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Virtual reality – future of diagnosis, medical education and therapy

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Abstract

Virtual reality (VR) has found a variety of applications in the biomedical field. It refers to a computer-generated, three-dimensional image of objects, space and even whole events. It is an extremely promising prospect for medicine, both in the training area and as an aid in carrying out certain procedures or diagnostic processes. The number of conducted research and great interest of scientists in this subject indicates that in the future it will be one of the basic tools of medical personnel in diagnostic processes and therapy. It could be also helpful addition to increase education quality of medical students and specialization education. VR increased the safety of surgical training and has significantly improved it, creating completely new possibilities of imaging complex structures during operations and extending the possibilities of already existing imaging examinations. What is important, VR can be successfully adapted for use by specialists from various, often extremely different medical fields. This article describes the use of virtual reality (both VR and AR technologies) in medical training, procedures and diagnostics.

Key words: virtual reality (VR); education; augmented reality; computer simulation; computing methodologies

Introduction

Recently, the term "virtual reality" has become very popular. It refers to a computer-generated, three-dimensional image of objects, space and even whole events. The most popular method of achieving this effect is the use of special glasses, which are closed on the sides, and in combination with headphones they provide a credible illusion of reality [1]. This technology has of course been used in entertainment, but also in places where the implementation of certain activities in reality would be expensive or dangerous, such as learning how to pilot aircraft. It is also an extremely promising prospect for medicine, both in the training area and as an aid in carrying out certain procedures or diagnostic processes. Computer-generated simulations usually divide into two basic categories: virtual reality (VR) and augmented reality (AR), which are slightly different from each other [2]. While in virtual reality the whole image is computer-generated, augmented reality is created by superimposing additionally created images and sounds on the real world - so it does not require the use of special equipment, even an ordinary tablet can be capable to handle it [2].

Description of the state of knowledge

Research has shown that only about 10% of what we read can be remembered immediately and permanently. Thanks to the use of active learning processes, the student is able to statistically reproduce 75% of what was given to him/her [3].On the market there are available various programs and applications for learning anatomy using 3D imaging such as BioDigital Human or Human Anatomy Atlas - an application for mobile devices, allowing students to engage in content and independent learning [4].VR and AR technologies show educational potential in presenting of the spatial relationships between the elements in three dimensions [4].On this basis, prototypes of immersion atlases of human anatomy are created. By using the glasses and headset combination described above, along with image bending software, the user is transferred to a virtual operating room with a mannequin that authoritatively recreates human anatomy. Thereby allowing the students to learn the structure of the organism by performing virtual sections [3]. Control is done by controllers for each hand. For a given hand-held structure, detailed information can be developed. At any time it is possible to reset the whole scene and return to the original organ position. The gripping function uses a specially designed collision detection algorithm to reach only those structures that are accessible from the outside. This significantly increases the authenticity of the simulation [3].

At the beginning of their studies, every young student of medical faculties is confronted with the learning of human anatomy, which includes the study of anatomical museums available at universities. Recently there has been an idea to use the possibilities of augmented reality to improve the knowledge acquired in this way. Some anatomical museums have already introduced appropriate systems based on AR markers - additional information about a given specimen is displayed on the screen of a mobile device when the lens of its camera captures the appropriate marker placed at the exposure [4]. The main disadvantage of such a solution is the mandatory presence of these markers, but a system has already been developed for which the image of the anatomical specimen itself is a marker. The most advanced interface uses a head-mounted display - its main advantage is the possibility of virtual manipulation of the viewed objects and scaling them [4].

