Virtual Reality in Digital Health: A Literature Review

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Abstract

Due to its numerous use cases across a variety of sectors, virtual reality (VR) is becoming a more and more vital technology nowadays. With the help of this technology, 3D visualization for different real-life situations is improved. It offers a fresh method of interacting with the patient's soft tissue. Therefore, the applications of this technology are in the sphere of medicine and are becoming more and more adopted by the healthcare community. This article presents a literature review on research projects related to virtual reality in health informatics. For this, we have screened 430 research publications related to virtual reality in healthcare and selected 17 publications for the review that matched our selection criteria. Finally, we discussed future research perspectives and research challenges in virtual reality-enabled healthcare architecture.

Keywords

Virtual Reality, e-health, digital health, VR in Healthcare

1. Introduction

Virtual reality is a 3D environment that the user can easily explore and interact with. Depending on the level of presence, virtual reality technology can be classified into immersive virtual reality which includes interactivity and user participation in the virtual environment to create a "present" and non-immersive virtual reality sensation. Utilizing computer technology, virtual reality produces a simulated environment. It enables user interaction in a 3D virtual environment utilizing a screen, helping to imitate vision, hearing, and touch in the synthetic 3D environment. This device features a head-mounted display that can fill an entire room. Software is used to create an artificial environment that users can perceive as real. This technology's primary use is to build a fictional setting for video games, interactive stories, and training exercises. [1,20] In order to engage with virtual features, this technology creates realistic visuals in a virtual setting. Currently, it is used for training purposes in the area of medical, design, automotive, driving training, aviation simulator, and the military. It offers thorough details about the patient's anatomy and other bodily parts.

Virtual reality simulators can provide a learning experience similar to reality, with important potential benefits in the teaching and self-teaching of manual surgical skills (14). In addition, it has the potential to stratify different performance levels of healthcare students (15). Using VR headsets, they are able to feel the holographic visuals. [11,2] With the evolution of hardware and software, VR technology is becoming ever more popular. It helps a surgeon perform their work safely. Staff members of the intensive care unit can swiftly rehearse the technique during emergency scenarios. In order to establish trust and make wise decisions, it offers the finest way to research complicated issues and solutions. Different cognitive problems are worked out to adequately treat the patient. [3-5]

It is a valuable technique for managing pain and beneficial to lessening the discomfort during therapy. This technology is starting to be applied in ways that could lead to a breakthrough in the

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treatment of anxiety. In the virtual world, the patient can now encounter fear without any issues. High-end virtual surgery is accessible to enhance the experience. Now that doctors may practice in the virtual world, surgical errors will be less prevalent. Practicing successful surgery with fewer errors is desirable. This technology is a more effective way to advance surgical techniques and tackle various complex challenges. [6,7] VR is a cutting-edge approach to medical training. It can be utilized to provide adequate medical communication for a scope of scenarios like in orthopaedics, it is used to identify and evaluate broken bones. Wearing VR glasses promotes the efficiency and effectiveness of operations. [8,9]

The rehabilitation of cancer patients using VR is a very crucial application of this technology. The patient's chemotherapy is administered with precision and comfort. It readily submits to dialysis for patients with chronic illnesses and disabilities. One can view the patient's body and its components from various perspectives utilizing a VR headset. [10-12] When a patient uses VR glasses, this response produces their confidence by reducing their apprehension because the information they receive is more convincing. With the aid of this technology, a cardiac surgeon may now monitor a patient's heart rhythm and rate hikes. It creates accurate sounds and sights in a made-up or virtual world. [13,14] The screen, lenses, eye tracking, motion detection, activity recognition, and microphone and speakers that provide the live sound, are all independent components of VR technology. It includes robotic surgery, surgery modeling, PTSD treatment, and skills enhancement in the medical industry. This technology transmits better information in the most cost-efficient way possible. It is used to communicate effectively and slash therapeutic ideas. [15–17] This technology appears to be helpful for treating brain pain. It is utilized to jog the patient's memory and help them deal with various stressful situations. In VR, information is accurate and presented as it would be in the actual world. It helps with risk detection so that results are effective. The creation of new diseases is aided by this technology. A surgeon can now practice Simulink training in a secure environment as it teaches medical personnel how to handle a challenging situation. [7,18] In orthopaedics, it is advantageous to guide and give the proper mobility of fingertips and limbs. It is a clever strategy to cope with discomfort. This technology educates the patient for a greater grasp of the operation and treatment plan by educating them about diseases, their advantages, and their downsides. [19] The need for VR in the medical industry is briefly discussed in this essay. Significant applications are identified and discussed, as well as the processes this technology uses. Paper gives doctors and surgeons greater ideas for difficult treatments.

