The Application of Virtual Reality Technology in Clinical Practice of Psychiatry

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Abstract: *Virtual reality (VR) is a comprehensive information technology that combines sensing technology, simulation technology, human-machine interface technology, network technology, and other technologies. It has three major characteristics: interactivity, immersion, and imagination. In recent years, with the vigorous development of the VR industry, more and more VR technologies have been applied to clinical practice in psychiatry, and the applicability has been proven effective by a large number of studies both domestically and internationally. This article takes the treatment of neurosis and schizophrenia as examples to illustrate the current status and progress of virtual reality technology in clinical practice of psychiatry.*

I.   Introduction

Virtual Reality (VR) technology, also known as Spirit Realm technology, mainly utilizes computer systems to synthesize 3D image environments from digital data, creating a virtual environment with multiple senses of sight, hearing, smell, and touch. Through input devices, it collects reaction and motion information of users, changes the virtual environment accordingly, and allows users to interact with the environment, create an illusion of immersion in the environment and an immersive experience [1].

VR has the following three main characteristics: First, imagination. Also known as creativity, it is the starting point of the virtual world. Imagination enables designers to conceive and design virtual worlds, and reflects their creative thinking. Second, immersive, also known as presence, refers to the degree to which users feel that they are the protagonist in a simulated environment, to the extent that virtual situations make it difficult for users to distinguish between true and false. The ideal virtual reality environment should allow users to fully immerse themselves, providing a high degree of realism in visual, auditory, tactile, taste, and other aspects, making users feel like they are in the real world. Third, interaction, it refers to the degree to which participants can manipulate objects within the virtual environment and the natural level of feedback received from the environment (including real-time performance). For example, he can directly grasp an object in a virtual environment with his hands, and at the same time, his hands have the feeling of grasping the object, and he can feel the weight of the object. The object caught in the field of view also immediately moves with the movement of his hands. Fourth, imaginative, it refers to the degree to which objects in a virtual environment move autonomously according to the requirements of the operators and their respective motion models and rules. For example, when pushed by an external force, a ball will move in the direction of the force, flip over, or fall from the desktop to the ground [1].

With the development of computers and human-computer interaction methods, VR technology has made significant progress and gradually penetrated into various professional fields, such as military, aerospace, communication, commerce, medicine, architecture, education, entertainment, and art. In the past decades, more and more researchers have applied VR to clinical practice in psychiatry, achieving good results.

II.   The application of VR in clinical practice of psychiatry

2.1 Application in mental assessment

Traditional mental assessment mainly uses paper-pencil tests, computer tests, behavioral observation, self-reporting, and clinical interviews as the main means. Although these evaluation methods are widely used, most of them are implemented in laboratories, which are significantly different from real-life scenarios. Moreover, they are time based evaluations and far from the patients' overall mental state, resulting in low ecological validity. The application of VR technology can revolutionize mental assessment. The main application form of virtual reality in mental assessment is to allow evaluators and doctors to design a testing scenario and evaluate patients' cognitive abilities, emotions, behaviors, and physiological responses by setting some tasks in the scenario. During the evaluation process, the images generated by the device on the head are

synchronized with the user's actions. Patients move and interact with the virtual world through head movements, full body rotation, or joystick movements, while sound is presented through speakers or headphones. In some VR environments, users can even experience tactile feedback, allowing patients to feel personally present. It can be seen that VR based evaluation can simulate real-life scenarios, enhance the authenticity of participants' experiences, and is easy to operate, can be implemented anytime and anywhere, with high ecological validity.

2.1.1 Virtual Apartments

Virtual apartments are mainly used to observe the behavior of patients at home, in order to evaluate their cognitive impairment and medication self-management skills. Henry et al. [2] designed a virtual environment and presented visual and auditory dual channel go/no-go tasks and Stroop tasks on the operating system of the TV in the apartment. The subjects wore Head-Mounted Displays (HMDs) and completed the task in a VR environment throughout the entire process. The researchers also set up three types of strictly controlled interference stimuli during the task process: the first type is audio-visual interference, such as school buses and off-road vehicles passing by the window, mobile phones vibrating on the coffee table, and toy robots walking on the floor; The second category is visual interference, including paper plane passing through the room and women passing through the kitchen; The third type is auditory interference, including the sound of paper wrinkling, doorbell ringing, clock ticking, vacuum cleaner sound, pencil falling on the ground, and airplane flying over the roof. The results indicate that this study can not only evaluate attention and inhibition functions from multiple aspects (including selective attention, inhibition of internal and external interference, inhibition of single and multiple interferences, etc.), but also strictly control the test-environment stimuli. It has the characteristics of simple operation without time and space constraints, short-time consumption, pleasant, and portable.