Essential help with specialization training

VR technology is an indispensable scientific aid not only for medical students but also for training specialists. The methods of acquiring knowledge and skills in the field of surgery developed over the years have been verified in recent years. Based on the conclusions drawn from the experience of various fields of science, it has been noted that the use of simulators reduces training costs and increases the safety of the entire process, compared to traditional assistance and observation of the work of more experienced supervisors. Neurosurgeons can serve as an example. Due to the rapidly growing popularity of minimally invasive procedures in their area of specialization, more efficient methods of surgical training are required. Despite the popularity of these procedures, the complicated arrangement of anatomical structures remains a challenge [5]. Excellent understanding of the spatial relationships postitioned in the brain, anatomy of particular vessels and functional areas are essential skills. Using educational systems that allow interaction based on 3D images can significantly increase the practical skills of manipulating structures, performance and confidence of the future surgeon [5]. It also avoids the time-consuming process of mental translation of information learned from two-dimensional images for spatial thinking. In order to locate tumors, surgeons can use holographic displays such as Microsoft's Hololens or Magic Leap. With augmented reality, the available information can be supplemented with computer-generated images to provide an enhanced image during surgery - making it easier to perform the procedure. This fusion, together with the use of touch simulation, can shorten the training process [5]. Minimal invasive procedures include endoscopic sinus surgery and skull base surgery. A number of different simulators have been developed for operator training, one of the latest being the Neuro Touch Endo developed by Canadian engineers and neurosurgeons [6]. The scenarios included in it are based on actual clinical cases, e.g. endoscopic trans-sphenoidal pituitary procedures. The simulation involves the user’s insertion of a virtual endoscope provided with haptic feedback. All structures are anatomically reproduced with high accuracy. If the endoscope's contact with the mucous membrane is too strong, bleeding is simulated, making it difficult for the operator to see, and rinsing is done with the use of a special pedal. The user's assessment is based on the force used to perform the procedure, the number of goals achieved and the duration of the procedure [6]. Nowadays, more and more surgical procedures are performed with the use of laparoscopic techniques. They do not require such large incisions, generate fewer complications, and reduce the time of later convalescence of the patient. Operators performing such procedures must show slightly different skills than classical surgeons, because during surgery they rely basically on a two-dimensional image from a camera, and the instruments they use are inconvenient and do not give direct feedback, for example, about hitting an obstacle [7]. Currently, laparoscopic surgery training is based on the use of two types of "inanimate" simulators: Box-trainers (BT) and Virtual-reality simulators (VRS), which main advantages are the lack of need for supervision by a more experienced physician, easy availability and safety. While BT simulators are based on simple physics principles, VRS uses computer-generated organs and objects [7]. One of the biggest advantages of using VRS is the evaluation system based on laparoscopic tasks performed in a specific time. Several trials have shown that trainees with longer training on VRS have significantly improved their performance in the clinic. By using simulation, it is possible to develop basic skills that allow more effective use of later training on animals and reduce the time of individual procedures [7]. An additional aspect is the ability to program surgical complications in a virtual scenario, which translates into a higher didactic

value of training. Thoracic surgery is an example of a field of surgery that has made significant progress in reducing the percentage of intraoperative complications by using minimally invasive methods [8]. The surgical treatment of lung cancer has traditionally involved thoracotomy and rib dilatation, which made the recovery process among patients prolonged and difficult to do without complications. The solution was the widespread use of video-assisted thoracic surgery (VATS), which in addition to reducing the recovery time, also had a positive impact on the tolerance of chemotherapy by patients [8]. The need for professionals familiar with this technique is growing rapidly, and therefore there is a need to develop an efficient training process for them. Numerous studies have confirmed that VR medical simulation is a more efficient, safe and effective solution to better prepare young surgeons for surgery than traditional training, which was associated with an increased possibility for a novice doctor to make a serious mistake [8]. However, the use of virtual reality in surgical training is not without its drawbacks. One of them is certainly the still high cost of this type of equipment. In addition, classical training based on BT simulators and using animals provides a more direct physical response to the actions performed by the trainee, which significantly increases realism [7]. However, the simulation certainly excludes questionable ethical factors and this is a significant advantage.

The future of medical diagnosis and therapy?

