Virtual Reality in Medicine

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Abstract:

For the last few years, we have been witnessing a surge of commercially available virtual reality systems that are on a high grade of usability for both professional and home-based application. Early examples of virtual reality systems used in the medical field were highly sophisticated, expensive and hard to use devices. Now we have reached a point where both prices and ease of use are at a level that it can be easily applied even as a home therapy system. The aim of this paper is to give an overview of the use of virtual reality in selected practical medical fields: psychotherapy, rehabilitation therapy, medical training, and pain management. This review demonstrates different fields of medicine where virtual reality is already an established tool and medical fields where it has just started to become an indispensable tool for a modern-day medical practitioner. We find virtual reality systems to be powerful immersive tools that allow both practitioners to improve their skills and experiences without any damage to the patients and patients to receive better and more personalised care and treatment.

Keywords: virtual reality; phobia therapy; rehabilitation therapy; medical training; pain management.

Sažetak:

Virtualna stvarnost u medicini

Posljednjih nekoliko godina svjedočimo porastu komercijalno dostupnih sustava virtualne stvarnosti koji su na visokoj razini iskoristivosti kako za profesionalnu tako i za kućnu upotrebu. Od ranih primjeraka sustava virtualne stvarnosti u medicini koji su korišteni kao izuzetno sofisticirani, skupi i zahtjevni za upotrebu, došli smo do trenutka u kojemu su i cijena i jednostavnost upotrebe na tako visokoj razini da se koriste čak i kao terapija u domu. Cilj ovog rada bio je istražiti dosadašnja istraživanja koja su se bavila upotrebom virtualne stvarnosti u nekoliko izabranih medicinskih područja: psihijatriji, rehabilitacijskoj terapiji, medicinskoj izobrazbi i kontroli boli. Ovaj rad prikazuje različita područja medicine gdje je virtualna stvarnost već afirmirani alat te ona područja gdje je tek na početku profiliranja kao neizostavni alat u medicini. Smatramo kako sustavi virtualne stvarnosti imaju visoku razinu uvjerljivosti što omogućava medicinskom osoblju poboljšavanje vlastitih vještina i iskustava bez štete po bolesnika, dok bolesniku omogućuje prilagođenu i bolju njegu i liječenje.

Ključne riječi: virtualna stvarnost; terapija fobija; rehabilitacijska terapija; medicinski trening; kontroliranje boli

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Introduction

Virtual reality (VR) is defined as a simulated experience that is either trying to simulate the real world or create a completely imaginary world. It is usually achieved by using a head mounted display (HMD), earphones and a couple of controllers. Most modern VR systems include an HMD that supports 6 degrees of freedom and controllers that allow the user to interact with the simulation using both of their arms (Figure 1). It means that with most systems users can freely move about and interact with the simulation with a high level of immersion. In the broader sense, VR also encompasses augmented reality (AR) and mixed reality (MR).

VR has been used as a simple show of concept or even in professional applications since the 1960s and has been growing in function and ability to immerse users ever since[1]. With technological advancement came better and more believable systems. While the use of VR in medical field, such as psychotherapy, dates back to 1995 with the fear of heights study, the cost of such a hardware system was around $150,000 and required a graduate student in computer science to operate it[2]. In year 2000 the fear of flying study was conducted with the hardware cost of around $20,000 and the therapists themselves could operate the system[3]. Year 2010 was the rebirth of consumer level VR and in 2016 first commercial room scale VR systems were available to the public. Today the hardware needed costs roughly $1,000 and can be run by virtually anyone[4,,5].

With these relatively recent advancements in VR combined with the lower cost and easier manageability, more options and easier way of VR implementation in different medical applications is possible.

The aim of this review is to give an overview of the use of VR in selected practical medical fields: psychotherapy, rehabilitation therapy, medical training, and pain management. In the search of scientific and review papers the following keywords were searched on the PubMed search engine: virtual reality, therapy, training, pain management, rehabilitation. For the purpose of this review articles published in English between 1995 and 2019 were selected according to relevance for the topic.