2.1.2 Virtual store

Virtual stores are generally used to evaluate the execution of daily behavior and measure the execution function of participants. At present, virtual store environment built on VR technology are often used in conjunction with multitasking tests, which can effectively measure subjects' perceptual ability, memory, problem-solving ability, execution planning ability, prospective memory, and other executive functions. Therefore, it can be widely used in the evaluation of Alzheimer's disease, Parkinson's disease, brain injury, and schizophrenia.

Josman et al. [3] evaluated and compared the performance of 23 stroke patients (average age 59.1 ± 5.5 years old), 27 mild cognitive impairment patients (average age 69.5 ± 7.3 years old), and 30 schizophrenia patients (average age 46.7 ± 10.6 years old) in a medium-sized virtual supermarket, with middle-aged and elderly individuals as the research subjects. The supermarket has 4 cash registers, involving virtual characters such as cashiers, fish vendors, meat vendors, and customers. The participants first familiarize themselves with the scene through the practice session, and then undergo an open-ended shopping test, which involves purchasing 7 items based on the shopping list. Participants are required to perform 12 behaviors simultaneously during shopping. If they repeatedly select products or leave the supermarket without checking out, it will be considered as execution failure. The system records information such as the execution time, path, number of stops, and quantity of purchased goods of the participants. The test results indicate that although the execution of schizophrenia patients is similar to that of stroke patients, there are significant differences in five aspects: overall execution time, number of purchased products, etc. For patients with mild cognitive impairment, although they may experience the most staying and failing behaviors, they are still able to complete shopping tasks. For patients with schizophrenia, although their execution time is the shortest and their stay is the least, 14 patients (47%) may neglect to check out and leave. Among these three groups, stroke patients performed the best. Based on the above evaluation results, over 70% of the participants can be correctly classified.

2.1.3 Virtual classroom

The virtual classroom assesses attention by incorporating cognitive tasks such as continuous operation test tasks, and can be used to identify attention deficit hyperactivity disorder (ADHD). In a virtual classroom scene, the basic facilities include tables and chairs, a lecture table, and a blackboard or whiteboard, and the characters in the environment include a teacher and several students. Researchers can modify the number of interfering components and other parameters in the virtual scene based on the age, grade, or other experimental needs of the subjects. They can also directly build virtual classroom scenes based on the classroom environment in which the subjects learn in real life. The system will evaluate the attention of participants based on their reaction time and error rate during execution task. This new method can be applied to children or adolescents for attention assessment, and can effectively evaluate the attention persistence of children with ADHD, and the inhibitory and control ability of children with autism [7].

Rizzo et al. [4, 5] evaluate the attention status of ADHD children using virtual classrooms as scenarios. The basic facilities in the scene include arranged tables and chairs, a teacher's desk, and a blackboard, with characters involving several elementary school students and a teacher. You can see the playground and the streets where vehicles come and go through the classroom window. Students are generally required to wear Head-Mounted Displays (HMDs) to sit in front of a virtual desk and perform certain age-related tasks. Indoor noise, student movements, and activities outside the window become interfering elements. According to the needs of the evaluation task, the tester can change parameters such as student position, number of students, teacher gender, etc. at any time. The system measures the attention of participants by recording their reaction time and number of errors during task execution. This system can be used to evaluate attention components such as selective attention, sustained attention, and divided attention.

2.1.4 Navigation in a virtual environment

Weniger et al. [6] proved the difference of self-centered navigation ability between AD and MCI patients by asking them to remember the route of the virtual park, which is consistent with the results of traditional cognitive assessment. Cushman et al. [7] tested and compared the memory and navigation abilities of AD patients and normal elderly people in virtual and real environments. They provided path demonstrations in both the real and virtual worlds, and then evaluated the cognitive function of the patients from aspects such as route recall and free recall of seeing objects on the route. The study also confirmed that there was no significant difference in the performance of participants in the real and virtual world, and cognitive assessment based on VR technology had good ecological validity.

