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Extended Reality in the Pharmaceutical Industry

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ABSTRACT

Immersive technologies play a crucial role in the pharmaceutical industry worldwide.

In today's world, extended reality has soaked most industries and pharma is not an exception. Extended reality (XR) is an umbrella term used for technologies like virtual reality (VR), augmented reality (AR), and mixed reality (MR). XR bridges the gap between real and virtual worlds and can play a vital role in every aspect of healthcare and pharmacy. XR lowers human error by enabling greater collaboration and training through guided instruction and remote assistance. XR devices offer many advantages for pharmaceutical applications. This paper introduces extended reality and describes how it can be applied in the pharmaceutical industry.

KEYWORDS: *virtual reality, VR, augmented reality, AR, mixed reality, MR, extended reality, XR, immersive technologies, pharmaceutical industry, pharma*

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INTRODUCTION

The rise of computing has transformed nearly every field, and the computer has transformed every industry. We have witnessed a continuous exponential growth in computing power with a simultaneous decrease in cost—a phenomenon known as Moore's Law. Newly available devices allow computers to be used in completely different ways. Users can view immersive virtual worlds or view 3D digital information overlaid onto the physical world. In the pharma sector, many executives are aware of the disruptive potential of digital transformation and immersive technologies.

Human beings are visual creatures. Both hearing and seeing are central to our sense of space. As we have been spending an increasing amount of time in front of computers, the need to explore more of the role of virtual environments also needs to be increased.

Advances in display technology and computing have led to new devices capable of overlaying digital information onto the physical world or incorporating aspects of the physical world into virtual scenes. These combinations of digital and physical environments are referred to as extended realities. Extended reality devices have been applied to education and medical practice such as cardiac interventions and patient anatomy.

WHAT IS EXTENDED REALITY?

There are four types of digital realities [1,2]:

- *Augmented reality* (AR)— designed to add digital elements over real-world views with limited interaction.
- *Virtual reality* (VR)— immersive experiences helping to isolate users from the real world, usually via a headset device and headphones designed for such activities.
- *Mixed reality* (MR)— combining AR and VR elements so that digital objects can interact with the real world means businesses can design elements anchored within a real environment.
- *Extended reality* (XR)— covering all types of technologies that enhance our senses, including the three types previously mentioned.

These devices also enable new user interactions including spatially tracked 3D controllers, voice inputs, gaze tracking, and hand gesture controls.

Extended reality (XR) is the overarching term used to describe employing technology to blend real life and the digital world. It includes all the machine-human interfaces beyond the physical realm (reality) such as augmented reality (AR), mixed reality (MR), assisted reality (aR), and virtual reality (VR), as illustrated in Figure 1 [3]. Figure 2 shows the XR spectrum [4]. A range of devices makes up XR, and these are used by consumers and in many industries for entertainment, safety, training, or productivity purposes.

1. *VIRTUAL REALITY:* Virtual reality (VR) is XR at its most extreme. It completely immerses the user in a digital world, often using a computer-generated environment with scenes and objects that appear to be real. The term "virtual reality" essentially means "near-reality." Virtual reality is the key technology for experiencing sensations of sight, hearing, and touch of the past, present, and future. VR is a fully immersive technology where users wear a head-mounted display and experience a simulated world of imagery and sounds. VR enables active learning. The terms, "virtual reality" and "cyberspace" are often used interchangeably. A cyberspace may be regarded as a networked virtual reality. Virtual reality is a simulated experience that can be similar to or different from the real world. It is a computer-generated, 3D environment that completely immerses the senses of sight, sound, and touch. The complete immersion of the senses overwhelms users engrossing them in the action. Virtual reality technology includes multiple components divided into two main groups: hardware and software components [5].

