Virtual Reality Applications in Nursing
Hemşirelikte Sanal Gerçeklik Uygulamaları

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***Özetçe*—20. yüzyılda teknolojik ve bilimsel alanlardaki gelişmeler, insanların yaşamlarını önemli ölçüde değiştirmiş ve şekillendirmiştir. Sağlık hizmetlerinde teknoloji, hem profesyonellerin hem de hastaların ihtiyaçlarına çözümler sunarak yaşam kalitesini iyileştirmeye yönelik yöntemlerin, sistemlerin, ilaçların, cihazların, aşıların ve organize bilgilerin uygulanması olarak tanımlanabilir. Güvenliği artırırken parçalanmayı ve maliyetleri azaltma potansiyelinin yanı sıra, teknolojinin kullanımı güvenli, sürdürülebilir ve kişi merkezli bir sağlık bakımı ortamına ulaşmanın anahtarı olarak kabul edilebilir. Sanal Gerçeklik (VR), çoklu duyusal yöntemleri harekete geçiren, bilgisayar tarafından üretilen üç boyutlu etkileşimli bir ortamdır. VR'nin bu yüzyılın önemli teknolojik trendlerinden biri olduğu düşünüldüğünde, VR sağlık sektörünü 2025 yılına kadar derinden etkileme potansiyeline sahip bir teknolojidir. VR, görsel, işitsel ve dokunsal deneyimler içeren gerçek zamanlı bir grafik simülasyonudur. Sağlık alanında VR, tıp öğrencilerinin kritik ameliyatlar için yetiştirilmesi, hemşirelik adaylarının eğitimi ve bazı hastalıkların tedavisi olarak çok amaçlı kullanılmaktadır. Sağlık ekibinin temel üyeleri olarak hemşireler, verimli ve kaliteli bakım sağlamak için hızla gelişen teknolojinin sıkı bir takipçisi olmalıdır. Hemşirelik eğitiminde sanal gerçeklik kullanımının hatalı müdahaleleri azaltma avantajı vardır, bu da hasta güvenliğini ve gelecekte sağlık hizmetlerinin kalitesini artırmaktadır.**

***Anahtar Kelimeler*—Sanal gerçeklik, Hemşirelik, Hemşirelik eğitimi, Sağlık.**

***Abstract*—The progress in technological and scientific fields in the 20th century has transformed and shaped the lives of people remarkably. In healthcare, technology can be described as the application of the methods, systems, medicines, devices, vaccines and organized information to improve the quality of life by providing solutions for the needs of both professionals and patients. Besides its potential of reducing fragmentation and costs while increasing the safety, utilization of technology can be considered as the key to achieving a safe, sustainable, and person-centered healthcare environment. Virtual Reality (VR) is a computer-generated three-dimensional interactive environment that stimulates multiple sensory methods. Considering the fact that VR is one of the crucial technological trends of this century, it has the potential of affecting the health industry until 2025 extremely. It is a real-time graphic simulation that includes visual, auditory, and tactile experiences. In the field of health, VR is used for multiple purposes as training of medical students for critical surgeries, education of nursing candidates, and treatment of some diseases. As essential members of the healthcare team, nurses should be a strict follower of the rapidly evolving technology to provide efficient and quality care. The utilization of VR in nursing education has the advantage of decreasing faulty interventions, which enhances patient safety as well as the quality of the healthcare services in the future.**

***Keywords*—Virtual reality; Nursing; Nursing education; Health.**

I. INTRODUCTION

Technological and scientific developments in the twentieth century changed people's lives dramatically. This process continues at an accelerating pace today and new technologies manifest themselves in several areas such as entertainment, commerce, business, education, health, and medicine [1]. In healthcare, technology can be described as the application of the methods, systems, medicine, devices, vaccines, and organized information to improve the quality of life by providing solutions for the needs of both professionals and patients [2].