2. Background

Robert Mann created the first virtual system for use in medicine in 1965 [22]. It was used to determine the ideal course of action for an orthopaedic illness. Additionally, this approach was employed to train inhabitants [23]. The first simulators with 3D visuals debuted in the 1960s. The helmet-mounted display (HDM) was created in the 1980s, and "virtual reality" was defined. A decade or more later, the first laparoscopy simulator debuted along with the use of virtual reality in medical education (modelling of colonoscopy and higher gastrointestinal endoscopy). Even though simulation technologies improved over time, developing a tactile interface between people and machines was still important. Information is transmitted between a human and a computer using haptic systems. In the modern day, force-feedback haptic devices are strongly related to virtual reality [23].

In order to give comprehensive training and ensure the surgical operation's success, this technology was introduced to the medical industry in the 1990s. To innovate in the medical field, doctors, surgeons, scientists, researchers, and students must work together more effectively. VR is a practical technology that links these teams to resolve challenging issues. In a healthcare organization, we must determine how it aids in preparing better solutions and delivering appropriate training. It appears to be a helpful training device for medical professionals. We need to explore how students can use a computerized simulation of complicated surgery performed in a surgical suite to aid in giving the cancer patient the right treatment.

One of the top 3 sectors that will continue to be early adopters of VR technology through 2025 is healthcare, according to Goldman Sachs Global Investment Research. According to Accenture, 82% of healthcare workers feel that virtual reality offers medical students and working healthcare

professionals a convenient way to access and study knowledge. 62 percent of patients, according to the organization, would be open to using virtual reality medical services instead of more conventional ones.

The programme VR is used to accelerate training without any risk or worry. It is applied to treat a variety of diseases in the medical field. This technology is helpful in enhancing the capabilities of the medical industry. [20,21] It is a helpful and practical technology to raise trainee and patient satisfaction. As seen in the image, this technology uses its method in the medical industry to deliver an acceptable solution. VR is a crucial technology for the creation of specialised, cutting-edge software and hardware. First, we can gather the necessary background data and determine the precise treatment's goal. To create 3D virtual data that creates a 3D virtual world, various hardware and software are required. The best method is used to construct and identify the virtual reality of the necessary medical data. This process can be used to plan the course of treatment and ultimately aids in carrying out the actual surgery.

3. Research Methodology

The convention followed for this review lines up with a five-step structure framed by Arksey and O'Malley, and progressed by Levac et al. [4]. The system incorporates distinguishing the examination questions and important investigations, choosing of studies, information extraction from the chosen research works, and discussion of the outcomes.

3.1. Research Questions

1. How has virtual reality affected the medical services industry?
2. How is virtual reality being extended to supplement the current medical services framework?
3. What is the most targeted population and medical area in research work related to virtual reality in healthcare?
4. What will be the future of virtual reality in the healthcare industry?

3.2. Literature Search

As part of this scoping review, literature from the following databases was searched:

ISI Web of Science®, IEEE Xplore®, PubMed®. Significant article identification criteria are publication year and keywords. Keywords that were looked through in these data sets incorporate, however, are not restricted to those displayed in Table1.

Table 1

Keywords

Virtual Reality	VR in Healthcare	e-health
Virtual Surgery	Social Cognition	VR in CBT

3.3. Selection Criteria

Table 2

Inclusion & Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• Title is related to the questions. Studies should report on marginal and internal fit. • Included studies are relevant to study design. • Included studies must have been published between 2017 and 2022	• Review study and studies related to policies of VR in Healthcare • Study with no citation count. • Study was published more than 5 years ago Study was published in a language other than