Flight phobia therapy

VR is already considered an effective tool for the treatment of many psychological disorders[6]. There are two advantages of VR in the treatment of these afflictions: the allowed control of the environment and the flexibility. Virtual world allows for greater possibilities compared to the real-world exposure therapy with the added protection and safety. The biggest advantages of VR can be seen in the area of phobias while carrying out exposure therapy. Although exposure therapy is the technique of choice for phobias, it is often rejected for being too aversive in the eyes of the patients. This is the problem that VR can alleviate with the provided control, flexibility and safety[7]. Virtual reality exposure therapy (VRET) is not a new form of therapy, but rather a form of technological adjunct[8].

Advantages offered by VR compared to in vivo exposure therapy are efficacy, preservation of patient's privacy, increased control of the exposure and increased comfort for both the therapist and the patient. Disadvantage of this form of therapy is that some patients are unable to immerse themselves into the VR. In addition, there is a lack of data about who makes a good candidate for VR opposed to in vivo exposure[9].

In recent years 10 randomized controlled studies were conducted, seven clinical trials and few case studies being performed comparing VR exposure therapy to different forms of treatment for flight phobias. Results presented in these studies have shown that VRET for flight phobia reduces symptoms of fear, both physiological and cognitive as well as behavioural avoidance in the real world. All of these studies have shown that waitlist control conditions have been outperformed by the VRET and that VRET results are similar to those shown after in vivo exposure, which is the gold-standard treatment for flight phobia[10].

Posttraumatic stress disorder (PTSD) therapy

According to American Psychiatric Association: "PTSD requires exposure to a traumatic event and symptoms from each of the 4 PTSD symptom clusters, including: intrusive symptoms, avoidance symptoms, negative alterations in cognitions and mood, and alterations in arousal and reactivity"[11]. Today, especially in war-affected areas, PTSD represents a significant disease burden[12]. As an example, epidemiological data from the Republic of Croatia indicates that PTSD has a 12-month prevalence rate of 6.67%[13].

In vivo PTSD exposure treatments are difficult, seldomly expensive and sometimes impossible to conduct. On the contrary, a perfect stand-in would be VRET, which can replicate and easily repeat the situations that have led the patients to develop the disorder. Also, the therapist can easily control all the factors within the VRET. One of the benefits of VRET as a treatment option for PTSD is the appeal to the video game generation[10].

The existing literature of VR exposure therapy for PTSD provides support for its efficacy. According to it VRET shows significantly better results than wait list controls and comparable to the standard exposure therapy. Treatment impact on other commonly occurring comorbid symptoms should be incorporated in future research on VRET for PTSD because it might reveal other effects of treatment or reasons for caution due to possible unforeseen side effects[14].

Rehabilitation therapy

It has been shown that important aspects, which propagate positive impact on rehabilitation and functional recovery of the patients with spinal cord injury (SCI), are training variety, motivating training tasks and movement repetition, while the subject's treatment location is of no importance[15]. A study of feasibility of in-home training with 12 patients that have an in-

complete SCI (iSCI) was performed using a home-based, mobile version of a lower limb VR training system. During the 4 weeks of home-based training motivating scenarios and combined action observation and execution were performed with virtual representation of the legs and feet. The study has shown that unsupervised VR training system at home is a beneficial form of functional training for patients with chronic iSCI, which also suggests that it could be used as a neurorehabilitation tool[16].
A study on 8 patients with chronic complete spinal cord injury was performed over 12 months using a multi-stage brain-machine interface system. The system included intense immersive virtual reality training, visual-tactile feedback and walking with two EEG-controlled robotic actuators (lower limb exoskeleton with tactile feedback capability). With the conclusion of the study all 8 patients experienced neurological improvements in somatic sensation in multiple dermatomes and have also regained voluntary motor control in key muscles below the level of the injury resulting in marked improvement in their walking index. The result was that half of the patients were upgraded to an incomplete paraplegic at the end of the experiment[17].