- *Hardware Components:* The hardware components include a computer workstation, sensory displays, a tracking system, wearable devices, and input devices. Sensory displays are used to display the simulated virtual worlds to the user. The most common type is the head-mounted displays (HMDs), which is used in combination with tracking systems. Head-mounted displays are shown in Figure 3 [6]. Users interact with the simulated environment through some wearable devices. VR depends on special responses such as raising hands, turning the head, or swinging the body. A wearable device is important in making these effects realistic. Special input devices are required to interact with the virtual world. These include the 3D mouse, the wired glove, motion controllers, and optical tracking sensors. These devices are used to stimulate our senses together to create the illusion of reality.
- *Software Components:* Besides the hardware, the underlying software plays an important role. It is responsible for the managing of I/O devices and time-critical applications. The software components are 3D modeling software, 2D graphics software, digital sound editing software, and VR simulation software. VR technology has been designed to ensure visual comfort and ergonomic usage.

2. *AUGMENTED REALITY:* Augmented reality (AR) is a technology that combines real-world environments with computer-generated generated information such as images, text, videos, animations, and sound. It can record and analyze the environment in real-time.. For example, AR allows consumers to visualize a product in more detail before they purchase it. This feature enhances consumer interaction and helps them never to repurchase the wrong item. The key objective of AR is to bring computer-generated objects into the real world and allows the user only to see them. In other words, we use AR to track the position and orientation of the user's head to enhance/augment their perception of the world. Augmented reality falls into two categories: 2D information overlays and 3D presentations, like those used with games. AR blends the virtual and real worlds by overlaying digital objects and information onto the users' view of the physical world.

To obtain a sufficiently accurate representation of reality, AR needs the following five components [7]:

- *Sensors:* AR needs suitable sensors in the environment and possibly on a user, including fine-grained geolocation and image recognition. These are activating elements that trigger the display of virtual information.
- *Image augmentation:* This requires techniques such as image processing and face recognition.
- *Head-mounted Display*: HMDs are used to view the augmented world where the virtual computer-generated information is properly aligned with the real world. Display technologies are of two types: video display and optical see-through display.
- *User Interface:* This includes technologies for input modalities that include gaze tracking, touch, and gesture. AR is a user interface technology in which a camera-recorded view of the real world is augmented with computer-generated content such as graphics, animations, and 2D or 3D models.

- *Information infrastructure:* AR requires significant computing and communications infrastructure undergirding all these technologies. The infrastructure determines what real-world components to augment, with what, and when.

3. *MIXED REALITY:* Mixed reality (MR) is a term used to describe the merging of a real-world environment and a computer-generated one. Physical and virtual objects may co-exist in mixed reality environments and interact in real time. This is an extension of AR that allows real and virtual elements to interact in an environment. MR liberates us from screen-bound experiences by offering instinctual interactions with data in our living spaces and with our friends. Online explorers, in hundreds of millions around the world, have experienced mixed reality through their handheld devices. Mixed reality is a blend of physical and digital worlds, unlocking natural and intuitive 3D human, computer, and environmental interactions, as shown in Figure 4 [8]. This new reality is based on advancements in computer vision, graphical processing, display technologies, input systems, and cloud computing. Mixed reality has been used in applications across fields including design, education, entertainment, military training, healthcare, product content management, and human-in-the-loop operation of robots [9].
4. *ASSISTED REALITY:* Like mixed reality, assisted reality (aR) is an extension of augmented reality, with a few notable differences to both. One of these differences is that aR is primarily hands-free through the wearing of a headset, whereas AR usually requires the holding of a device such as a mobile phone. While MR is a digital-first, real-world second reality, aR is a real-world first system. It combines software and a head-mounted display. It is best experienced using smart glasses or other wearable technology. The aR market is growing rapidly and promises to be the next great leap to boost workers' productivity. A worker wearing an aR device is shown in Figure 5 [10].
5. *EXTENDED REALITY:* The term “extended reality” (XR) has recently gained favor as an umbrella term that encompasses all of AR, VR, and MR. The primary user inputs for XR devices are described as follows. Voice interfaces are now ubiquitous thanks to mobile devices and standalone smart speakers. Apple’s Siri, Amazon’s Alexa, Google’s Assistant, and Microsoft’s Cortana are all voice-driven software interfaces that are continuously gaining new capabilities. Many XR devices enable user control with handheld controllers, which have capabilities beyond button press inputs. Both voice-driven interfaces and human-computer interactions have been developed specifically for XR devices, including gaze and gesture controls [11]. Figure 6 compares conventional computing with extended reality [11].