The use of technology in healthcare can be considered as a crucial factor for creating a sustainable and secure environment where the main focus is on the comforts of both patients and the healthcare team. Furthermore, it is a strong possibility that utilizing modern technology in healthcare can decrease costs and improve safety. It is widely used for maintenance of health status, delaying or preventing the initial phase of diseases, and finding solutions for healthcare problems. These technologies improve the quality of service by increasing the efficiency of healthcare, decrease the possibility of error for healthcare professionals, and shorten the duration of recovery for patients [3], [4]. The trends such as personalized medicine, 3D printing, nanotechnology, the spread of mobile health technology, artificial intelligence, and virtual reality are considered important developments that have the potential of affecting the healthcare sector by 2025 [4].

A. Virtual Reality

Virtual Reality (VR) is a concept that consists of opposing words as virtual and reality. According to the Turkish Language Association, virtual is defined as unreal and imaginary that originates from the Latin word virtualis. The other part of the concept, reality, is defined as all of the things that exist

in the real world [5], [6]. To be more precise, VR can be described as a 3D interactive environment that is constructed by a computer and allows individuals to enter a real-time graphical simulation by stimulating visual, auditory, and haptic sensory paths. VR piece multiple technologies together as Head Mounted Display (HMD), earmuff, manipulation, and navigation devices, and in this way users interact with the virtual environments that bring animals, objects, and people out by different graphical applications [1]. According to Moshell et al., VR is a graphics simulation that can be controlled via different tools that interact with the perception, movements, and visual direction of the user in a closed environment. In other words, VR is a highly interactive platform that convinces individuals to the reality of the experience although they are in a virtual environment [7].

A VR system generally consists of 4 parts as a computer with an advanced graphics card and a suitable processor, software that supports VR, a controller to track head or hand movements of the user, and a high resolution, large digital display. The display system can be attached to the head which is called HDM. HDM reflects the computer image to the user using an optical system and consists of stereo headphones and small displays to provide both auditory and visual virtual reality experiences [8].

VR applications include three different approaches as passive, exploratory, and immersive applications. In passive application, users can see the environment, hear the sounds, and feel the movements however, they cannot control anything. In exploratory applications, users can move inside the environment however, they are not allowed to control the movements of other objects. Finally, in immersive applications, prior problems are solved since users can control both their actions and movements of external objects [9].

Some features of VR distinguish it from other technologies like virtual environments, interactive 3D (I3D), visualization, digital prototypes, simulation, and 4D Computer-Aided Design (4D CAD) [10]. Furthermore, VR technology has three fundamental characteristics that differ from other multimedia applications as navigation, interaction, and immersion. Navigation is the most common user action and provides comfortable and efficient movements between long distances. The interaction between the user and the environment is real-time, and it occurs simultaneously with 3D objects which creates a feeling of presence for the user. Finally, immersion symbolizes the emotions of the user. It is defined as the ability to act in the environment and the feeling of presence. It allows the user to have a realistic experience via the isolation from the external environment [11].

VR applications are crated with different systems by considering the type of technology that user needs and utilizes. Desktop VR is one of these systems which allows users to see the virtual environment via television or monitors. This type of VR requires users to follow the screen constantly [12]. In immersion VR systems, users experience a virtual environment with HMDs, and the users interact with the sound coming from the headphones and scenes on the screen that disconnects them from the outside world [1]. Another VR system that has become widespread is Augmented Reality (AR) that connects the real world and computer graphics. The user can interact with computer-generated objects and individuals via a smartphone or tablet. Several head-mounted devices have been developed to provide an immersive user experience [13].

Apart from previous classifications, VR systems are also categorized according to immersion as fully immersive, semi-immersive, and non-immersive. In fully immersive systems the visual field of the user is surrounded where individuals are isolated with devices such as HMDs. Semi-immersive systems are constructed using large screens that restrict the feeling of presence. It is widely used for the captain or pilot training simulations and driving courses that include several groups of users to provide collaborative works. Lastly, non-immersive systems use desktop monitors that cannot make users feel immersed [1].

