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Immersive Technologies: An Overview

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ABSTRACT

Immersive technologies are a group of emerging technologies that all share a common aim: to create an experience for users that mediates their perception of their physical environment. In their simplest form, immersive technologies consist in adding virtual objects to the real world. They create distinct experiences by merging the physical world with a digital or simulated reality. Immersive technologies allow a person to engage in a virtual reality environment. The technical ability of these technologies to simulate virtual environments or overlay visual or aural information onto the physical environment continues to develop. It seems that everyone, in different sectors, is trying to incorporate immersive technologies for their business needs. Integrating cutting-edge immersive technology can help businesses preserve or enhance their competitiveness. This paper provides an overview of immersive technologies and their applications.

KEYWORDS: *virtual reality, VR, augmented reality, AR, mixed reality, MR, extended reality, XR, immersive technologies, applications of immersive tech.*

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INTRODUCTION

Immersive technology describes myriad ways to create, display, and interact with new experiential content. It is a technology that levels up your reality by bringing digital technology, which can be in the form of digital or simulated world, into your real environment. The growth of this technology has made it a part of almost every professional and personal sphere. The technology has rapidly emerged just from an experiment to a staple in media, education, automobile, games, and entertainment. It is on the verge of becoming a part of everyday life, providing businesses with easier access to value at scale. Figure 1 shows a representation of immersive technology [1]. The digital world can be experienced in two different ways: either bring in the virtual content or world into your surroundings, or even turn your physical world into a virtual environment in a super interactive and stunning visual.

WHAT ARE IMMERSIVE TECHNOLOGIES?

Immersive technology is any technology that extends reality or creates a new reality by leveraging the 360 space. At the moment, there are nine types of immersive technologies [2,3]:

1. *360*: 360 stands for 360-degree video. Companies could give users a full 360-degree view of events.
2. *Holograms*: These are 3D projections that can be seen from any angle as physical objects.
3. *Virtual Reality*: VR immerses the user in a fully digital environment, blocking out the real world.
4. *Augmented Reality*: AR overlays digital images onto the real-world environment.
5. *Mixed Reality:* MR combines VR and AR, allowing real and virtual elements to interact in real-time.
6. *Extended Reality*: XR describes technologies that can extend your view of reality.
7. *Telepresence*: This can give people a physical presence at remote events.
8. *Haptics:* Haptic technologies are devices that react to, detect or simulate touch for a user.
9. *FPV Drone Flight*: This is a form of immersive technology that combines unmanned aerial vehicles (or drones) with wireless camera feeds.

Despite their differences, immersive technologies often share many hardware and software elements such as cameras, motion sensors, visual display devices, and rendering engines.

Virtual reality (VR), augmented reality (AR), mixed reality (MR), extended reality (XR), and assisted reality (aR) are the most popular, principal types of immersive technologies. Therefore, we will consider in detail only five types of digital realities leading to different types of immersive technologies [4,5]:

- *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 2 [6]. Figure 3 shows the XR spectrum [7]. Immersive technologies reside along a continuous scale ranging between the completely real and the completely virtual world. At one end, the real environment refers to the actual physical space, objects, and people that exist in the tangible world around us. At the other end, the virtual environment represents a completely computer-generated and immersive digital space, distinct from the physical reality. The space in the middle is called mixed reality, which is a blend of the real and virtual environments, where digital and physical elements coexist and interact in real time. 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. A person using virtual reality can look around an artificial world, move around it, and interact with virtual features or items. This effect is commonly created by virtual reality headsets. Head-mounted displays immerse the user in a virtual environment. 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 [8].

   - *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 4 [9]. 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. In augmented reality, the user typically experiences the real world through a device such as a smartphone, tablet, smart glasses, or head-mounted display. 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 [10]:

- *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 5[11] and Figure 6 [12]. 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 [13].

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 7[14].

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 [15]. Figure 8 compares conventional computing with extended reality [15].

APPLICATIONS OF IMMERSIVE TECHNOLOGIES

There are a virtually unlimited number of ways to use immersive technology. Over the years, game developers, advertising agencies, construction companies, and the automobile sector have shown interest in immersive technologies. Immersive technologies have diverse applications in education, healthcare, engineering, legal practice, gaming, entertainment, marketing, advertisement, and law enforcement. Common applications of immersive technology include the following [2,16,17]:

- *Training:* Immersive technology can vastly improve training. This means different things for different fields. But immersive tech will generally improve retention and speed up the learning process. Employees can get fully safeguarded, hands-on training in the various areas they will be working in. This means that people can practice otherwise dangerous procedures or situations in a safe environment to be ready for them in the real world.
- *Education:* Immersive technology is also becoming a more common sight within the educational sector. It can create more engaging learning experiences and increase students' understanding and retention of new information. Virtual reality, augmented reality, and mixed reality have all proven themselves as powerful tools within an educational context. You will also find immersive tech used in universities and higher levels of education. In education, AR is allowing students to visualize text and interactive elements in lectures. Similarly, Google Expeditions enables students to go on "field trips" without leaving the classroom. When learners immerse in a simulated environment to embark on multi-sensory and kinesthetic learning, they can make mistakes safely and enjoy better learning outcomes.
- *Gaming:* Most investment in immersive technologies has occurred in the gaming industry. When it comes to gaming, tech advances have offered a new and creative medium to game developers. Gaming and immersive technology have been connected almost from the start. This has caused some issues with the use of immersive tech in other fields. The connection with gaming is a little too strong in many people's minds. Immersive technology has had some amazing implementations within games. For example, Pokémon GO's AR caught the world by storm. Immersive technology can use software called serious games that are designed primarily for education, training, or problem-solving. These games use engaging and interactive play to simulate real-world processes or environments.
- *Marketing:* The best immersive technology company know-how emerging technologies can impact marketing and communication in an organization. Such techs offer powerful tools to communicate with clients and teams, additionally helps in market services and products to potential clients. AR and VR technology can attract a new audience and take required actions that are effective for marketing the products.
- *Medicine:* Medicine has been at the forefront of immersive technology adoption. Already, surgeons are using AR headsets to visualize where to make incisions on the body and pull up patient's health information during operations. Immersive technologies that have the potential to improve medical practice and education. The primary recipients of immersive technology-based medical practice and education are doctors, medical students and interns. Immersive technology-based rehabilitation allows patients to obtain a more intensive learning and rehabilitation experience by immersing themselves in an enriched practice environment specifically designed for rehabilitation purposes. The combination of immersive technologies and telehealth allow patients to complete their daily healthcare tasks without requiring a health care professional to stand next to them. Despite their potential benefits, the successful utilization of VR and AR necessitates complete integration into current healthcare practices and should be in accordance with the requirements of patients and healthcare professionals. Figure 9 shows various use of immersive technologies in medicine [18], while Figure 10 shows a specific use of immersive tech in medicine [19].
- *Ecommerce:* Immersive Technology has put new meaning to the term online shopping. More and more stores are using AR apps to allow users to test out their products beforehand. Even with VR, brands like those within the car industry are using virtual showrooms where consumers can look at cars, take virtual test drives and even "sit inside" them.
- *Workplace:* The modern workforce understands the requirement of technology in the workplace, from all operations from training to sales. Those who get the opportunity to use immersive tech in their day-to-day tasks tend to feel more confident in their work, more prepared for unexpected scenarios, and feel a higher level of overall satisfaction than those in workplaces that do not

value the importance of using modern tools. Companies who incorporate immersive technology into their training, sales, and employee support operations see a dramatic increase in knowledge retention, productivity, and customer engagement as well as reduction in wastage and operating costs. Figure 11 shows the use of immersive tech in the workplace [20].

BENEFITS

Immersive technology is quickly becoming a popular and powerful tool for people in many industries. It provides an unprecedented level of interaction, engagement, and immersion that is not available with traditional methods. The benefits of immersive technologies are vast and expanding, providing significant value for businesses, professionals, patients, and learners of all ages, both monetarily and through intangible yet profound ways. AR can be particularly beneficial for telemedicine, remote assistance, and patient evaluation. VR has become a game-changing tool in healthcare services, offering an improved patient experience, better medical training, and innovative therapeutic interventions. Other benefits of immersive tech include the following [21]:

- *Improve Safety:* Immersive technology can increase safety in physical environments by allowing customers to experience a product or environment without physical interaction. Immersive technology reduces the burden associated with planning and conducting full-scale disaster exercises. Users can explore and interact with their environment while remaining outside potentially contaminated response areas.
- *Enhance Customer Experience:* Immersive technology creates a highly engaging experience for customers, allowing them to interact with the brand in an interactive and memorable way. For example, the AR experience allows customers to try the skincare products virtually, seeing how they look and feel before making a purchase. The brand effectively leveraged AR to increase customer engagement and awareness, increasing sales and customer loyalty.
- *Increase Efficiency:* The technology has the potential to drastically reduce the training time required for specific tasks while allowing workers to engage more deeply with their work. With the increasing number of productivity apps that make use of this technology, businesses have a greater ability to streamline processes, automate tedious tasks, and use analytics for better decision-making.
- *Attract Top Talent:* Instead of relying solely on traditional recruiting methods, companies can tap into the potential of immersive technologies to find the most talented individual for the job. In particular, immersive technologies allow potential employees to experience what it would be like to do a job or go on a business trip without leaving their current location.
- *Expand Opportunities:* Immersive technologies can offer a range of opportunities for all individuals, when they are designed with inclusivity and accessibility in mind. This includes opportunities to enhance educational and learning experiences and serve as a complementary tool to aid therapeutic interventions.
- *Enhance Collaboration:* Immersive technology provides an interactive environment that brings people together from anywhere in the world and allows them to work together through shared digital experiences. When it comes to productivity and collaboration, there are several examples to highlight the power of immersive technology. Because our senses are innately 3D, flat screens can be limiting for deeply understanding and collaborating on complex data, such as human anatomy or a molecular structure.