APPLICATIONS OF EXTENDED REALITY IN PHARMACEUTICAL

Extended Reality (XR) has undergone significant advancements and is rapidly progressing across various fields. It is a very powerful tool for the pharma business. It helps engineers and technicians communicate complex information in a fully immersive and interactive virtual reality format. XR has a wide range of potential applications in the pharmaceutical industry. Areas of common application of extended reality in pharmaceutical include the following [11-13].

- *Healthcare:* An interesting aspect of extended reality in medical practice is that extended reality devices necessitate new paradigms for human-computer interaction. Medical extended reality (MXR) has emerged as a dynamic field at the intersection of healthcare and immersive technology. It is intriguing to imagine what medicine will look like once these devices are fully deployed. Parents of congenital heart disease patients could put on AR goggles to view a 3D hologram of their child’s anatomy in the center of the room with their physician. In the treatment planning phase, teams of clinicians could use 3D displays to view patient-specific anatomy obtained from CT to determine the optimal therapeutic intervention. While performing procedures, doctors and staff could see regions of bright colors near the fluoroscopy machine when it is in use, indicating areas of high radiation exposure. The 3D views provided by extended devices can give clinicians a better sense of patient anatomy and can help track surgical tooling and register images. The simplest medical applications of XR take advantage of the ability of XR displays to provide 3D visualizations of anatomy. Figure 7 shows a typical use of XR to enhance healthcare [14].

- *Pharmaceutical Manufacturing:* Pharmaceutical manufacturing requires a very high level of control from design to market. Most of the production relies on complex equipment that involves precise steps. VR enhances manufacturing processes by displaying and simulating the whole assembly process or any maintenance scenario you want to run. Virtual assembly is one of the biggest benefits VR brings to manufacturing. Manufacturing industries have drastically changed over the past few years. Traditionally, the manufacturing of goods has evolved from craftsmanship to highly organized mass producing factories to highly customized Industry 4.0. Global competition drives manufactured goods nowadays and there is a need for fast adaptation of skills, process, and production to meet the transformative markets' requests. It is highly important that workers in manufacturing environments should be trained and re-trained to meet the evolving market needs. AR is used in manufacturing to provide workers with real-time instructions on assembly lines. VR simulations help train employees in complex machinery operations, improving efficiency and safety in the workplace.