2.2 The Application of VR in Clinical Training and Consultation

There are various ways of psychotherapy, each with its advantages and disadvantages. For example, cognitive therapy, psychoanalysis, family therapy, etc. are all a process of helping individuals by guiding their memories and imagination through corresponding technologies, but each has its own limitations [8]. Constructivist theory holds that when an individual is exposed to external stimuli, if it is an experience that has not been experienced in the past in the brain, they will construct the stimulus based on their existing experience in the brain and the cognitive content of the outside world, but it will differ from the original statement. The generation of such results will have an impact on some psychological counseling and treatment techniques, such as imaginative relaxation therapy. And virtual reality technology, with its sense of authenticity, makes the simulated environment difficult to distinguish between true and false, which can effectively assist visitors. One of the major features in virtual technology is immersion, which allows visitors to experience the consultant's description firsthand through visual and auditory immersion of users, as well as matching sounds, actions, and other three-dimensional graphics, ensuring that the consultation achieves the expected results [9]. By combining the relevant characteristics of virtual reality technology with psychological counseling or treatment, scholars or counselors at home and abroad have achieved considerable results.

2.2.1 Application in counseling skill training

Scholars have applied VR technology to the training of psychological counselors, believing that VR technology can be used to simulate visitors in psychological counseling and safely and effectively cultivate clinical skills. The facial expressions and movements of virtual visitors can be obtained by capturing the facial expressions and movements of real visitors in videos of consulting work. In addition, this system can also provide feedback based on the trainees' performance. If the trainees' performance is appropriate, the virtual visitor will jump on the background and show a scene of progress; If the trainee's performance is not correct, the virtual visitor will continue to start at the point where they were interrupted just now, not only will they not make progress, but they will gradually perform worse. In this way, VR can encourage trainees to improve their skills [8].

2.2.2 Application in Psychological Counseling Work

Researchers have combined VR technology with artificial intelligence to develop a system called "Super Clinician". This system can provide virtual psychological counselors for visitors. This virtual psychological counselor can capture clinical related information such as facial expressions, blinking, and voice features of visitors by artificial intelligence technology, and can remotely obtain relevant data of visitors. VR technology can also be used to simulate the counselor's expressions, movements, and other aspects to complete interaction and dialogue with visitors [8].

2.3 The Application of VR in Psychotherapy
2.3.1 The Application in the treatment of neurosis
Neurosis belongs to functional mental disorders, with no verifiable organic lesions as the basis for symptoms.

The main cause is mild dysfunction of brain nerve function, coupled with poor personality and unreasonable cognition. Most of patients are unwilling to face real-life experiences and cannot verify and correct existing unreasonable cognition or assumption in real life. The immersion and closure of VR enable patients to isolate themselves from adverse external stimuli, thereby relaxing their emotions, which fidelity can help patients better test existing hypotheses and correct unreasonable cognition.

⑴ The Application in Phobia and Anxiety Disorders

Exposure therapy is generally used to treat these problems. Exposure therapy is a treatment approach that involves exposing patients to stimuli that trigger their symptoms for a long time, allowing them to adapt to the progression of anxiety and terror, thereby eliminating symptoms, changing their perception and understanding of stimuli, and establishing new behavioral patterns [10]. The common techniques used in traditional exposure therapy are real-life exposure and imaginative exposure. Real-life exposure requires enormous manpower and financial resources, often accompanied by danger; Imagination exposure requires every patient to be able to imagine a certain situation, and requires high imagination ability of patients. Virtual reality technology can effectively solve these problems. It integrates the functions of computer graphics technology, body motion tracking, visual presentation systems, and other sensory input systems to provide patients with vivid forms of exposure, presenting comprehensive exposure scenarios for patients to experience and interact with, immersing them in a virtual environment, gradually exposing the things they fear and increasing exposure levels, increasing their fear threshold, and improving symptoms. VR can also eliminate the harm caused by uncontrollable factors in real exposure scenarios, such as patients' strong terrorist reactions, ensure their personal safety, and save treatment time. At present, VR has been applied to the treatment of various forms of phobia and anxiety disorders such as acrophobia, animal phobia, flight phobia, social phobia, and speech anxiety.