VR simulation consists of three stages, and the first one is simple VR that is limited to a user and a computer that does not use a support system or artificial intelligence. Anatomy Atlas is an example of a simple VR. Advanced VR includes a computer that generates a scene with haptic and visual feedback such as surgical simulations. The most complicated stage is the 3D VR where sensory input and outputs are combined via haptic systems. It provides cognitive evaluation and interaction with the help of artificial intelligence. In this stage, users are not passive, on the contrary, they can change the virtual world actively [14].

B. History of Virtual Reality

VR is an approach dating back to the 1930s, and the first development related to VR was a simulator called View-Master manufactured in 1939. View-Master is a visual simulator that shows placed images with the help of light. Sensorama is another product that was developed in the way of VR by Morton Heilig in 1962. It simulates a motorcycle that travels in the streets of Brooklyn. It was equipped with visual and sound systems and was a device that gives off smell and shakes the body to provide a cinematic sense. This system is still functional and has an option that users can watch movies. Thomas A. Furness developed a flight simulator for air forces in 1966. VR can be constructed via a helmet or an environment, and Evan Sutherland developed the pioneer of HMDs in 1968 that was named Sword of Damocles because of its scary appearance. This helmet was made of two pieces that can be worn on the head, and it is the inspiration for modern virtual glasses. Sega company developed a device named SegaVR that included stereo speakers, an LCD screen, and a sensor that can detect head movements in 1991. After a few years, in 1995, Nintendo released Virtual Boy for virtual games, and Philip Rosedale accelerated the process with his studies on 360 degrees of view. In 2001, a computer-based 3D cube room was introduced by Z-A Production and was followed by the StreetView application of Google in 2007 that provided a perception with 360 degree real images. A system called Oculus Rift was developed in 2010 by Oculus VR that allows users to connect to the virtual world directly by only head-worn glasses. Sony manufactured a VR headset called

PlayStation4, and a system that can be used with smartphones, named CradBoard, was introduced into the market by Google. The first controllable device called GearVR was released by Samsung in 2017 which can be controlled via hand movements and the first platform that allowed users to move freely in the virtual environment was called Virtuix Omni. Vituix Omni has a structure similar to a treadmill and allows users to direct the movement 360 degrees by running or walking [15]. Apart from these, simple applications have been developed with small budgets such as Google CardBoard and Microsoft VR [16].

C. Application Areas of Virtual Reality

VR as a computer-based costly technology was only used in military or space researches for many years. However, lately with applications developed for mobile devices, VR has been widely used in several areas. As an observation device, VR presents a 360-degree navigable environment for both indoor or outdoor areas that provides a more comfortable perception. VR is used for the digitalization of equipment and environments along with the design and test processes. In several fields, especially game development, VR has become an essential tool for education and practice, and as course materials, some products are interactive with VR. Creating a more realistic environment with virtual objects, providing an interesting education environment, facilitating learning, being easily and continuously available are among the features of VR [15].

The entertainment market utilizes VR for 3D games with HMDs. Furthermore, as an example of education, flight simulators have been used for the training of pilots or pilot candidates. In the real estate field, buyers can walk around the property for evaluation, and architectures can deliver projects to customers. By using VR to design impressive campaigns, target audiences can be reached in the marketing, and 360-degree visualization provides a virtual tour in tourism and travel. In the field of healthcare, VR has used for the teaching critical surgeries in medicine, training, and education of nursing students, and treatment of some diseases [15].

D. Virtual Reality Applications in Healthcare

The first attempt of using simulators in medicine was in 1963 with Sim One simulator which was a mannequin mimicking physiologic responses such as heart beat [17]. Nowadays, changes and advancements have been accelerating rapidly in medicine, and to adapt to these developments and to provide quality health education current technologies started to be utilized. These technologies such as VR and AR have started to change education experiences. Instead of a rote-learning based education system, practical learning has been supported, and problem-based learning, communication skills training, and simulation-based learning have entered the curriculum. The increased effort to present clinical learning experiences and the challenge of providing this, especially simulation gained acceleration as a solution for problems in clinical learning [18].