- *Drug Discovery:* The drug discovery process is notoriously lengthy and expensive. XR in the pharmaceutical industry is being utilized to accelerate this process by enabling drug designers to interact with 3D models of drug candidates. XR might also be useful for new drug designing. Extended reality technologies are overcoming traditional 2D challenges in the complex process of drug development. Virtual reality enables researchers to be fully immersed in their 3D models, and visualize complex three-dimensional data from within. VR is an ideal tool to discover new drugs and enhance preclinical research phases, such as drug-target interaction studies, and predicting the outcomes of a drug's effect in the human body before clinical trials.
- *Training:* It is crucial to familiarize and train yourself with pharmaceutical manufacturing equipment and medical devices before using it in real life. However, some of these machines are very expensive, and many scenarios cannot be tested with the real equipment. Training in the pharmaceutical sector is usually costly and time-consuming. XR in pharma can be a solution to these challenges. Simulation processes eliminate the need for physical equipment (and such equipment is usually very expensive) and at the same time, it increases information retention. Using VR and AR in pharma training creates a sense of personal connection as it feels like real one-on-one training in a virtual world. You can train technicians in VR simulations that would have been too dangerous or too rare to be done with traditional training methods. Medical trainees require hands-on experience in surgery if they want to become surgeons. However, hands-on experience with actual patients is risky. XR technologies solve this problem by offering immersive simulations where trainees can hone their surgical skills without any risk to anyone. Augmented reality technology can be used to teach students anatomy through an immersive and collaborative environment. Figure 8 shows how XR is used in training medical students [15].
- *Education:* This is another area where XR in pharma is making a significant impact. Extended reality provides an unparalleled medium for augmenting the learning experience for students in diverse disciplines. For example, medical and nursing students engage in immersive VR simulations featuring virtual anatomical and physiological visualizations. XR plays a dominant role not only in training healthcare professionals but also in patient education. Companies are already leveraging AR to educate patients about their medications effectively. By using AR applications, pharmaceutical companies can develop interactive educational tools that help patients understand their medications better. For example, patients can visualize how drugs interact within their bodies or learn about potential side effects through immersive experiences. This enhanced understanding can improve patient adherence to treatment regimens and ultimately lead to better health outcomes.
- *Sales:* A huge obstacle for successful sales in the drug industry is competing for a professional's time and attention. This is why a VR presentation is a great tool to communicate accurately, efficiently, and have a lasting effect, compared to a traditional sales pitch. AR allows pharmaceutical companies to showcase medicines and other healthcare products to their buyers. 3D visualization technologies help salesmen representing pharmaceutical companies to demonstrate drug composition, production methods, clinical trial results, medical research outcomes, and drug effect mechanisms to anyone concerned. Sales meetings with clients can be simplified with AR-based tools.
- *Virtualization:* Data visualization is a useful feature of AR that helps in identifying elements that would otherwise be almost impossible to find for pharma companies and researchers. Thanks to extended reality in the pharmaceutical industry, you can review 3D assets and view 3D models at full scale. It enables scientists and engineers to inspect data in a spatial context and visualize their models at full scale. By using AR and VR data visualization, they can see their products in their

world, their office, laboratory or factory. Virtual reality technology can allow users to segment and visualize medical imaging modalities in three dimensions. Users can create patient-specific 3-D models from radiological images for enhanced visualization and learning of complex patient-specific pathologies and anatomy. Virtual reality technology can be used to simulate procedures for interventional radiologists. Advancements in using XR tools have allowed interventional radiologists to overcome the limitations of procedural navigation in image-guided procedures. Figure 9 shows using VR technology to visualize a medical image [15].

- *Clinical Trials:* XR could be used to conduct virtual clinical trials. This would allow pharmaceutical companies to recruit a broader range of participants for clinical trials and reduce the cost of conducting clinical trials. Clinical applications of XR in nonsurgical specialties include medicine, pediatrics, dentistry, and nursing. It covers a wide range of applications including oncology, hematology, cardiology, gastroenterology, endocrinology, and infectious diseases, among others. XR in clinical trials focuses on using, evaluating, and understanding XR for treating neurological disorders, psychological conditions, and supporting neurosensory modulation to help manage acute and chronic pain.

BENEFITS

Extended reality is one of the cutting-edge technologies that is speeding up procedures in all aspects of our lives. XR technologies have enabled increased efficiency and comfort for both scientists and specialists and have made their lives much easier and more convenient. XR tools enable users to segment and visualize medical images in 3-D efficiently. Virtual reality allows you to display the 3D model of your pharmaceutical products at 1:1 scale, and interact with it in real time. Other benefits of XR in pharmacy include the following [16]:

- *Enhanced Data Analytics:* This pharmaceutical industry deals with many complex data. With VR, you can visualize them in three dimensions and immerse yourself in it, and uncover new insights. It will help you and your coworkers understand complex content.
- *Reduced Error Rates:* VR reduces the need for expensive physical prototypes, which is crucial when you take into account the complexity of manufacturing equipment and processes in this sector.
- *Reduced Costs:* After the initial investment in a virtual reality system, all other costs are reduced as only need one virtual prototype, and you can collaborate better and more efficiently on the same CAD model. AR can be used to reduce the cost of pharmaceutical manufacturing and development. This can be achieved by reducing the need for physical prototypes and improving manufacturing process efficiency.
- *Safety:* AR can be used to train pharmaceutical professionals in a safe and controlled environment. This can help to reduce the risk of errors and improve patient safety.
- *Accessibility:* AR can make pharmaceutical education and information more accessible to patients and healthcare professionals. This can help to improve patient compliance and reduce the risk of adverse events.
- *Patient Monitoring:* XR could be used to monitor patients remotely. This would allow healthcare providers to monitor patients' vital signs and progress from a distance.
- *Reduce Huma Error:* One of the main jobs of AR is to reduce the element of human error from pharmaceutical functions and operations. We can safely say that AR's capabilities meet this requirement by allowing the virtual testing of new production processes without human intervention, thereby reducing the likelihood of accidents or deaths caused due to workers' poor understanding of new machines and production operations.

CHALLENGES

While XR offers new possibilities for clinical cardiology, there are still technical challenges. One of the key hurdles is simply to overcome the wait-and-see mindset that is common when introducing new technology into regulated industries. A difficulty of incorporating XR into more medical procedures is the lack of mechanical feedback. Some VR users report side effects such as nausea, headaches, dizziness, or blurred vision. Most companies that have not used VR or AR technologies believe that implementing XR in pharma is a very daunting and uphill task. Other challenges include the following [13]:

- *Regulatory Compliance:* One of the most significant challenges facing the pharmaceutical industry is maintaining regulatory compliance while innovating. The rapid evolution of XR technologies outpaces the development of regulatory standards, leading to uncertainties in compliance, safety, and efficacy assessments. XR technologies can create virtual simulations of manufacturing processes, allowing engineers and scientists to test and optimize these processes without physical interaction with equipment. By simulating scenarios that adhere to compliance requirements, companies can ensure that their operations meet necessary guidelines more effectively. Engineers and scientists can test and optimize processes without physically interacting with the equipment. This can help to reduce the risk of non-compliance with regulatory standards.

- *Quality:* Extended reality has proved its huge impact on quality control and safety standards in the pharmaceutical sector. When it comes to quality in pharma, the risk is much higher than in most sectors. Any mistake can damage the entire product development cycle and brand reputation. XR in pharma lowers human error but allows keeping a high level of regularity in products. AR can provide real-time feedback on the quality of pharmaceutical products.
- *Collaboration:* Collaboration is of the utmost importance in most industries and the pharmaceutical sector is not an exception. Thanks to XR in pharma, different teams of experts and scientists located all over the world can work together, fully synced on molecular structures using smartphones and AR/VR software. They can visualize, edit, and update the shared structures for future processing. If pharmaceutical companies want to align with demand and growth, they must be able to improve efficiency, uncover new opportunities and build better collaboration with their prescribers, patients and other stakeholders. VR reduces the barrier to view and interact with structural data, enabling scientists to share detailed visualization with non-experts in their field, thus fostering new collaborations. The AR experience also allows the users to collaborate almost seamlessly in both worlds.
- *Cost:* High-quality scientific XR technology is expensive to develop. Pharmaceutical companies may easily underestimate the expense of deploying such systems. This expense seems less daunting when it is seen as an investment that offers a substantial return.
- *Required Training:* There is a bit of training required in terms of how to function in a virtual environment. For example, integrating XR technology into existing radiology curricula can be challenging. It requires alignment with educational goals and careful planning to ensure that XR complements rather than replaces traditional teaching methods. Another challenge is the potential resistance within the education community to adopt new technologies.
- *Data Privacy:* Data privacy and ethical considerations are paramount, especially given the use of patient data in developing realistic and patient-specific XR training modules. Because XR applications often involve the use of sensitive patient data, they must navigate a complex landscape of health information privacy regulations, such as HIPAA.
- *Ethical Considerations:* These extend to the portrayal and handling of virtual patients within XR environments. Ethical considerations are pivotal, including equitable access, safeguarding data privacy, maintaining security, and ensuring the authenticity of personal identity within XR environments. The creation of realistic patient avatars or scenarios must be approached with sensitivity and a commitment to ethical standards. There is a growing need for comprehensive ethical frameworks and guidelines for XR in healthcare.