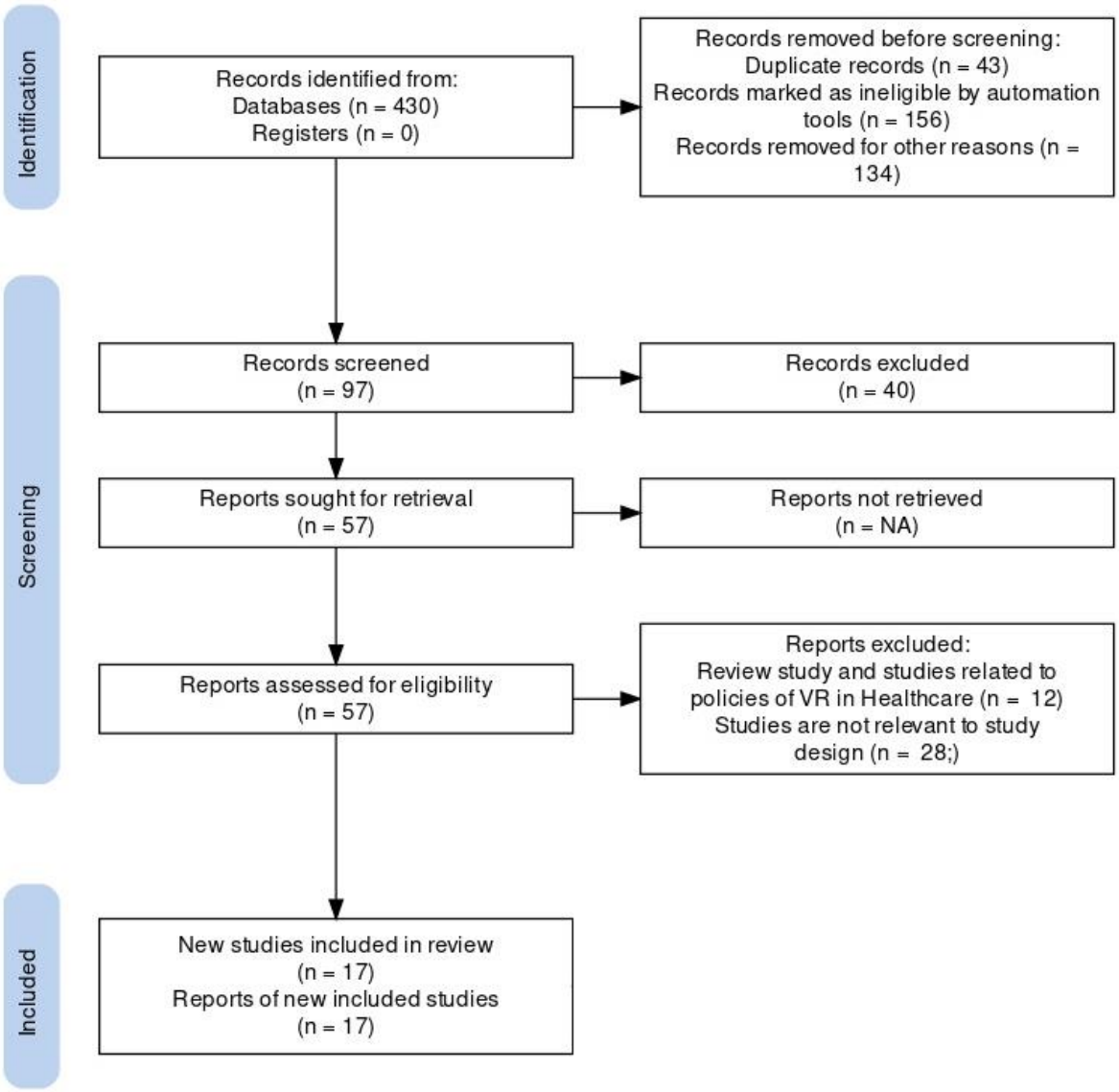

Figure 1: Prisma Diagram

3.4. Articles Included

Table 3
Included Studies for Review

Sr. No.	Year	Title	Study Design	Target Population	No. of participants/ Patients	Study Aim
1.	2020	Virtual Reality Social Prediction Improvement and Rehabilitation Intensive Training (VR-SPIRIT) (…) [31]	Randomised Controlled Trial	Patients with cerebellar malformations having deficit in social cognition	42	Social Cognitive intensive training
2.	2022	Feasibility and acceptability of virtual reality for cancer pain in people (…) [32]	Randomized Controlled Trial	People receiving palliative care – Cancer patients	13	controlled trials of 3D head-mounted (HMD) virtual reality for managing cancer pain in adults.
3.	2018	Virtual reality as a distraction technique for pain and anxiety (…) [33]	Randomized Controlled Trial	Females with breast cancer	80	Reducing pain and anxiety among female breast cancer patients.
4.	2019	Virtual reality for management of pain in hospitalized patients(…) [34]	Clinical Trial	Hospitalized patients with pain	120	Therapeutic virtual reality on pain management for hospitalized patients.
5.	2019	Virtual Reality Rehabilitation Versus Conventional Physical Therapy (…) [35]	Randomized Controlled Trial	Patients with Parkinson's disease	28	To investigate the manner of walking and balance in Parkinson's disease patients.
6.	2018	Mobile Game-based Virtual Reality Program for Upper Extremity Stroke Rehabilitation [36]	Clinical Trial	Stroke patients with upper extremity issues	24	virtual reality upper extremity stroke rehabilitation program
7.	2020	Virtual Reality Rehabilitation in Patients with Chronic Obstructive Pulmonary Disease [37]	Clinical Trial	Patients with Chronic Obstructive Pulmonary Disease (COPD)	106	Compares the effects of inpatient-based rehabilitation program for patients with COPD using non-immersive virtual reality training with a traditional pulmonary rehabilitation program.

