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# Preliminary Study of VR and AR Applications in Medical and Healthcare Education

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## Abstract

As technology advances, mobile devices have gradually turned into wearable devices, and Virtual Reality (VR), Augmented Reality (AR) as well as Mixed Reality (MR) have been applied more and more widely. For example, VR, AR and MR are applied in the medical fields like medical education and training, surgical simulation, neurological rehabilitation, psychotherapy, and telemedicine. Related research result has proved that VR, AR and MR ameliorate inconvenience of traditional medical care, reduce medical malpractice caused by unskilled operation, and lower the cost of medical education and training. Moreover, the application has enhanced effectiveness of medical education and training, raised the level of diagnosis and treatment, improved the doctor-patient relationship, and boosted efficiency of medical execution. This study introduces VR, AR, and MR applications in medical practices and education, and aims to help health professionals know more about these applications, becoming interested to improve the quality of medical care via the technology.

**Keywords:** Virtual reality; Augmented reality; Mixed reality; Medical practice; Healthcare education

## Introduction

Virtual Reality (VR) and Augmented Reality (AR) are something well-known nowadays. As the technology and software body are getting advanced, VR and AR have been commonly used in the field of health services, hospitality, education, tourism, cultural, military, construction, design, engineering, gaming, entertainment and so on. Some people get confused easily between the terms of VR and AR. Virtual Reality (VR) means user could watch and interact through the VR device but all the images displayed are "fake", which are all virtual. In another interesting way, people describe it as a "spiritual journey". On the other hand, Augmented Reality (AR) known to be a virtual object that is generated by a computer through the real environment seen by a mobile phone, tablet or AR glasses. The AR presents a semi-true and false image, which is the combination of real and virtual, some people commonly describe it as the "third eye". Media reported 2016 as the year that virtual reality (VR) and augmented reality (AR) being popularized, YouTube, Vimeo and many other video platforms have started to support VR applications and VR video watching, more and more VR Experiencing Museum has also existed. In 6th August 2016 "Pokémon Go" was released in Taiwan. Players are crazy about it. According to media reports, LBS combined with AR technology was used by "Pokémon Go", and so the term AR augmentation becoming popular [1].

According to industry ARC research report, the healthcare market of VR and AR will reach 2.54 billion U.S. dollars by 2020, mainly including the application of surgery, medical rehabilitation, medical consultation, medical diagnosis and medical education and training [2]. In view of this, the main purpose of this paper is to explore the application of VR, AR and MR in medical nursing practice and education, as well as to introduce the hardware devices and applications (APP) that have been used in practice.

## Literature Review of VR, AR and MR

Milgram and Kishino considered the real environment and the virtual environment as a continuum [3], as shown in **Figure 1**. The real environment and the virtual environment are taken as two ends of the continuum respectively. The left showed a real environment which inwardly extended to form Augmented Reality (AR), whereas the right demonstrated a virtual environment extended to form Augmented Virtuality. Mixed reality (mixed reality, MR) is located in between the real environment and virtual environment.

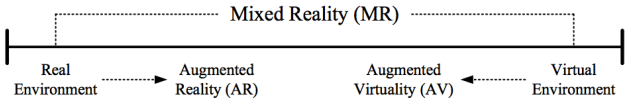


**Figure 1** Schematic diagram of real and virtual performance [3].

Mixed reality is a combination of VR and AR, the real world and the virtual environment to create a virtual image which in line with human vision, so that people can instantly interact with virtual objects.

## The virtual reality (VR) characteristics and applications

VR technology has a wide range of applications, such as military, nursing, medical, education, entertainment and training [4]. In the medical field, users are visually impressed with their experience. This technology can make up for many inadequate resources and equipment and improve the traditional teaching methods. VR compromised of many features that are ideal for surgical simulation training, rehabilitation, pain management, behavioral therapy, such as: VR medical care training, allowing users to interact with VR, as if immersive in the actual scene, can reduce the technical operation Health care caused by negligence. The use of VR to build virtual organs or tissues can assist physicians in their work, enable doctors and nurses to communicate more effectively with their patients, enhance the ability of doctors to diagnose patients, provide information about their illness and the progress of surgery, and are low-cost, non-invasive conducting and ex-post evaluation, training in the treatment of disease and technical training will not pose any real risk to the patient. However, the time spent on VR should not be too long. If VR is used for a long time, it may easily cause health problems. This may result in excessive headaches, dizziness and nausea.