CONCLUSION

Technological advances mean that the way we digitally alter reality is getting more and more immersive and advanced. To keep up with market demands and the overall digitization of the pharmaceutical sector, successful drug companies recognize the need for smart and immersive technology. Extended reality is a broad term encompassing all forms of technology that blend the real and virtual worlds. It is one of the cutting-edge technologies that advance processes in all areas of our lives. It is a rapidly emerging technology with the potential to revolutionize the pharmaceutical industry.

As extended reality continues to advance and become more affordable, we are likely to see even greater innovations become commonplace in day-to-day activities across pharma in the near future. As XR continues to develop, we can expect to see even more innovative applications for XR in the pharmaceutical industry. More information on the integration of immersive technology into the pharmaceutical industry is available from the following related journals:

- *Journal of Medical Extended Reality*
- *Technologies*

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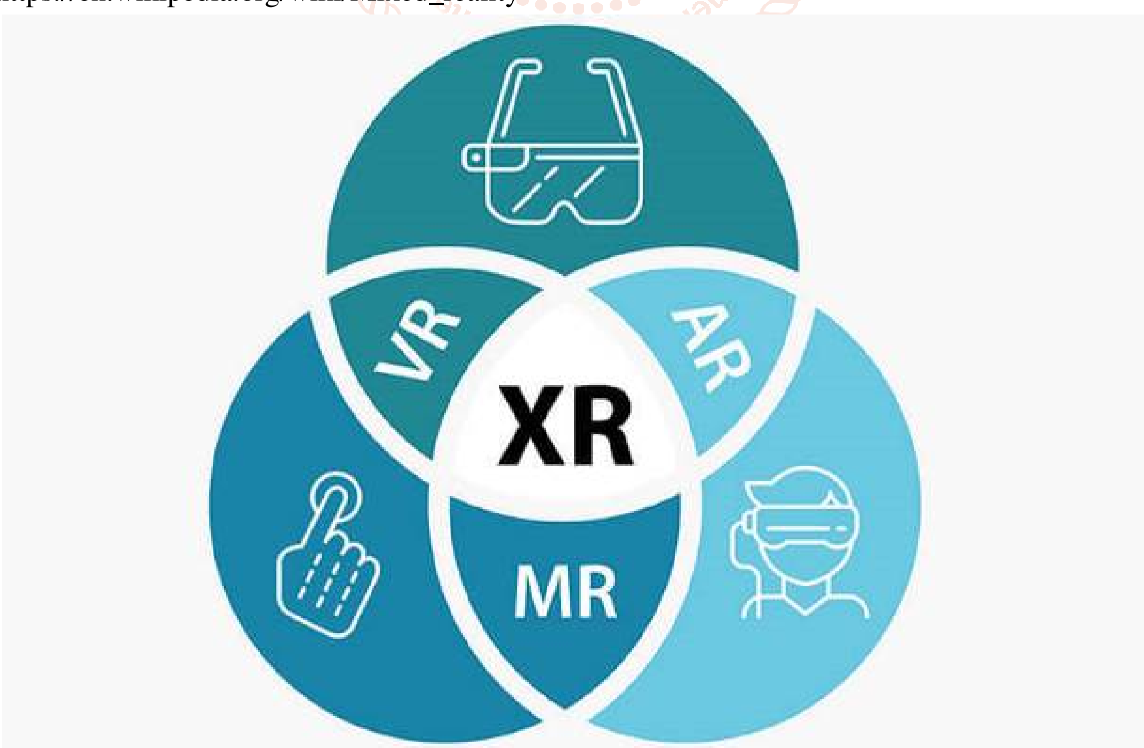

Figure 1 Extended reality (XR) includes AR,MR, and VR [3].

