Current Medical Science
DOI https://doi.org/10.1007/s11596-019-2093-4
39(5):690-694,2019

Application of Virtual Reality Technology in Disaster Medicine*

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Summary: The occurrence of major emergencies often leads to environmental damage, property damage, health challenges and life threats. Despite the tremendous progress we have made in responding to the many challenges posed by disasters in recent years, there are still many shortcomings. As an emerging technology widely used in recent years, virtual reality (VR) technology is very suitable for many fields of disaster medicine, such as basic education, professional training, psychotherapy, etc. The purpose of this review article is to introduce the application of VR technology in the disaster medical field and prospect its trend in the future.
Key words: virtual reality; disaster medicine; education; psychotherapy

Disaster medicine as a new subject has developed rapidly in recent years, and the related teaching, training and research have been steadily advanced, which has continuously promoted the development of disaster's prevention, rescue and reconstruction. With the rapid development of computer technology and internet and other electronic information technologies, some new technologies are gradually being applied in disaster medicine, in which virtual reality (VR) technology characterized by custom scenes, real-time dynamic interaction, and autonomous operation[1, 2] have been paid great attention to.

1 VR and Disaster Medicine

VR is a cutting-edge technology in the information technology (IT) field, a computer simulation system that can create and experience virtual worlds[3]. It uses the computer to generate a simulation environment, and combines the multi-source information, interactive three-dimensional dynamic vision and physical behavior, highlighting the characteristics of perceptuality, interactivity, and autonomy[4], so that users are immersed in the fictional environment.

Disaster medicine refers to a new interdisciplinary subject related to disasters, including public health, emergency medicine and disaster management, which mainly studies emergency medical rescue, and disease prevention, control and cure, and mental health problems before and after disasters[5]. At present, the international community is facing the severe national security situation and various major natural disasters and man-made disasters often occur. However, disaster medicine has just started in many country and has not yet provided favorable support for disaster relief. Therefore, we should pay more attention to the construction of this discipline.

2 History and Current Status of VR

Professor Sutherland[6], an important founder of Computer Graphics, published a paper entitled "The ultimate display" in 1965, proposing a new theory of human-computer collaboration, which is characterized by real feeling and interaction, and depicting a new display technology, with which users are directly immersed in a computer-controlled virtual environment and interact with objects in the virtual environment in a natural way. He invented the helmet-mounted stereo display in 1968, which is considered the first VR device. During the 1980s, with the rapid development of computer technology, communication technology, human-computer interaction technology and the Internet, VR began to appear in the military and

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The original version of this article was revised due to a retrospective Open Access order.
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*This study was supported by grants from the National Natural Science Foundation of China (No. 81974355), Major Project of Technological Innovation of Hubei (No. 2018AAA067), Excellent Projects Funded by Science and Technological of Returned Students from Ministry of Personnel and Social Affairs (No. 2016-176).

aerospace fields[7, 8]. In the 21st century, VR technology is developed rapidly and has been widely used in the fields of entertainment, architecture, transportation, industry, archaeology, culture and even medicine from the initial military and aerospace fields[9]. And its application in the medical field is much more significant.

3 Application of VR in Disaster Medicine

The occurrence of natural disasters and man-made disasters is sudden. There is no technology that can effectively prevent disasters from occurring, but through appropriate education and training, injuries can be minimized and life can be saved[10–12]. However, through the analysis of the paper of disaster medical rescue, it is not difficult to find that the development of disaster medicine still has obvious shortcomings in disaster prevention, rescue, reconstruction and so on. The combination of VR and disaster medicine is currently the most promising development direction. With VR's unique three-dimensional computer graphics, stereo display, dynamic capture and other technologies[13], it can be applied to many aspects of disaster medicine, and it is expected to overcome the bottleneck in disaster medical development. Moreover, VR will revolutionize the development of disaster medicine, especially in education, professional training, popularization of knowledge, and psychotherapy.

3.1 Application of VR in the Education of Disaster Medicine

In October 2008, China officially incorporated disaster medical education into university courses, but disaster medical education has not been systematically carried out. At present, there is no international academic organization for disaster medicine, and discipline construction is still in its infancy[14]. In the traditional theoretical teaching process, there are some difficulties affecting the teaching effect: (1) the teaching form is single, and only the flat materials such as disaster pictures and statistical data can be displayed; (2) real-time expansion and update of learning content cannot be realized; (3) lack of communication and cooperation between students[15].

With the help of VR, the "scenario case" mode can be used in teaching. According to different cases, virtual scenes of different disasters are designed by computer, and students can directly enter the virtual environment in which students can intuitively interact with the computer environment in a fully immersive scene. On one hand, its immersive and interactive characteristics can greatly enhance students' perception level and interest in learning, and students can use their professional knowledge to solve problems in different disasters and deepen their understanding of studying content. On the other hand, the scene presentation function of holographic imaging technology can provide teachers with an image expression tool, which makes many abstract teaching problems become concrete and enhance the acceptability of knowledge. Luigi Ingrassia *et al*[16] compared the VR simulation training and real-time simulation training between the two groups students to test the ability of different groups of students to perform mass casualty triage, and conclued that VR simulation proved to be a valuable tool, equivalent to live simulation, to test medical students' abilities to perform mass casualty triage and to detect improvement in such skills. Andreatta *et al*[17] compared the results of VR training with standardized patient (SP) training, concluded that VR can provide a viable alternative to the training of first aiders in large-scale disaster classification.