Broadly understood didactics and training are not the only areas of medical science in which the technology of virtual reality is becoming more and more important. Currently, VR-based diagnostic solutions are being tested, which may soon become an important clinical tool in the field of imaging research. An example is GI endoscopy, which has been improved by zooming in on the image coupled with the operator's head movement, the so-called "intuitive zoom", which allows real-time zooming of the image of a given area during the examination [9]. Combined with 3D reconstruction of the intestinal mucosa based on light intensity, it significantly enhances the ability to assess lesions and brings a new quality to the training of endoscopists. During a polyp biopsy, the operator instinctively moves his head forward, causing an intuitive zoom of the area of interest, while the head movement in the opposite direction after the task is completed returns the operator to the standard image size. With this solution, the endoscopist is able to achieve the desired magnification of a specific part of the image only with head movements [9]. This is, of course, only one option for VR in endoscopy. This technology can also be used in electronic chromoscopy. Based on the light intensity values, it is possible to reproduce the "landscape" of the intestinal mucosa in 3D, allowing a detailed examination of its surface and even small changes present on it [9]. Implementation of the new technology in diagnostic processes and therapy opens new possibilities not only in the case of strictly surgical medical specializations. The results of research on the use of VR in cognitive-behavioral therapy in psychiatry are published more and more often. This applies in particular to the exposure therapy used in patients with phobias and post-traumatic stress syndrome [10]. The VRET (Virtual Reality Exposure Therapy) system, based on the mechanisms of exposure therapy, has been developed. This type of therapy includes a number of approaches in which patients are encouraged to confront situations causing their pathological anxiety in order to reduce its level and control strong emotions [11]. The VRET system remains in use by the US Army. It gives a detailed account of the conditions that soldiers who have developed PTSD have encountered during their missions in Iraq and Afghanistan. The system is able to provide a variety of stimuli, ranging from visual 3D, through sound, vibrations and olfactory sensations [12]. Veterans are under

the constant control of a physician during the VR scenario, having voice contact with him. The doctor has full control over the content of the stimuli presented to the patient during the simulation. The crucial factor for the therapeutic process is the emotional processing of traumatic memories and the adaptation of the "level of anxiety" to the progress of treatment [12]. There are also less complicated forms of using VR in psychiatry, for example as a form of interaction with patients based on their emotions, such as controlling a created avatar. Scenarios can be designed to improve patients' social skills, promote the expression of emotions and teach empathy [10]. The use of virtual reality technology may revolutionize the therapy of addicts. It makes it possible to create repetitive exposures to signals associated with a given addiction (e.g. drugs) in VR conditions [13]. The first studies to check the effectiveness of this type of therapy have shown that it has succeeded in inducing a sense of excitement in patients dependent on a variety of drugs. It has been proven that, for example, showing the casino environment to gamblers can make them want to play [13]. Due to the virtually limitless potential of the technology, it is possible to create a variety of environments in virtual reality, including those designed for autistic patients, schizophrenics and those suffering from various anxiety disorders. One of the most dynamically developing fields of medicine is transplantology. Treatments that until recently seemed unrealistic are now being performed, which gives hope to many patients. An example is a face transplant performed on people with very severe injuries of this part of the body, when all conventional methods have failed [14]. The critical point in the whole procedure of this type of treatment is the right choice of donor. A proper intraoperative match between the tissues of the recipient and the donor is a time-consuming and inaccurate solution. It is not surprising that specialists are interested in using modern technologies to improve this process [14]. Thanks to the implementation of specially designed software, a three-dimensional reconstruction based on imaging examinations and a simulation of facial surgery has become possible. The AYRA system developed in Spain, using conventional CT images, is able to generate a 3D model of the patient's face, which provides the surgeon with the choice of the optimal, least invasive method of conducting the procedure [14]. As the studies have shown, the use of virtual reality and digital imaging has had a positive impact on shortening the planning time of complex reconstructions, as well as on the level of precision of the procedures themselves. The didactic dimension of the system is also an obvious advantage. In-depth examination of anatomy is of great importance in the case of experimental and innovative techniques, which are increasingly being introduced into transplantology [14]. Cholecystectomy is one of the most common laparoscopic procedures. Despite constant improvement of laparoscopic technique and better and better training of surgeons, anatomical variability in vascular and biliary structures remains a difficulty, which may lead to postoperative complications [15]. Once again, the augmented reality comes with help, in the field of pre-operative planning it allows physicians to print a 3D model of a given organ. Intraoperatively it enables to expand in real time the image of the surgeon's surgical field and to visualize structures that are difficult to reach or located deep inside other organs (blood vessels, bile ducts) [15]. A huge and interesting improvement is the display of a standard operating table image on the monitor simultaneously with 3D pictures reconstructed with the use of AR. This allows to unify visual information for all doctors present during the procedure. Currently, 3D cameras recording this image still operate in relatively low resolution, but due to the dynamic development of technology we can expect more and more sophisticated solutions [15].