In medical education pre-experience of diagnosis and treatment modules have been performed using surgical procedure simulators. Virtual operating rooms, laboratories, and virtual classes have been tried by some educational institutions. As an example, with the Real Image Viewing technique holographic images of scanned tissues and organs can be represented, and various procedures such as cutting can be performed with an electronic lancet on those images [15].

Since the 1990s, VR has promising applications in medicine and science. It has been utilized both as an intervention technique and a diagnosis tool. The usage of VR interventions in several areas such as phobia therapy, anxiety, chronic pain, obsessive-compulsive disorder, and obesity have been studied. The immersive and entertaining characteristics of VR can distract the focus of the patients during painful treatments and decrease anxiety as well as discomfort. It has been widely used during burn care, creating a feared environment for phobia and distracting the focus of patients suffer from Post-Traumatic Stress Disorder (PTSD) during treatment. In the treatment of eating disorders and obesity, patients are placed in realistic avatars for stressful situations such as food shopping to improve their perception of a healthy body and a healthy diet. Additionally, VR helped individuals to improve body postures and movements in a less discouraging environment [19]–[24]. In a study conducted by Hoffman et al. in 2008 with patients assigned with wound care, it was found that VR technology had an effect of decreasing the pain [25]. Likewise, Piskorz and Czub found the same comforting effect of VR in 2017 [26]. Thapa et al. suggested that VR technology had the potential of being an effective intervention method for patients with dementia [27]. In a study conducted in 2008 by Coelho et al., it was concluded that VR was effective for the treatment of acrophobia [28].

VR has been accepted especially in medicine and nursing areas since it provides the needed skills from the virtual application experience when it is utilized with the accurate education software. These pieces of training are transferred into practice with 360-video, interactive VR, and screen-based learning. 360-video is a 360 degrees shooting method to create the full image of the environment. To record the 360-degree video, a camera that can record in every direction at the same time is utilized and it is converted to an immersive experience with HMD and headphones. In the case of providing a non-interactive experience to the students, the 360-video method is useful. One of the application examples of this technology is distracting the focus of patients during painful procedures. However, 360-video is a passive experience and users cannot interact with the environment which can cause nausea due to the disconnection between the movements of users and representation of the movements in the virtual world. On the other side, interactive VR contains a fully immersive, adaptable, and interactive universe. In the case of medical applications, this method is used in virtual hospitals, patients, and professionals. As an example, in a scenario where a patient comes to the emergency with chest pain, a medical student can perform examination, diagnosis, and treatment on the patient as professionals do in real life. Different components such as family members, a multi-disciplinary team, patient observations, a dynamic and adaptable conversation can be added into the environment. Besides, patients can be adjusted

to be more complicated and the rush in a virtual hospital can be simulated. In this way, students can be put in a difficult and stressful situation to improve their ability to decide, critical thinking, and clinical reasoning. After the simulations are completed, students can get a virtual report and display the feedback of their performances. This property provides an opportunity for students to learn their strong and weak sides and it allows coeducation. Students have a chance of discussing their skills and the procedures with their colleges and supervisors. Companies like Oxford Medical Simulation presents this kind of platform to the world with scenarios that cover medicine, nursing, pediatrics, psychiatry, and community health [18].

There are several advantages of utilizing VR such as repeatability of a procedure without damaging the human body, modeling organs transparently, providing foresight about situation, recovery, treatment, and surgical procedures of patients. The model in the virtual world is immortal, thus patient safety is supported and possible complications are reduced. In the case of an emergency, locations of life-saving equipment and medical personnel for the public can be mapped using VR. It helps to gain experience in dangerous operations such as handling toxic or radioactive wastes. It is used for the treatment of phobias and several diseases and also provides 3D ultrasonic images to plan critical surgeries. Taking into account all of these, VR improves the quality of education in several areas especially in medical training and nursing education where the safety of human life is essential [8].