## The characteristics, classification and application of augmented reality (AR)

Augmented reality (AR), also known as augmented reality may expand or enhance reality. The use of ARs in many movies, such as the “Minority Report” performed by Tom Cruise in Azuma, and the “Iron Man”, the American superhero film released in 2008, are the most representative. AR is an extension of VR, which enhances the perceived effect of integrating virtual information or objects into a real-world environment via computer-generated images, objects, information or scenes and interaction to enhance the perception [5]. AR technology contains three characteristics of “combining virtual reality with real world”, “real-time interaction” and “essential 3D space.” AR applications and prospects are extremely broad, many people have played SNOW APP, which is one of AR applications, the use of face detection and AR technology, when the phone lens to capture the face, the user can choose Virtual stickers, animation effects, instantly display on the phone screen, combined with taking pictures and video recording, so that photos and video recording became more lively and interesting.

AR technology is mainly work through the identification of the target object, and then tracking the identified objects, after that imposed virtual images onto the tacked object which then present it by the display device. At present AR is divided into three categories, (a) marker-based AR (marker-based AR): refers to the black box as a marker, better identification and tracking. (B) markerless AR (markerless AR): As the image processing technology advances, most of today are markerless AR, which is to identify and track the natural pattern, which can be photos, wedding invitations, greeting cards, Posters, business cards, credit cards, DM and so on. (3) LBS AR: LBS is location-based services, or “mobile location service”, “geo location service” and “location service”. Geographic location the basic application of value-added services. LBS is the mobile device GPS positioning function to provide the current location information. The technology used by Pokémon Go is based on the geo-location service LBS AR, where players hold their smartphones for gaming. With GPS positioning, map information is presented based on LBS technology, displaying the player's geographic location in real-time, combined with the AR technology Players experience the process of capturing treasure dream. In the player's mobile phone screen, through the camera lens in addition to see the real environment, and can see the virtual Pokémon, which is superimposed on the virtual environment in the virtual object.

## The mixed reality (MR) definition and application

Mixed reality (MR) is more forward-looking in the medical community. Mixed reality is a combination of AR and VR features that mixing real and virtual environments to create a completely new environment [3]. MR is based on the AR, providing a more realistic and highly interactive experience than the AR, interacting with virtual objects through real hands. In addition to VR and AR glasses, Acer, Microsoft and other manufacturers have also introduced MR glasses. Microsoft introduced HoloLens smart glasses, that is, MR glasses, the application of MR in the future nursing and medical health field will be more vigorous developed.

## VR, AR and MR in medical practice and education related applications

VR and AR are increasingly being used in the medical field [6,7] as VR surgical simulation systems that provide trainee or inexperienced surgeons with surgical training when operating a VR surgical simulation system, you can simulate the realism of the actual operation and reduce the incidence of errors during the actual operation in the future. There has been a steady growth in the use of virtual reality (VR) in health care [8]. In the teaching of human anatomy [9], three-dimensional stereoscopic visual effects can be presented through VR to understand the relative positional relationship between objects. For clinicians or medical students in the understanding of human structure and learning, has very good potential applications. In healthcare education, intravenous injection can also be learned through VR and AR [10]. The needles of different thickness classes are used to simulate needle penetration into the patient's arm and produce force feedback through hardware devices. Simulations The feeling of the actual injection, mainly to avoid the novice care for the unskilled injection caused the patient’s pain or uncomfortable. There are many VR simulation system, such as: subcutaneous

injection simulation training system, bronchoscopy surgery simulation system, sigmoidoscopy operation simulation system, ovulation ligation surgery simulation system, EndoVR endoscopy computer simulation teaching system, LapVR laparoscopic computer simulation teaching system, CathLabVR catheter interventional treatment computer simulation teaching system (http://healthcare.kyst.com.tw/products_2.php?bgid=24). In addition, virtual reality can also provide patients with rehabilitation, make repetitive and dry rehabilitation activities more interesting, and engage patients [10-12]. The following shows a brief description of current related applications and APPs in healthcare practices and healthcare education.

## Applications in health care practices

**VR exposure therapy:** The development of VR content has moved from the gaming field into the medical field. VR technology brings the real environment into people's minds and able to heal people's anxiety and fear such as Acrophobia, claustrophobia and social anxiety through the VR "exposure therapy" [13]. The Limbix company (https://www.limbix.com/) also uses the expose therapies through VR technology that allow patients to safely exposed in a situation by wearing a VR device and virtually exposing themselves on a high building to treat Acrophobias; or with virtual spiders that allow patients to overcome the fear of spiders [14].