Medical training

Several relate studies that showed better performance in medical practitioners who were trained with augmented reality than the ones trained in traditional ways[18,19]. Jaeger et al. showed that residents which were using computerized training platform that displays an ultrasound image and real-time needle position in a three-dimensional (3D) anatomical model as an example of AR had better performance metrics on ultrasound-guided lumbar puncture models[20]. Yeo et. al. preformed an experiment on 40 volunteers that were divided into two groups. The aim of their study was to determine if learning the correct placement of a needle for percutaneous facet joint injection would be easier using AR image overlay and laser guidance systems. The overlay group that was trained using AR assistance had a statistically significant higher success rate, and less tissue damage potential[18].
Study by Saratzis A. et al. reported that a VR simulation training for endovascular aneurysm repair, that included 16 vascular surgery trainees, led to significantly decreased procedure duration, fewer complications, and improved selection of device size[21].
Another study, this time on communications skills, showed similar results. Forty-five physician trainees were included in a VR simulation training study to address vaccine hesitancy among parents of paediatric patients. The participants were put into a simulated situation faced with a graphical character that represented a vaccine hesitant parent. The study resulted in better performing physicians that helped reduce vaccine anxiety among parents for the VR simulation training group[22].
As shown in a tech demo in late 2018 using mixed reality (VR integrated with the physical surroundings) allowed six people to share a common VR experience, which leads us to believe that an operating room team training for collaborative learning, at least from the technological standpoint, is possible[23].
While most simulators are made for surgical procedure training, some are used to plan the surgery. Patient-specific VR simulation tool allow for a far superior preparation of surgeons without the risk of harming the actual patient[19]. There is an abundance of papers showing VR/AR advantages in preoperative planning compared to currently available systems[24]. The VR systems allow for the operator to examine the actual patient's CT scan reconstructed in full 3D and plan in high definition course of the procedure.
Although limited evidence is available and there is a significant heterogeneity in the methodology in VR simulation based surgical training, in summary all the recent studies showed a positive association between VR based surgical training and increased surgical skill acquisition[25].

Pain management

Several studies suggest that VR-based distraction therapy can reduce the standard pharmacotherapy in acute pain patients, procedural pain patients and the psychological distress induced by the severity of the medical condition. The best results were reported with immersive VR-based gaming applications[26].
Patients following acute traumatic injury, after receiving VR hypnosis therapy, reported reductions in pain intensity and unpleasantness both immediately and 8 hours later[27].
In the management of burn wound care, as an addition to narcotic pharmacotherapy, VR was used as a distraction therapy during wound debridement. All participants reported decreased paint unpleasantness, lower pain intensity, less time thinking about pain and increased enjoyment. In addition, patients reported pain reduction as VR therapy increased[28].
Similar benefits were shown for paediatric patients while undergoing subcutaneous vascular port venous access as an adjuvant to the standard analgesic pharmacotherapy. Patients using VR-based distraction therapy had reduction in pulse rate during the procedures, reduced patient-reported pain and parent-perceived patient pain and anxiety[29, 30].
In two oncology patients studies (women with breast cancer and patients with metastatic cancer), while undergoing their respective therapies, VR distraction therapy was used and showed significant reduction in patient-reported fatigue and anxiety [131, 32].
Compared to the previously mentioned studies concerning acute and procedural pain there have been a rather few studies on using VR in chronic pain management. Thirty participants with various chronic pain conditions were subject to a 5-minute VR application. The pain was reduced to some degree during or after the session for all participants. VR-based therapy showed as a promising non-opioid treatment option for chronic patients [33].

Conclusion

Although virtual reality systems are neither new technologies nor their use in medicine is a novelty, the costs and difficulty of use

restricted it from being commonly used in everyday practice and medical training. With the development of low cost, but high quality and easy to use virtual reality systems, we are at a point in time where physicians can and are devising new and innovative ways of using it.

The studies we reviewed are a good prediction of a bright future virtual reality systems should and will have in everyday medical profession, still new prospective studies that encompass larger samples should be conducted to substantiate the results.

Virtual reality systems have been here for a while and it is only a question of time when they will become an integral part of medicine, from education to improving established methods and introducing completely new ways of tackling our day-to-day professional problems.

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