In medical education, the utilization of VR technology improves the skill levels of professionals and has a positive effect on patient safety, especially in applications such as colonoscopy, laparoscopy, ureterorenoscopy, orthopedics, eye surgery, and radiological procedures [29]–[34]. There are several available applications of VR in the market and literature in the medical area and one of them is Human Sim. It was created by integrating dynamic virtual human technology and a physiological-pharmacological model. While it emphasizes learning by practicing model, it also provides sustainable medical education. It helps improve the abilities of healthcare professionals in making decisions and evaluating patients in critical situations without taking risks. Another platform is Human Sim Anesthesia which is a computer-based application that provides a 2D environment for users to help them learn about medicine, physiology, and pharmacology. It presents the physiological effects of decisions made in critical situations [8], [35]. Floreo uses the power of VR to develop an extra approach to teach social skills to people that have Autism Spectrum Disorder (ASD). It contains several lessons for different communication situations such as the daily talks in the cafeteria and school along with modules of gestures and imitation [36]. Farmoo is a platform developed to reduce the pain of individuals who suffer from cancer with games and activities [8]. VisitU is an application for patients who stay in hospital. It brings VR and videoconferencing together to connect hospitalized patients and families while they are separated. The 360-degree camera of this system is placed wherever the patient wants and real-time communication with the family members is provided by a 3D VR headset [37]. There are several visually impaired people around the world and IrisVision is an FDA Class I product developed for individuals who suffer from low vision. The smartphone camera captures the scene and the VR headset allows users to zoom in and out and see with different contrast modes [38]. Embodied Lab provided a product that helps young people to feel how being old is like from the perspective of elderly patients. There are several modules such as Alfred who suffers from macular degeneration and hearing loss, and Beatriz who has Alzheimer's disease. Users experience the stories of patients with VR headsets to understand the difficulties of several diseases by living [39]. MindMaze is a product that can be used as a digital therapeutics for nine neurological disorders including Parkinson's Disease, Alzheimer's Disease. It is also a neurorehabilitation platform for stroke patients where they can train their motor functions with different games that are adaptable to VR [40]. IMventro Sim is a computer-aided simulation to improve the ventrogluteal region intramuscular drug administration skills of nursing students. This interactive platform provides patient safety and quality of care by giving training opportunities to nursing students [41]. Aside from these, there exist several VR simulators in different education areas which are exemplified in Table 1 [42].

E. Virtual Reality Applications in Nursing

The fast developments in technology and healthcare caused the acceleration in the usage of VR and increased the demand and need for professional nurses who adopt the innovations. It is vital to equip nurses with the necessary knowledge and skills to adapt them to this progress [14]. It is observed that in literature, VR has been utilized for nursing education in the procedures of intravenous (IV) catheterization, urinary catheterization, nasogastric tube, intramuscular (IM) drug administration, and pain control [41], [43]–[46].

In a paper published by Jamison et al., the mannequin IV and a simulator called CathSim were compared as a pre-test and post-test study. An increment in post-test scores of the simulator was observed which indicates the superiority of simulator over mannequin during education [47]. Likewise, Jung et al. observed the same supremacy of VR application in 2012 for IV catheterization training [43]. In a study of the usage of CathSim for IV catheterization skills of nursing students, Chang et al. stated that utilization of simulators can decrease the anxiety levels of students [48]. In another study conducted by Farra et al., nursing students stated that they found VR effective during the decontamination training [49]. In a paper published by Smith and Hamilton, it was concluded that VR was an adequate method in the Foley catheterization training of nursing students [50]. In 2015, Ismailoglu and Zaybak conducted semi-experimental research on IV catheterization skills of nursing students. The study aimed to compare the intravenous catheterization simulator and plastic mannequin, and Intravenous Catheterization Skill Test, Self-Confidence and Satisfaction Scale, and Fear Symptoms Scale were utilized to analyze the comparison. The results showed that satisfaction scores and psychomotor skills were greater for students who used the simulator [51]. In 2017 Choi suggested that experiencing the nasogastric tube application with virtual reality