Roy et al. [11] used VR technology for the treatment of social anxiety disorder. They established four different virtual social scenarios: speaking to virtual listeners in a virtual conference room, chatting with virtual friends, receiving attention from virtual customers and servers in a virtual coffee shop, and patients' own interests being violated by virtual characters. Researchers placed a female patient with severe social anxiety in these four different virtual scenarios and then treated her multiple times using behavioral cognitive and exposure therapy. During the treatment, it was found that the psychological and physiological reactions of the patient in various virtual social scenarios were basically the same as those in real life. After a period of treatment, the patient's social anxiety symptoms were significantly reduced, and the follow-up examinations also showed that the treatment effect was quite stable.

The use of VR is to activate the fear or anxiety structure of patients by confronting suspicious stimuli. However, there are still some unresolved issues in the treatment of specific phobias and anxiety disorders. Some scholars believe that the susceptibility of patients exposed to virtual environments may increase [12].

⑵ The Application in eating disorders

Self-image disorder is one of the most prominent clinical indicators of eating disorders (Nye & Cash, 2006), and it is also one of the most important related prognostic factors for bulimia nervosa and anorexia [13]. VR is used to solve self-image disorders and treat eating disorders.

Marco et al. [14] selected 34 Spanish women diagnosed with anorexia (average age 21.82 years old) as participants. The Patients were randomly divided into an experimental group and a control group. The researchers used VR to generate 5 regions in virtual environment to cooperate with the treatment of the experimental group. Zone 1 is a virtual scale designed to distinguish and understand the concepts of real weight, subjective weight, ideal weight, and healthy weight, reminding patients not to use unrealistic rules to learn weight. Area 2 is the body size photo area, which allows patients to understand that the weight they value is related to gender, height, and physical fitness. Patients are encouraged to evaluate their physical condition based on the body image presented in the area. Zone 3 is the mirror area, which compares the patient's imagined body image with their actual body image, making them understand from different angles such as the front and side that they have exaggerated their body size. Patients need to operate a 3D manikin to increase or decrease a certain area, forming their own cognitive body model until it is aligned with the real manikin in another mirror. Area 4 is a door frame with colored bands, and patients must remove a certain number of colored bands to form a precise space for them to pass through this door frame horizontally. Area 5 presents five different body types, allowing patients to understand the difference between their actual, ideal, and healthy body types, as well as how others perceive them. The setting of the five areas conforms to the principle of gradual progression in psychotherapy. Regions 1, 2, and 3 can help patients recognize the importance of their own image recognition, distinguish between the body and body image correctly, do not feel uncomfortable just to change the body image, and take the consequences of body image distortion seriously and understand how everyone's body image is formed. Areas 4 and 5 aim to change patients' incorrect attitudes and beliefs about their body and

appearance. The exposure of a patient's true image can promote the establishment of new positive connections between themselves and their own body. The research results showed that 30 participants (4 of whom withdrew from treatment) significantly improved their self-image disorder, and the treatment effect of the experimental group was significantly better than that of the control group.

Another study [15] pointed out that VR assisted relaxation training can reduce anxiety and depression of obese patients with bulimia nervosa, improve their self-efficacy of weight loss, and reduce their weight. This effect can be maintained until 3 months after follow-up. Riva et al. [16] combined virtual reality and cognitive-behavioral technology to treat eating disorders and obesity. The treatment results showed that both groups of patients changed their dissatisfaction with their bodies, gained a reasonable understanding of their physical appearance, and showed strong motivation for change.

Cognitive behavioral therapy is often used for the treatment of eating disorders. Related studies have confirmed that eating disorders are directly related to patients' body image intervention. However, traditional cognitive behavioral therapies for treating eating disorders lack a focus on body image treatment [14]. The treatment of eating disorders using virtual reality technology mainly focuses on providing patients with operable and controllable body image treatment plans.