Sr. No.	Year	Title	Study Design	Target Population	No. of participants/ Patients	Study Aim
8.	2017	Virtual reality improves embodiment and neuropathic pain caused by spinal cord injury[38]	Randomized Controlled Trial	Patients with SCI – Spinal Cord Injury and Paraplegia	40	Using multisensory own body illusions and virtual reality on patients with spinal cord injury.
9.	2019	Using a Virtual Reality System to Improve Quality of Life (…) [39]	Clinical trial	Old people suffering from depression	5	virtual reality system with a 360-degree virtual garden view to encouraging the elderly with depression symptoms
10.	2021	The Effect of a Virtual Reality Immersive Experience Upon Anxiety Levels, Procedural Understanding(…) [40]	Randomized Controlled Trial	Patients going through cardiac catheterization	64	Use of immersive virtual reality utilizing video-based material to enhance informed consent and explanation process.
11.	2021	Virtual Reality-Based Cognitive Stimulation on People with Mild to Moderate Dementia due to Alzheimer's Disease [41]	Randomized Controlled Trial	People suffering from dementia due to Alzheimer's Disease	17	The effect of VR-based cognitive simulation that reproduces Instrumental Activities of Daily Living.
12.	2018	Virtual reality rehabilitation in children with brain injury [42]	Randomized Clinical Trial	Children with brain injury	80	The usefulness of VR system for rehabilitation of children with brain injury to improve the functioning of their upper-limb.
13.	2022	The benefits and acceptability of virtual reality interventions for women with metastatic breast cancer in their homes [43]	Pilot Randomised Trial	Women with metastatic breast cancer (MBC)	38	Virtual reality to relieve the physical and psychological symptoms in women suffering from metastatic breast cancer.
14.	2020	Can hypnosis and virtual reality reduce anxiety, pain and fatigue among patients who undergo cardiac surgery[44]	Randomised Controlled Trial	Patients undergoing cardiac surgery	100	Applications of VR, hypnosis and VRH in medical procedures.
15	2021	Virtual Reality Relaxation for Patients with a Psychiatric Disorder [45]	Crossover Randomized Controlled Trial	Patients with Psychiatric disorder	50	To assess the effectiveness of virtual reality relaxation tool by testing with clinical trials in psychiatric patients.

Sr. No.	Year	Title	Study Design	Target Population	No. of participants/ Patients	Study Aim
16.	2021	Application of virtual reality on non-drug behavioural management of short-term dental procedure in children. [46]	Randomized Controlled Trial	Children	120	To measure the efficacy of virtual reality as a distraction for behaviour management in dental procedures in children.
17.	2021	Effects of immersive virtual reality for preventing and managing anxiety, nausea and vomiting (…) [47]	Study protocol for an Exploratory trial	Paediatric cancer patients.	20	Virtual Reality (IMR), in intervention for distracting paediatric cancer patients to manage anxiety, nausea and vomiting when receiving their first chemotherapy.

4. Discussion

4.1. Virtual Reality for Pain Reduction and Psychiatric Treatment

Among the articles reviewed 30% of research work presents novel approaches to the utilization of Virtual Reality as a distraction technique to reduce pain and anxiety in different scenarios. VR has been applied to treat patients for preventing and managing anxiety. Especially in patients during chemotherapy, with a successful decrease in the perception of pain and anxiety during treatment (20).

In the perception of pain during surgical procedures, VR also has the potential to become a method to prevent preventing and manage anxiety, nausea, and vomiting during clinical procedures (21). In distractions through virtual reality, this methodology can be considered a relevant intervention for treatments (9), reducing the anxiety of patients undergoing procedures such as chemotherapy (22).

