cerebral palsy.

2.3.4 Application of VR in clinical practice of autistic spectrum disorder

Autism spectrum disorders (ASD) is a serious developmental disorders of nervous system. It is characterized by lack of communication and emotional response, language development disorder, stereotyped repetitive actions and strange response to the environment. Sensory processing difficulties, social skill defects and limited and repetitive behaviors, interests or activities are the core symptoms of ASD. After continuous and appropriate training and treatment, about 3% ~ 25% of children with ASD have reached or approached the normal level in adaptability, cognition and social interaction [28]. However, due to the lack of specific drug for the core symptoms of ASD, the relative shortage of qualified training institutions and employees, short supply and uneven level, the traditional treatment mode can not meet the actual treatment needs of ASD. Therefore, it is necessary to seek more convenient and popular intervention methods. Digital multimedia audio-visual integration system and VR have been gradually applied to the rehabilitation of ASD and achieved positive results. Compared with the traditional intervention training methods, the intervention method with VR has the advantages of safety, solving multi-source perceptual barriers, emphasizing visual skills and so on.

Wang Yuejuan et al. [29] randomly divided 70 children with autism into observation group and control group, with 35 cases in each group. The control group only received traditional behavior training, while the observation

group received digital audio-visual integration training on the basis of behavior training, 45 minutes a day, 15 days as a course of treatment, and the next course of treatment began after an interval of 2 months. After three courses of treatment, the scores of Autism Behavior Scale (ABC), Children's Autism Rating Scale (CARS), development quotient (DQ) or intelligence quotient (IQ), development status and characteristic symptoms of the two groups before and after treatment were evaluated and compared. The results showed that there was no significant difference in the scores of CARS, ABC and DQ (IQ), development status and characteristic symptoms between the two groups before treatment. After three courses of treatment, the scores of CARS, ABC, DQ and IQ of observation group were significant higher than those of control group. At the same time, the development status indicators (such as language normality, cognitive ability, social ability and self-care ability, etc.) and characteristic symptoms (eye contact, imitation action, imaginative game, repetitive stereotyped action, etc.) of observation group have been improved to varying degrees.

On the basis of fully investigating the application status of VR in intervention training for autistic children, Qi Jingyi [30] studied social skill training for autistic children based on WorldViz platform, and designed and implemented the program for intervention training of emotional understanding skills, life skills and social communication skills for autistic children. Then, the feasibility test and analysis of the scheme were carried out: 10 children with mild autism and 10 normal children (who needed to have the ability to express simple words and understand simple instructions) were selected to be trained with the above training program for eight days, 20 minutes every two days, a total of four times. Before and after the training, parents are asked to evaluate the social skills of the subjects according to the "Observation Table of Some Social Skills of Autistic Children" compiled by the researchers. The experimental results showed that the score of "Observation Table of Some Social Skills of Autistic Children" after training is significantly higher than that before training, and the score of normal children is significantly higher than that of ASD children.

Sha Qingqing [31] developed the VR game named “The Underwater World” by making model with 3Dsmax software and constructing scenes with Unity3D software.

Three autistic chilaren were asked to play the VR game and showed concentrated attention and less problem behaviors than real enviroment with occasional emotional behavior. They learned the training content and preliminarily grasped the skills of dialogue and retelling.

2.3.5 Application of VR in teaching and training of children with intellectual disabilities

Children with intellectual disabilities show obvious lag in intelligence and social adaptability. VR can provide such children with safe and real situations to improve their learning effect and life skills. Its ease of use, interest and applicability also make it an ideal choice for this special group to receive teaching and training. Yalon- chamovitz and Weiss [32] conducted a comparative study of 33 children with moderate mental retardation and severe cerebral palsy for 12 weeks (ie, VR game activities 2-3 times a week). The results showed that children with intellectual disabilities can successfully understand and participated in VR games, and showed continuous interest in learning. Wuang et al. [33] compared the therapeutic effects of standard occupational therapy and Wii game based VR on children with intellectual disabilities. The results showed that the Wii game group had a great improvement in visual comprehensive ability and even sensory integration ability, and the Wii game technology had advantages in improving the sensory function of children with intellectual disabilities. Attree et al. [34] studied five groups of children with intellectual disabilities and found that VR technology promoted the improvement of their daily life skills and enhanced their cognitive and social skills.

2.4 Application of VR in clinical practice of children with behavioral disorders

Children's behavior disorder is a kind of non adaptive behavior that occurs in the process of children's development and exceeds the normal range (5% - 15%) allowed by the corresponding age in severity and duration. It is mainly manifested in the obstacles of continuous attention, executive function, memory and learning. Clinically, the mode of "removing etiology + psychotherapy + drug" is usually used to treat this obstacle. Due to the side effects brought by long-term medication, the treatment compliance is poor and the curative effect is poor [35].

2.4.1 Application of VR in clinical practice of attention-deficit / hyperactivity disorder (ADHD)

ADHD is a behavioral emotional syndrome characterized by persistent inattention and hyperactivity impulse. It is one of the most common behavioral disorders in childhood [36]. The prevalence rate in children and adolescents in China is about 5%, mostly boys [37]. Children with ADHD may be unable to complete their studies, prone to interpersonal conflict and suffer from various mental and psychological diseases [36].