**AR autism treatment:** The Autism Glass Project of the medical school of Stanford University uses the Google Glass AR technology to help children with autism to interpret the others' emotions and hoping to help them correctly interpreting emotions without wearing the Google Glass in the future, but with their previous practices and memories, hence develop social relationship as normal people do [15].

**AR phantom limb pain treatment:** Phantom limb pain refers to patient who has loss part of their limbs but they can still feel the present of it or feel the pains of their amputated limbs very often [16]. The phantom limb pain treatment is the use of AR technology [17]. AR technology allows amputees to see the virtual arm appear on the screen, when the patient moves the amputated arm, the virtual arm on the screen will also appear the same action, through the interactions to activate and allow the patient to control the originally amputated limb with their brain, in order to achieve a therapeutic effect [18].

## Applications in medical education

**VR virtual anatomy:** The Anatomage table is a virtual anatomical table is a platform which designed for anatomy teaching by visualizing the detailed structures of each part of the human body, including head and neck, chest, abdomen, pelvis, joints and the other parts, it has provided trainee and students of medical institutions or schools a great teaching material. Clinicians, medical students and medical staffs can also understand and learn more conveniently. In addition, it can help physicians in some discussion of research as well as showing the patient's preoperative explanations, so that patients can better understand their own surgical conditions, UTA has also introduced Taiwan's first virtual anatomical table (http: //www.isu.edu.tw/ipages/344-2-22762.html).

**VR surgery simulation:** VR technology will be increasingly common for surgical training, doctors use the VR technology to carry out virtual surgery training which can reduce the possibility of operational errors in the future. Many companies have been developing the VR surgical system, Fundamental VR company has develop a system for knee arthroscopy that simulates knee cap replacement surgery and allows physicians to practice how to inject anesthetics in the surgery correctly. The VR medical visualization platform developed by Surgical Theater Company simplifies the surgical planning process and increases the surgical accuracy so that the surgeon can understand the operation process better and provides the safest and most effective surgical procedures (http://www.surgicaltheater.net/). Other than providing a risk-free environment, VR surgery simulation can also allow the interns to learn from mistakes and some potential risks from the VR operating environment. There are getting more hospitals within Taiwan have introduced VR into their surgical training. For example, Taipei Veterans General Hospital uses VR technology in "endoscopic skull base surgical anatomy training", which enables surgeons to practice more skillfully and shorten their study duration which effectively reduce the possible errors in surgical training (http://www.healthnews.com.tw/news/article/34341/).

**AR anatomy teaching:** In traditional medical education, human anatomy is introduced in anatomy, physiology and pathology. However, explanations can only be made through picture, videos or models in the past. It was less likely for students to operate repeatedly on patients to enhance their learning outcome.

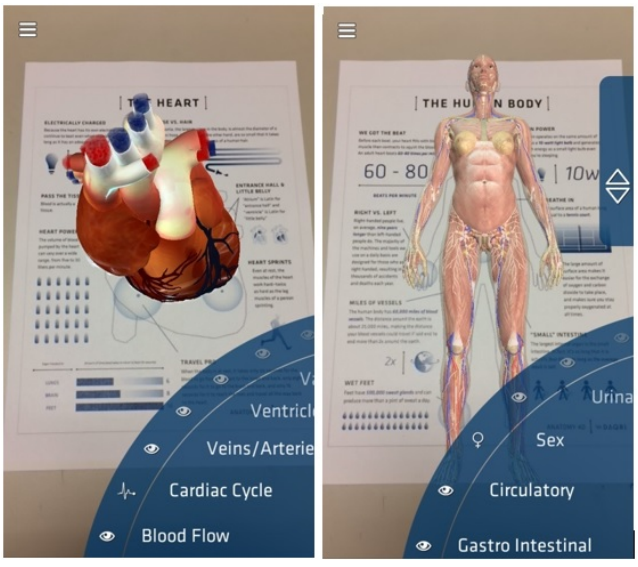


**Figure 2** Anatomy 4D App - virtual heart (left) and human anatomy (right) AR display.

With AR and VR technologies, 3D stereoscopic visual effects can be rendered for an immersive experience, with the main advantage of saving time and costs. Another example is the