Virtual reality-based treatments prove to be effective in enhancing psychiatric treatments. It has the ability to reduce stress and can be used as a treatment for anxiety, psychotic, depressive, or bipolar disorder. Compared to standard relaxation, VR-based treatments have shown a significantly greater reduction of total negative affective state. It had a stronger beneficial effect on momentary anxiety, sadness, and cheerfulness. Virtual Reality also showed improved cognitive function, effective for neurocognitive stimulation. In a clinical trial by Angkana Suwanjatuporn for developing a VR system to treat depression in old people. Providing a virtual reality system with a 360-degree virtual garden view to encourage the elderly with depression symptoms to move their arms, and help them to stimulate their brain functions and overcome depression quickly. Almost all the participants were able to learn and make use of the VR system with a virtual 360-degree garden view. The elder people were highly satisfied by the experience. They were eager and excited to learn to use the system [39]. VR is also feasible and acceptable by children to improve social skills. It was very effective in improving social interaction, empathy, opinions, and emotional recognition in particular children.

4.2. Virtual Reality for Rehabilitation & Medical Education

Virtual reality (VR) technology is rapidly becoming a popular application for physical rehabilitation and motor control research. Twenty-five percent of the reviewed article presented different approaches to utilizing VR in rehabilitation. VR rehabilitation training performs better on gait and balance in patients with PD than conventional rehabilitation trainingVR rehabilitation preparation can be utilized as elective treatment. A VR-based non-intrusive treatment program can add an incentive for patients and clinicians concerning genuine information assortment (to support consistency checking, the movement toward objectives, and exercise security), expanded commitment, and expanded admittance. Computer-generated reality headsets might be utilized to cause circumstances that challenge your visual framework while you are in vestibular recovery. Recordings of thrill rides, swooshing vehicles flashing by, or optokinetic shapes might be extended before your eyes while attempting to keep up with great equilibrium. This difficulties your visual info and nerves that assist you with remaining upstanding, attempting to fortify the fundamental connections between your vestibular organs and eye developments.

Virtual reality improves knowledge and skills outcomes compared to traditional education or other types of education; however, studies are limited and future research should assess the effectiveness of this technology in addition to other variables such as attitude, satisfaction, cost-benefit, and clinical or behavioural change [18].

In some universities, this technology has already been introduced into their preclinical curriculum, with promising results as there has been an improvement in student performance, and it can be a valuable adjunct during professional training.

Virtual reality has also been used to teach aesthetic techniques using a simulator. The training of anesthesia to block the inferior alveolar nerve was highly appropriate considering the application of the needle in an appropriate area, depth of insertion, as well as sensitivity of the needle. the virtual resistance of the tissue.

This technology is becoming an essential part of modern education. The benefits of virtual reality in health care are constantly evaluated as a method or adjunct to improve fine motor skills, and hand-eye coordination in preclinical settings, and overcome the monetary and intellectual challenges related to student training.

As an educational tool, this technology has provided better opportunities for college students and will become a key function in the future of healthcare education. Offering new teaching possibilities by combining digital elements with a real learning environment, there are still several uncertainties that limit the widespread implementation of this technology. Most of these uncertainties can be resolved through continued progress in information technology.

4.3. Research Challenges

In contrast to many other industries where VR-based solutions are being created and used, the healthcare industry is unique. The analysis of these distinctions is the focus of this part since knowing them is crucial to avoiding several errors that could jeopardize the success of a VR system that is otherwise well thought out and practical. From the perspective of engineering design, there are several elements that make the healthcare sector unique. The first and most important one is how pertinent its operations are to human life and health. Although this is obvious, engineers should keep it in mind as they attempt to comprehend the perspectives and judgments of health professionals. A system must first be demonstrated to be completely safe for patients before it can be fully validated and employed. After that, it must also be demonstrated that it serves the function for which it was designed. Companies and salesmen constantly approach healthcare professionals to try to persuade them to utilize a certain solution for a variety of issues. It happens that a product that initially appeared to be reliable later revealed harmful long-term adverse effects that did not surface during system testing. In connection with this, mass media is another element influencing healthcare professionals' choices. The public pays a tremendous amount of attention to any news affecting the healthcare industry. In an example, using bad news to your advantage is a great method to boost sales. Finally, politics are crucial because they can influence whether political parties succeed in winning elections. The logical result of all these factors is that medical practitioners become cautious when implementing real ideas, and the adoption of drastically different methodologies often develops more slowly than expected by the engineers who build them. Additionally, until the benefits of the new ideas are completely demonstrated, it is common to prefer old solutions and practices. This is not to say that the healthcare industry is opposed to technological development in any way; on the contrary, it is likely one of the industries where technology has had the greatest influence. It simply means that innovative solutions take more time to gain popular adoption. The second obstacle to the development of VR healthcare systems is complexity, which is also connected with high costs. Since they would provide outrageously implausible outcomes, many applications in this business cannot use the majority of the simplification assumptions that have been developed for other industries (simpler structures, simple transient characteristics, rigid rather than flexible units, etc.). As a result, dealing with complex issues is necessary for medical VR systems, and as is customary in VR, these issues must be resolved immediately. A VR system may become unprofitable as a result of the increased hardware and software costs and lengthened development timeframes.