Use in the reduction of pain and anxiety during the performance of medical procedures.

Some medical procedures are strongly associated with pain. Pain is not only an unpleasant physical experience, it is a complex feeling that includes psychological elements [16]. Fear of injections, vaccinations and sometimes just a white coat paralyses children in particular, whose crying and anxiety is an indispensable part of pediatricians' work. The problem has always been there, and doctors and nurses are still relying on their own creativity to calm young patients down. One traumatic situation for a child may affect further medical care and cause aversion to treatments and staff. Of course, medicine has a number of pharmacological solutions for pain relief, but the use of strong analgesics is not free of side effects [16]. It has long been known that distraction can be an effective method while performing painful procedures in children, which has been confirmed by numerous studies. Taking the above facts into account, it turns out that virtual reality can be an excellent tool for this purpose, because it involves many different senses and occupies them by participating in various programs - passive or requiring active interaction. This action is based on the theory of the limited "capacity" of human attention, pain and anxiety require a certain "portion" of attention, and if we are able to divert some of this attention, we mitigate unwanted symptoms [16]. A study was performed on healthy individuals using magnetic resonance imaging and a thermal stimulus to visualize brain activity related to pain response while using VR distraction. The result of the study showed a reduction in activity of more than half, comparable to opioid anaesthesia (results based on MR and test sheets). Synergic effects of drugs and VR have proven to be an even more effective method of pain relief [16]. VR can be used not only to treat acute pain, but also as part of a combined therapy for chronic patients, such as cancer. Complementary integrative therapies (CITs) are becoming increasingly popular. In this system, less conventional means are used to supplement pharmacological therapy, such as hypnosis, yoga, acupuncture, music therapy or virtual reality [17]. The choice of appropriate therapy and complementary agents may protect the patient from resignation from proper treatment and switching to alternative therapies. Such methods create an opportunity for optimal selection of means for a given patient, taking into account ethnocultural factors of individual preferences of the patient [17].

Summary

Due to the constant, extremely dynamic development of modern technologies, access to VR devices is increasing and they are becoming more and more affordable from an economic point of view. The above examples are only a fraction of the possibilities of using VR in medicine, the number of conducted research and great interest of scientists in this subject indicates that in the future it will be one of the basic tools of medical personnel for both diagnostic and treatment purposes. The value of the VR/AR medical market is growing every year, and in 2020 it is expected to reach approximately $2.54 million. As far as the education of medical students and specialization education is concerned, we can safely talk about the revolution that has taken place with the help of this technology. It has increased the safety of surgical training and has significantly improved it, creating completely new possibilities of imaging complex structures during operations and extending the possibilities of already existing imaging examinations. What is important, VR can be successfully adapted for use by specialists from various, often extremely different medical fields. From surgeons to psychiatrists, who can create virtual scenarios for their patients to improve confrontational therapies, addiction treatment and the fight against anxiety symptoms and phobias - one of the most effective applications of VR in medicine so far. In the near future, we can expect further interesting ways to implement this technology in other areas of medicine.

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