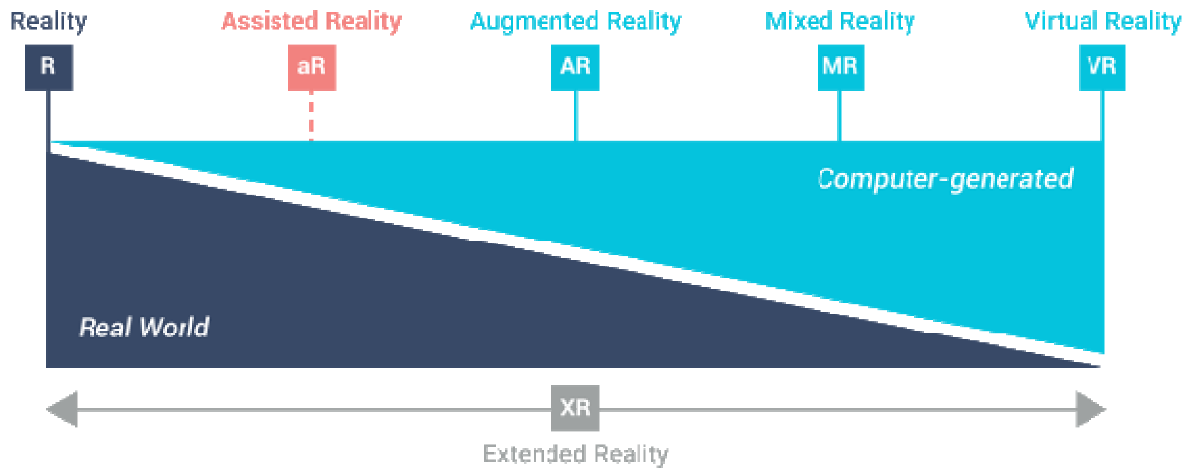

Figure 2 The XR spectrum [4].

Figure 3 Head-mounted displays [6].

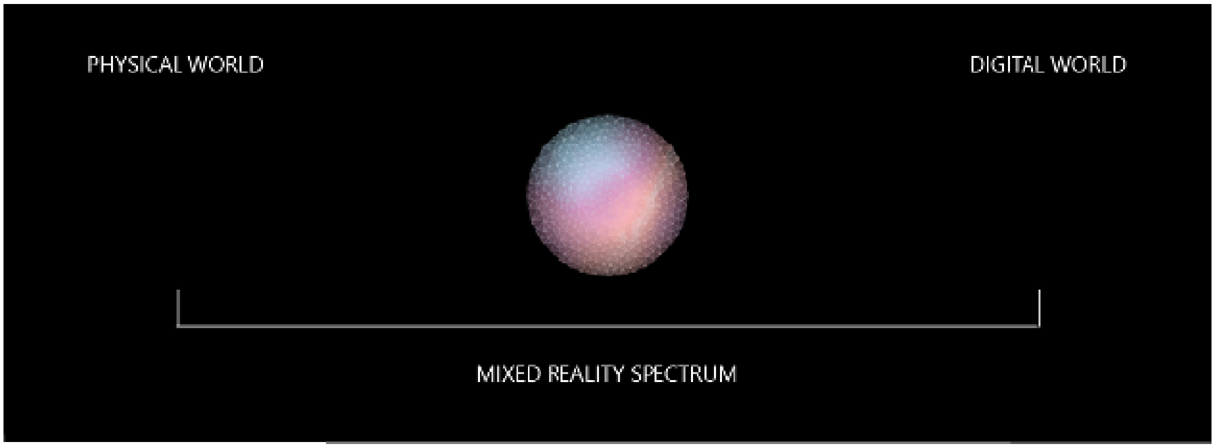

Figure 4 Mixed reality is a blend of physical and digital worlds [8].

Figure 5 A worker wearing an assisted reality device [10].