Education Area	Example
Physiology and Anatomy	Visible Human Project [56], Visible Korean Human [57], The Visible Body [58], The Virtual Human Embryo [59]
Open Surgery	Virtual reality educational surgical tools (VREST) [60]
Laparoscopic Surgery	MIST-VR [61], LaparoscopyVR [62], LapMentor [63], LapSim [64], SINERGIA [65], Xitact LS500 [66]
Robotic Surgery	RoSS [67], DV-Trainer [68], SEP Robot [69], da Vinci Skills Simulator (dVSS) [68]
Esophagogastroduodenoscopy,ERCP, Colonoscopy	GI Mentor [70], EndoVR [71], Olympus Endo TS-1 [72]
Neurosurgery	NeuroVR [73], ImmersiveTouch [74], RoboSim [75], EasyGuide Neuro [76], ANGIO Mentor [77], VIVENDI [78], Dextroscope [79], Anatomical Simulator for Pediatric Neurosurgery [80]
Interventional Cardiology and Cardiovascular Surgery	ANGIO Mentor [77], Vascular Intervention Simulation Trainer (VIST) [81], Vimedix (equipped with Hololens) [82], Nakao Cardiac Model [83], Minimally Invasive Cardiac Surgery Simulator [84], dVSS [85], EchoCom [86]
Urology	URO Mentor [87], University of Washington TURP Trainer [88],UROSim [89], PelvicVision TURP Simulator [90], GreenLight Laser Simulator [91], Kansai HoLEP [92]
Orthopedics	ImmersiveTouch [74], PHANToM haptics interface [93], Gaumard HAL S3000 [94], Arthro VR [95], Arthro MENTOR [96], ArthroSIM [97], ArthroS [98]
Endovascular Surgery	ANGIO Mentor [99], VIST [100], Cardio CT [101], SimSuite [102]
Gynecology and Obstetrics	HystSim [103], EssureSim [104], MIST-VR [105], LapSim [106]
Otolaryngology	OtoSim [107], VOXEL-MAN (supports Phantom haptics) [108], Ohio State University surgical simulator [109], Stanford surgical simulator [110], Mediseus [111], ImmersiveTouch [74], Desxtroscope [112]
Ophthalmology	EyeSi [113], MicrovisTouch [114], PhacoVision [115]
Intubation and Bronchoscopy	EndoVR [71], BRONCH Mentor [116], ORSIM [117]

Table I: Examples of Simulation and Training Specific to Education Areas Supported with Virtual Reality Technologies

simulators increased the opportunity to learn. Besides, it was indicated that students provided positive feedback on training with a simulator [52]. Vidal et al. performed research with nursing students on the skill of bloodletting, and the CathSim simulator was compared with traditional techniques. It was concluded that VR got ahead of traditional methods when the number of the entrance, hematoma formation, and pain scoring was considered [53]. Bowyer et al. compared the performance of CathSim and Virtual I.V. simulators and training with the traditional plastic arm on intravenous catheterization skills. While students who utilized both simulators showed higher performance than the students who utilized the traditional method, students who used the Virtual I.V. simulator presented greater progress [54]. Georg and Zyan indicated that the utilization of virtual patient model in nursing education could provide a positive contribution to clinical skills and decision making of nursing students [55].

II. CONCLUSION

Nurses, who are an indispensable part of the healthcare team, should follow the developing technology to provide effective and quality care. VR contributes to the reduction of costs by increasing the quality and it finds a place in revolutionary technologies for healthcare. Recently, the utilization of VR technology has become popular in healthcare in order to increase patient safety and improve patient care. It is extremely important to ensure that nursing students are professionally knowledgeable, competent, and equipped during their education. In the light of the literature, it is necessary to use virtual reality applications in nursing education for the development of basic skills, and in order to provide a more realistic education and training environment, it is essential to integrate knowledge and skills with these simulation methods. Virtual reality allows the repeated application of clinical scenarios on various models in a risk-free environment and provides the opportunity to learn equally to every student. This situation contributes to the development of knowledge and skills of nursing students by helping them to practice more and to increase their self-confidence by reducing anxiety. In conclusion, VR systems should be used in nursing education in order to increase patient safety in clinical practice, to reduce erroneous attempts, and to increase the quality and efficiency of care.

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