⑶ The application in post-traumatic stress disorder

Post traumatic stress disorder (PTSD) is a mental disorder caused by sudden, threatening, or catastrophic life events that delay or persist for a long time. Its clinical manifestations are characterized by re-experiencing trauma, accompanied by emotional irritability and avoidance behavior. Crisis intervention is the main treatment method for PTSD. At present, the main intervention measures include cognitive behavioral therapy, psychological relief, Severe stress inducing and relieving therapy, imaginative memory therapy, and so on. VR allows patients to expose trauma-related reactions (painful memories, related physiological and behavioral responses) in a relatively safe environment through prolonged or repeated exposure to the stress state, enabling them to continuously learn coping skills and adapt to the stress state. Ultimately, it is possible to correctly distinguish between safe and dangerous situations [17], which can more quickly and effectively reduce the high alertness and excessive fright of PTSD patients, reduce their psychological stress levels, improve their cognitive and coping abilities [18], improve their stress management skills [19], and reduce their flashbacks, avoidance, and emotional problems [20]. Many active duty soldiers refuse traditional talk therapy because they are afraid that the content of the conversation will be learnt about by colleagues and superiors and affect their career development, but are willing to receive VR mental treatment.

A survivor of the 9/11 terrorist attack diagnosed with acute PTSD, who failed to receive traditional imaginative exposure therapy, and received virtual reality exposure therapy. During six 1-hour virtual reality exposure treatments, the patient gradually became exposed to the 4 virtual scenes of "airplane flying towards the World Trade Center", "airplane colliding into the World Trade Center, accompanied by intense explosions and sound effects", "virtual humans jumping from burning buildings to death" and "twin towers collapsing, raising layers of dust clouds". The scores on the Self-rating Depression Scale showed a significant reduction in depressive symptoms in the patient (83%), while the scores on the Doctor-administered Depression Scale used showed a significant reduction in symptoms of PTSD (90%) [23].

The "virtual reality" treatment system developed by the United States can help soldiers who have served in Vietnam and Iraq overcome anxiety symptoms. Some soldiers, after returning from the battlefield, often immerse themselves in the memories of past wars filled with gunpowder, unable to forget those terrible experiences. Virtual reality exposure therapy can allow soldiers to enter virtual Vietnam and Iraq, experience the situation they face while on duty once again, in order to improve their ability to control their own memories and help soldiers with mental problems return to normal living conditions [22]. Reger et al. [22] used virtual reality technology to treat an active army soldier diagnosed with PTSD in war. They used an immersive virtual environment that simulated the Iraq War, consisting of six stages. The study provides two virtual scenes, namely the escort convoy scene and the hiking patrol scene in a certain city in Iraq. The patient can stay in the driver's seat of a car in a virtual scene, or sit in the passenger seat or tower. The convoy needs to pass through vast deserts, vast palm forests, or towns and villages in Iraq. The treatment room can activate audio and visual stimuli related to war, such as improvised explosive devices, explosions, mortars, casualties, etc., and ambushes can occur at any time in virtual scenes. After six stages of treatment, it can be seen that the patient's condition has significantly improved and discomfort symptoms have been significantly reduced, whether from the patient's self-report or family members' evaluations.

2.3.2 Application in the treatment of schizophrenia

The main characteristics of schizophrenia are basic personality changes, distorted thinking and perception, emotional dullness, and disharmony between mental activities and the environment. General psychotherapy has significant limitations because patients have resistance to treatment, therapists often find it difficult to grasp the patient's emotional fluctuations, and it is also difficult to confirm that their perception and thinking are distorted. The gameplay and fun performance of VR can reduce patients' resistance, improve treatment compliance [23], alleviate anxiety, reduce stress [24], help them better receive admission education, improve their language learning delay, improve their thinking speed [23] and cognitive function [25], and improve negative symptoms, psychopathological characteristics, social anxiety, depression, social avoidance, and social dysfunction, with fast onset and long-lasting therapeutic effect [25, 26]. At present, VR can be used in seven major aspects of schizophrenia treatment: symptom assessment (mainly for delusions of victimization), establishment of symptom correlation, prediction and identification of disease-related variables, prediction and identification of symptoms, prediction and identification of disease-related environmental factors, establishment of etiology, and progress in treatment [27].