At the same time, the infiltration feature of the VR enables the learner to be immersed in the different situation and has an overall perception of the disaster situation. In these virtual environments, students can repeatedly use different disaster scenarios to improve the ability of mental tolerance and emergency responsiveness[18, 19]. Liu *et al*[20] produced and used a mine rescue medical emergency training system. By importing the scene model, combined with third-party plug-ins and 3D sound effects, it truly simulates the true feelings and state of the bumps that occur when people walk on the mine, which can better train mine rescue personnel.

Compared with the traditional case review mode, VR's simulation functions can make some difficult and impossible scenes and operations in teaching be clearly demonstrated through computer dynamic simulation technology, greatly increasing students' learning interest and subjective initiative in disaster medicine. At the same time, it also enhances students' ability[21] to coordinate and respond to disasters, and establishes rational analytical ability and good psychological quality.

3.2 Application of VR in Disaster Medicine Professional Skills Training

Disaster rescue personnel are the important medical forces fighting in the disaster scene. Their professional technical ability and emergency response quality to deal with sudden dangers largely determine the success rate of disaster relief[22]. As professional rescuers, in addition to basic disaster relief knowledge, they also need to master the clinical professional operational skills. However, under the traditional training conditions, there are some problems such as difficulties in scenes recurring, equipment shortage, and first-aid operation insufficient.

The four basic trainings for emergency rescue including wound dressing, fracture fixation, hemostasis, and cardiopulmonary resuscitation. Human-computer interaction simulation technology based on force feedback and visual feedback plays an important role

in these training. Using the corresponding disaster scene and 3D model, combined with force feedback and visual feedback[23], the learner can interact with the virtual model through visual, auditory, tactile sense and other multi-senses. The learner can more realistically simulate the basic operation of emergency rescue, which greatly improves the authenticity and operability of the first-aid operation. At the same time, in order to improve the level of first-aid operation of the trainees, the steps of various first-aid operations can be stripped, designed, and the complicated operation steps can be reproduced, so that the trainees can carry out intensive training and improve first-aid skills in the shortest time. Semeraro *et al*[24] reported a virtual reality enhanced mannequin (VREM) that can present the patient's main clinical symptoms and reactions in a first-person perspective, while the user can be immersed in the VR scene and can perform cardiopulmonary resuscitation operations. This set of equipment has the characteristics of authenticity, safety and repeatability, and can carry out first aid training. Li *et al*[25] compared participants who used VR training, video training, and were untrained. They found that participants trained by using the VR method performed better, while participants trained under other conditions had greater volatility performance.

The combination of first-aid skills training and VR is of paramount importance for first-aid skills training. Similar systems have been widely used in other medical trainings and have achieved significant results[26, 27]. It is believed that in the near future, the VR will play an important role in the process of first aid skills training.

3.3 Application of VR in the Popularization of Disaster Medical Knowledge

In a disaster event, even if the professional disaster medical rescue team arrives quickly, they cannot be as timely as the people at the disaster site. People in the disaster site have the dual status of the rescued and the rescuer. Through the role transition, the affected people can implement self-help and mutual rescue, which is of great significance for disaster relief[28, 29]. When VR is combined into disaster drills and realistic three-dimensional virtual scenes are built, users seem to be in scenes such as fires, earthquakes, traffic accidents, and other various natural disasters. From learning disaster prevention and rescue knowledge through VR, users can simulate the choices they may make in a disaster, and reflect on the consequences of their choices[30], so that the general public are able to adequately cope with the disaster when it actually occurs.

Compared with the conventional disaster science method, VR has the advantages of simulating real environment, saving money and reducing material consumption. The popularization of disaster prevention and rescue through VR not only enables the residents to have a deeper understanding, but also enhances their enthusiasm for learning and the ability of dealing with emergency disasters, and makes them attach great importance to disaster prevention.

3.4 Application of VR in Post-disaster Psychotherapy

The psychological damage caused by disasters cannot be underestimated, and psychological reconstruction is also an important part of disaster medicine. The most common psychological disorder associated with major disasters is post-traumatic stress disorder (PTSD)[31]. PTSD refers to the delayed and long-lasting mental disorders caused by sudden, threatening or catastrophic life events, which is a state of post-traumatic psychological imbalance, characterized by re-experience of trauma, and accompanied by emotional irritability and avoidance behavior[32].

Traditional exposure therapy requires to intervene patients according to the patient's recall of the traumatic situation at the time, but sometimes the treatment does not achieve the desired results because of the patient's own deliberate avoidance and rejection of imagination. In recent years, the application of VR to exposure therapy in cognitive behavioral therapy is a major breakthrough in psychotherapy[33]. Through artificially designing the necessary stress conditions, and constructing an immersive interactive virtual environment[34] that integrates vision, hearing, smell, touch, force, and movement, people can get the feeling of being there. Treatment in this safe environment helps patients change behaviors, thoughts and emotions, and reduces sensitivity to traumatic events. Difede *et al*[35] applied VR to exposure therapy in patients with traumatic stress disorder after the 9/11 attacks. It is concluded that VR is an effective treatment tool for enhancing exposure therapy for both civilians and disaster workers with PTSD and may be especially useful for those patients who cannot engage in imaginal exposure therapy.

4 Outlook

With the rapid development of computer technology, VR will develop rapidly and become one of the most influential technologies. With its characteristic of immersive learning, VR has been widely used in systemic education, professional skills training, and knowledge popularization of disaster medicine. However, the combination with emerging disciplines is bound to be a great resistance. How to properly combine disaster medicine and VR to make better results is what we continue to think about and work hard on in the future.

Conflict of Interest Statement

The authors declare that there is no conflict of interest relevant to this article.

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(Received Mar. 22, 2019; revised May 17, 2019)