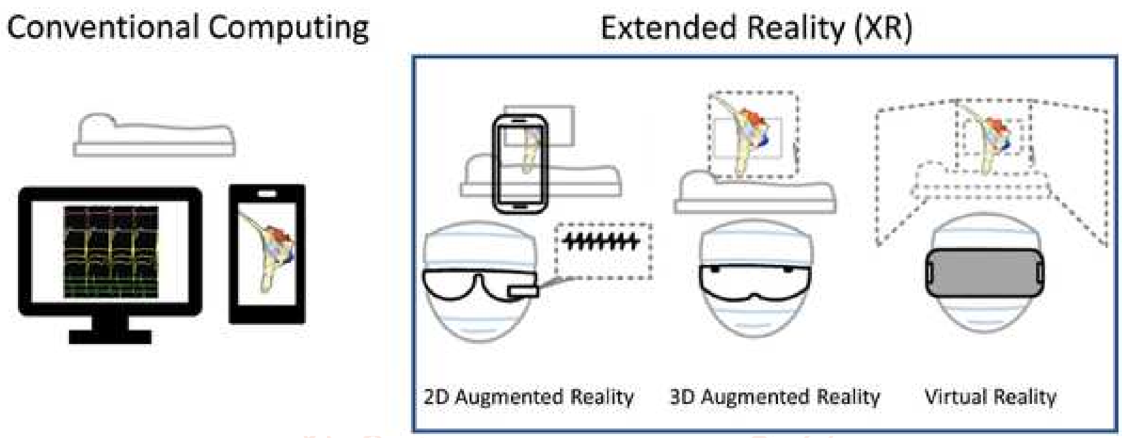

Figure 6 Comparing conventional computing with extended reality [11].

Figure 7 A typical use of XR to enhance healthcare [14].

Figure 8 XR is used in training medical students [15].

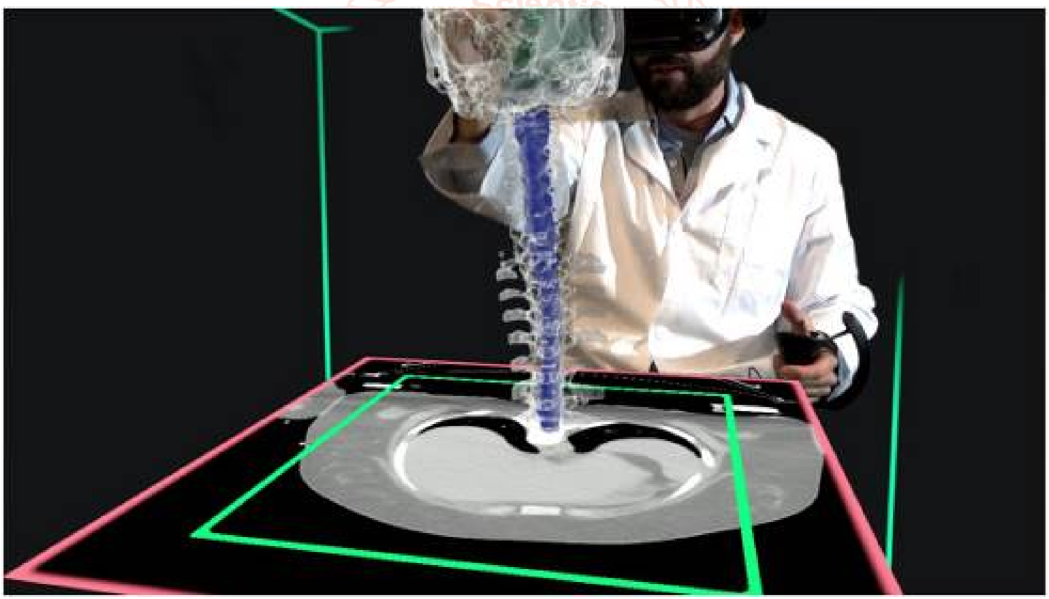

Figure 9 Using VR technology to visualize a medical image [15].