anatomy of the heart. Teachers will not be able to provide the "real heart" to each student. Through the AR technology, students are able to download the book scanning APP or real heart images by using smart devices. A virtual heart will appear immediately on the screen of the device and he size of it can be adjust easily by zooming in and out or rotating it in order to observe the heart pattern in different angles and the structures of it. Anatomy 4D is an AR Human Anatomy APP [19] that learns about organs, heart and respiratory system in the body. Download Anatomy 4D APP on your electronic smart devices (smartphone or tablet) and scan the card to instantly show the 3D model of the heart on the card. Rotate the card to see any view of the heart in every angle, in addition to teaching in the classroom as a teaching material, students can learn at home. Other than be used as teaching materials in the lectures, students can also do the self-learning at home with the well operations of this APP by clicking the "menu" at the lower right corner (**Figure 2**).

### The application of MR in medical practice and education

**Medical practices:** MR has been able to make use of assisting surgery in medical practice. HoloLens MR glasses is the combination of Scopis medical devices with Microsoft, surgeries can be planned preoperatively through the Holographic Navigation Platform to help doctors perform faster and more accurately during the operation and reduce the risk of surgery and shorten the surgery operating time (https://navigation.scopis.com/).

**Applications in medical education:** HoloLens MR glasses has provided an interaction between the medical school professor and students in the lesson of learning anatomy. HoloLens presents a 3D virtual human model. Students are able to interact with the virtual human model through gesture or dissect the parts of the virtual human body. It has inversed the traditional way of learning about anatomy (https://goo.gl/z7BjTw). Xiu Chuan Hospital and Qin Yi University of Science and Technology have also developed a medical use of MR glasses. It can help to observe the patient's under-skin organs, blood vessels and nerves and find out the surgical site more accurately before the operation.

## Discussion

### The future development and challenge in the field of medical practices

In the future, there are high possibilities of the applications of VR, AR and MR in the field of health care [20,21]. For example, wearing an AR glasses and walking could see the sign board of each store along the street. The visual displayed in the AR glasses can present a real environment and also the recent advertisement, offers or related information of the chain stores. If wearable glasses are used in medical care, we can give an example of what can be achieved in the future. Health care workers are commonly checking the patients' conditions through computer on the mobile medical cart, when delivering medication to patient, name and date of birth of the patient are required to identify the patient's identity. However, medical staff will only require to wear an AR glasses which combined GPS, Bluetooth, camera, sensor and face identification function and instantly connect with the hospital cloud database. AR Glasses display the patient's relevant information, such as: their past, diagnosis, the current medication, drug allergy history, DNR notes, etc, so that caregivers more easily understand the patient's details.

The MR can also be used in medical distance education, such as distal surgical knife training, cancer therapy and nursing education training [21], doctors and trainees in different spaces (hospitals), both sides wear MR glasses, you can immediately see the distal picture, the doctor Simultaneously sees the trainee simulates the surgical operation training situation, directs the teaching, may inform the other side to give the feedback at any time, the future may also combine to X ray, CT, MRI, angiography and Doppler ultrasound. Describing the Corning high-tech glass combination that will help and change our world in the future, 6:20 to 8:35 in "Glass Day 2: An Illustrated Version. The Story Behind Corning Vision" to describe the future in medical applications (https://goo.gl/sfGiQy) (**Figure 3**).

**Figure 3** "The day of the Glass 2: An illustrated version. The story behind the corning vision" QR code link.

These technologies should be implemented in clinical practice, may face layers of barriers, such as the cost of hardware construction, the integration of system software and hospital databases, the actual use of clinical equipment for the user equipment and easy to use Sexuality and long-term use of these devices will affect the health of users, training of personnel in introducing new technologies, skills required by medical staff, etc, are all possible problems and challenges in the future.

## Conclusion

VR, AR and MR technologies are gaining more and more attention in the healthcare field. Other than improving the inconvenience of traditional medical practices and education, it can also increase the effectiveness and efficiency of the nursing and medical health care services. However, there are still some technical problems have yet to be overcome. Such as

the integration of the nursing and medical health care information system, the clarity and resolution of the display image, the durability of hardware etc. Nowadays, there are many academic, medical institution and manufacturers are developing some new techniques in order to overcome some related technical problems. In short, the widely popularize of AR, VR and MR in the nursing and medical health care field are highly expected.

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