VR can be used to diagnose ADHD. VR can control a series of noises in the virtual system as interference stimuli, so as to effectively distinguish children with ADHD. A large number of studies have shown that VR is effective in the auxiliary evaluation of ADHD. Compared with the classical neuropsychological test,

VR is equivalent or even more effective in auxiliary evaluation. Pollak et al [38] asked 20 children with ADHD and 17 normal children to complete VR assisted continuous task (VR-CPT), then routine continuous task (no VR-CPT), and finally accept the general attention index test (TOVA). The results showed that children with ADHD performed worse than normal children in the above three tests, and the experimental utility of VR-CPT was equivalent to that of TOVA. Iriarte et al. [39] adopted AULA VR tools to conduct a cross-sectional study with sufficient subjects (n=1272). The results showed that: ① the overall executive function of boys was worse than that of girls; ② the inattention and impulsivity of low-age children were more obvious than those of high-age children; between the ages of 6 and 11, the symptoms of inattention and impulsivity of children gradually improve and decrease with the increase of age, but the changes in the age group of 12 to 16 were not obvious; ③ in the presence of interference factors, children's behavior was worse. The study suggests that age, gender and other factors may affect the experimental results, whether to take drugs at the same time and the executive function of different subtypes may also be different.

2.4.2 Application of VR in clinical practice of various behavior disorders of children

VR can also be used to treat a variety of children's behavior disorders. It uses the plasticity of the nervous system, activates various sensory pathways through specific sensory stimulation and the training of hand-eye coordination ability, improves the signal processing ability of the nervous system, and achieves the purpose of treating problems in emotion, attention, learning and so on. VR can induce children's strong excitement by presenting high-intensity stimulation, effectively attract their attention, and constantly change the excitement points to keep their attention on treatment for a long time. Its advantages are combination of dynamic and static, interesting, personalized training scheme, quantitative training results, safety and no side effects. Deng Xianghong et al. [40] used the "Perceptual Learning Virtual Reality Training System" to carry out targeted training for children with attention deficit disorder, and tested their attention with digital cancellation experiment. The results showed that after 6 months of training, most children's problem behaviors decreased, their attention concentration time prolonged, and their attention deficit improved. In addition, the improvement of cognitive function obtained by these children after training can be easily transferred to the situation of daily life, so as to completely improve the symptoms of attention deficit. Cho et al [41] randomly divided 28 children with attention disorder (impulse disorder) into VR group, no-VR group and control group. In eight experiments in two weeks, VR group received biofeedback training in VR system through helmet mounted display and tracker; No VR group used common computer to watch pictures from a fixed angle and received biofeedback training; The control group did not receive the intervention. Before and at the end of the experiment, continuous operation test (CPT) was used to understand the attention of three groups. The results showed that after training, attention of VR group was the best, no VR group was the second, and the control group was the worst.

III. Advantages and limitations of VR in pediatric clinical practice

3.1 Advantages

The pediatric clinical practice based on VR is equivalent to the traditional psychotherapy in terms of treatment conditions such as informed consent, confidentiality principle, professional qualification of therapists and treatment environment, and there are no special clinical and ethical limitations [42]. The interest, immersion and interactivity of VR psychotherapy are in line with children's cognitive law. The comfort and compliance are higher than the traditional pediatric clinical practice, and the risk is lower than the traditional pediatric clinical practice.

In theory, VR can construct any scenes that people need, especially the scenes that do not exist in nature or the environment that is not easy to recreate, so children can be treated in a comfortable and safe artificial environment. The treatment plan can be customized and the treatment efficiency is high; The same scene can be repeated to consolidate the curative effect; Connecting VR system with the Internet can not only collect and store clinical data, but also carry out standardized remote treatment, increase the scope of benefits and reduce the cost of treatment.

3.2 limitations

First, children's understanding of reality is blocked. VR system emphasizes that the user's senses are isolated from the real world and completely immersed in an information space completely controlled by the computer, which usually needs the help of special display equipment (such as immersion helmet mounted display). Therefore, children can't see the real environment, which hinders their understanding of the real environment.

Second, the technology is far from mature. ① VR provides the possibility to solve the contradiction between experimental control and ecological validity. However, transplanting the real scene into the virtual space will inevitably lose some elements or details, thus reducing the ecological validity. In other words, the current VR can not well solve the contradiction between experimental control and ecological validity. The

improvement of its ecological validity also depends on the improvement of hardware performance and careful preparation of software. This is very difficult to do, because it is difficult for us to create different virtual environments according to the characteristics of various patients. Even if the system is required to accurately reproduce a simple real environment, it needs to pay a huge price, Under the current technical conditions, it is difficult to achieve ideal results, and its fidelity can not fully match the human sensory ability. ② The real-time display of three-dimensional graphics requires a lot of accurate calculation. In the actual operation, there is often a time lag , which will affect the accuracy of operation, so that the operator can not timely and effectively use the feedback information to correct the current action. ③ It is very difficult to establish a high-quality virtual laboratory, mainly because the technology is very expensive.

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