VR is also used to simulate patients' hallucinations and delusions, creating an illusion avatar. Presenting these virtual hallucinations to them to face and understand the hallucinations are purely pathological, unreasonable and unreal, and requires specialized treatment, thereby improving patients' self-control and treatment compliance. At the same time, it is also hoped that through VR, refractory patients can adapt to various hallucinations in life and improve their social function. Using this technology requires creating virtual illusions based on the hallucination characteristics of each patient, which has a high degree of difficulty. At present, this therapy is still in the experimental stage [2].

III. Advantages and limitations of VR

3.1 Advantage

First, VR psychotherapy is similar to traditional psychotherapy in terms of clinical conditions (such as informed consent, confidentiality, professional qualifications of therapists), treatment environment, patient comfort and risk, and there are no special clinical or ethical limitations [28].

Second, VR technology can construct any scenario that people need, even scenes that do not exist in the real world, or environments that are difficult to recreate. The parties involved undergo treatment in a safe, comfortable, and convenient artificial environment, which saves time and has high compliance; The treatment plan can be personalized and customized; The same scenario can occur repeatedly, facilitating the consolidation of therapeutic effects; The system can obtain feedback information on treatment through multiple sensing devices and store relevant data; By connecting the system to the internet, standardized remote treatment can be carried out, increasing the scope of benefits and reducing treatment costs.

Third, the real experience created by VR can help counselors more effectively challenge the hypothesis of maladaptation of the parties involved. Since VR can safely and effectively help the parties focus on behavior, guide change, experience themselves, and challenge the original assumptions, it can enhance the parties' self-efficacy in and outside the consulting situation.

Fourth, psychological counselors can combine VR technology with their preferred treatment methods. For example, cognitive therapists can use VR scenarios to evaluate situational memory or disrupt patients' habitual selective attention patterns; Behavioral therapists can use VR to isolate individuals from the external world and help them practice correct behavior; Psychodynamic therapists can use VR environment as a complex symbolic system to evoke or release emotions.

3.2 Limitations

VR can effectively improve the efficiency of psychotherapy, supplement and assist various existing treatment orientations, but it cannot replace existing psychotherapy.

First, the effectiveness of VR technology is limited by both patients and therapists. Some personal characteristics of the patients involved (passive involvement tendency, concentration, and suggestiveness) limit the generation of a sense of presence, and VR can have side effects on some people; The doctor-patient relationship and the computer skills of consultants will also constrain the popularization of VR technology.

Second, the parties' understanding of reality is hindered. VR systems emphasize isolating users' senses from the real world and immersing themselves completely in an information space controlled by a computer. This usually requires the use of specialized display devices (such as immersive helmet mounted displays), which prevents users from interacting with the external real environment and hinders their understanding of the real environment.

Third, the technology is not yet mature. ⑴ VR technology provides the possibility to solve the contradiction between experimental control and ecological validity. However, transplanting a real laboratory into a virtual world inevitably loses certain factors or details, leading to a decrease in ecological validity.

Therefore, VR cannot completely solve the contradiction between experimental control and ecological validity. The improvement of its ecological validity also depends on the improvement of hardware and the careful preparation of software, which is not easy to achieve because it is difficult for us to create different virtual environments based on different types of patients. Even making the system accurately reproduce a simple environment requires a huge cost, and the results may not be ideal under current technological conditions, and its fidelity is always not fully matched with human sensory abilities. ⑵ The real-time display of 3D graphics requires a large amount of accurate calculations, which may lead to time delay during actual operation. The existence of time delay will affect the operation, making it difficult for the operator to effectively utilize feedback from previous actions to correct the current action. ⑶ There are great difficulties in establishing high-quality virtual laboratories, mainly due to the high technical costs. ⑷ The objective measurement of therapeutic effects and other issues also constrain the application of VR in psychotherapy.

In summary, VR has broken through the limitations of traditional psychotherapy techniques, providing a realistic and entertaining on-site experience, a controllable personalized training environment, and strong safety. Its application in psychotherapy is becoming increasingly widespread. From the perspective of the development of VR technology, commercial operation contributes to its popularization, and the development of computer and network technology helps to promote the application of remote VR. However, the clinical skills of consultants themselves remain the key to the successful application of VR.

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