4.4. Suggestions

There is no doubt in the fact that VR has a promising future in the healthcare industry. Many health professionals now consider VR-based solutions to be current and effective due to the gradual invention and development of VR systems, their entry into the market, and their strong reputation. Utilizing VR training systems for resident education in hospitals and institutions will boost their use, but more crucially, it will change professionals' mindsets—at least momentarily. As VR techniques are proven to be successful, more and more problems will be considered as prospective possibilities. (at least in some circumstances). To do this, it is crucial to establish interdisciplinary teams made up of engineers and professionals from the health sector in order to identify open issues and create

efficient solutions: failures or missed opportunities will result from a lack of understanding of actual demands or processes.

A new phase begins when a well-thought-out and built VR system has been made: convincing the users of the possible benefits it might provide. Young professionals tend to accept new technology more quickly in general. There are occasionally strange circumstances since senior professionals often make judgments about buying new technologies. Virtual reality (VR) systems typically deliver comments to evaluate how well experts implement the exercises; typically, this rating is based just on nimbleness, kinesthetic awareness, and physical capabilities, instead of expertise, the ability to make corrections, the capacity to make the best choice, etc. Senior experts typically receive lower ratings than newer, less experienced experts as a result. This fact may cause those who must determine if the entire system is worthwhile to unconsciously reject the system as a whole. Dexterity alone should not be the only factor included in practitioner assessments generated by VR systems.

When implementing VR applications for the healthcare sector, the following considerations can be made in light of all these factors:

First, it's critical to focus efforts on innovations that genuinely solve certain issues or meet pertinent demands. Since they are the ones with a broad perspective of the issues present in their sector, this must be ensured by obtaining input and cooperation from healthcare professionals at every level of development. This is merely another argument in support of multidisciplinary development teams, which are frequently required in the VR industry.

Second, it's crucial to consider the functional requirements for VR systems in the healthcare industry. It is crucial to prevent both the generation of irrelevant designs that don't actually solve any problems and the generation of excessively complicated designs that will be difficult to build, and sustain, which will cost a lot of money in terms of hardware and software. A balance between intricacy and utility must be achieved; in every case, a straightforward approach that achieves the desired result is the ideal choice, especially if it prevents the eventual need for trained operators to make the system function [26].

Third, from a technical standpoint, VR systems for the healthcare industry provide a significant difficulty. Numerous aspects still require improvement, such as the handling of deformable bodies, systems, and organisms, enhanced visual stimuli, more suitable sensory instruments, etc. Real-time simulations of intricate processes like chopping, grasping, slicing, etc. must also be created.

Last but not least, the development of Virtual reality technology for the medical industry involves much more than only the actual engineering issue. Other important variables to take into account include how the system will be used, the data it will provide regarding practitioners' performance, the kind of training activities that will be put up, etc. [26].

5. Conclusion

By generating a virtual, three-dimensional environment, virtual reality opens up new options and improves medical care. It provides a more accurate perception of the environment. It is possible to cure illnesses caused by stress with this technology, It has several uses in the disciplines of psychiatry, psychotherapy, physical rehabilitation, and other intervention methods. This technological development appears to be the best option in the medical industry because it may allow situations to be immersed. It might shorten the time spent with the therapist. These days, this technology can handle challenging patient conditions. Since a few years ago, the uses of this technology have been rapidly investigated in order to produce significant advancements. In order to effectively treat patients, VR technology successfully addresses these needs in the healthcare profession. VR seems to lower the overall cost of the rehabilitation process. By using this equipment, the patient is able to focus around the outside of the world and is alleviated of overall tension. By providing interactive movements and sensations, it gives the human brain an experience. This technology provides a potent and superior solution for stress management that helps patients and according to research, it might even help them live better life.

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