CHALLENGES

Despite the promising advancements in VR and AR technologies within healthcare, several research gaps persist that warrant further exploration. There is a notable scarcity of implementation models that effectively guide the systematic adoption of VR and AR in clinical settings, hindering their full integration into established healthcare practices. Future research should focus on expanding the clinical applications of these technologies, particularly in areas such as rehabilitation, pain management, and telemedicine. Other challenges of immersive tech include [22]:

- *Risk:* The risks of immersive technologies may arise in many ways – from the way these technologies function to social factors such as the dynamics among those developing these technologies. The severity and likelihood of the risks of these technologies will depend on: how they are designed and operated, what purpose they are used for, what contexts they are used in and what kind of people will be affected. Examples of these risks include algorithms used within immersive technology products that have been found to perpetuate bias and discrimination.
- *Harms:* Existing harms which are experienced both offline and in 2D online environments can be amplified in immersive environments. The

features of immersive technologies – such as their hyper-realistic nature – can lead to new manifestations of existing harms. Several harms are likely to be heightened in immersive environments:

- Terrorism and violent extremism.
- Child sexual exploitation and abuse.
- Exposure to age-inappropriate content and experiences for children.
- Sexual violence and gender-based violence.
- Negative online social experiences.

- *Data Protection:* At a technical level, immersive technologies operate through a process of data creation and processing that often involves specialized hardware products that collect a significantly higher volume of data than devices such as smartphones and laptops. This creates significant privacy and data-protection risks that developers must navigate.
- *Ethical Concern:* In vulnerable patient groups, such as those who are critically ill, there are ethical concerns surrounding the use of VR/AR technologies. VR/AR should always enhance, rather than replace, the human elements of healthcare, ensuring that advancements are both ethically sound and aligned with patient-centered care.
- *Regulation:* Given that immersive technologies may be used in a variety of settings, regulators may find that they need to determine how to apply existing regulatory guidance or whether new guidance may be needed to address the risks, be it for medical device regulation, employment law or online safety regulation. Effective governance of these systems requires a common understanding of their capabilities, technical components, and data lifecycle. Regulators will also need to consider what kinds of users may be affected and the contexts and functions for which these technologies may be deployed.

CONCLUSION

Although immersive technology is still relatively new, it is quickly becoming a part of every profession. Immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and Extended Reality (XR) have seen tremendous investment and growth in many different ways over the past eight years. As they advance, immersive technologies have increasingly utilized more sophisticated hardware, which, in turn, collects more data points from the user and their environment.

Immersive technologies, from video to virtual worlds, have evolved sufficiently that we can confidently predict the impact these delivery modalities will have on learners. Tech professionals have known for a while that there is a feeling of inevitability surrounding immersive tech. It simply will change our lives as we know them. Much like the smartphone, immersive tech will become seamlessly integrated into our lives. More information about immersive technologies can be found in the books in [23-27].

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Figure 1 A representation of immersive technology [1].

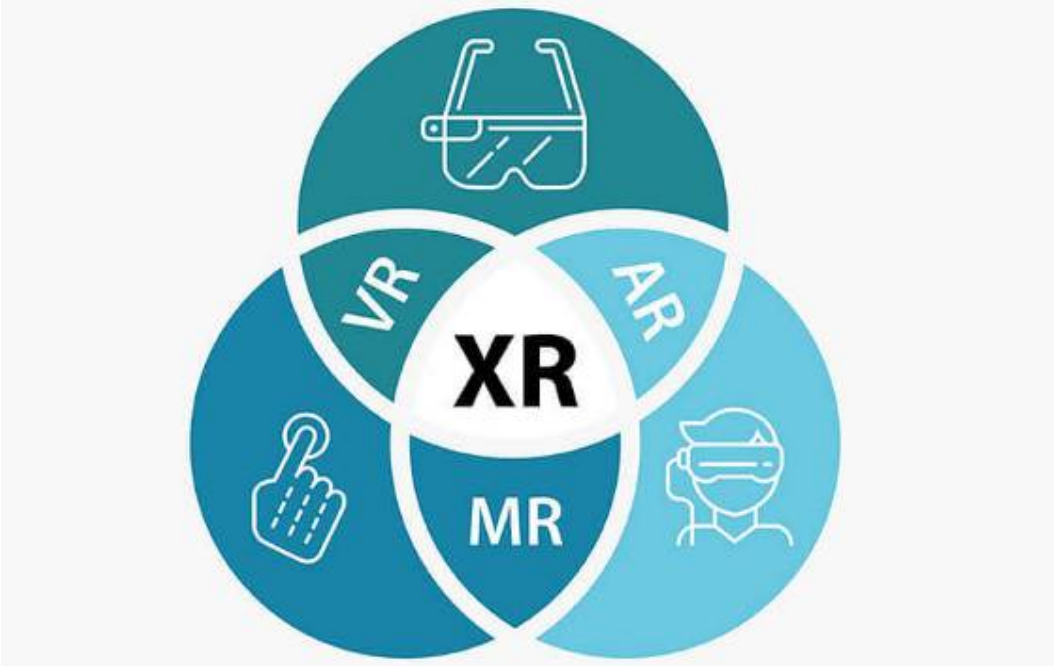

Figure 2 Extended reality (XR) includes AR, MR, and VR [6].

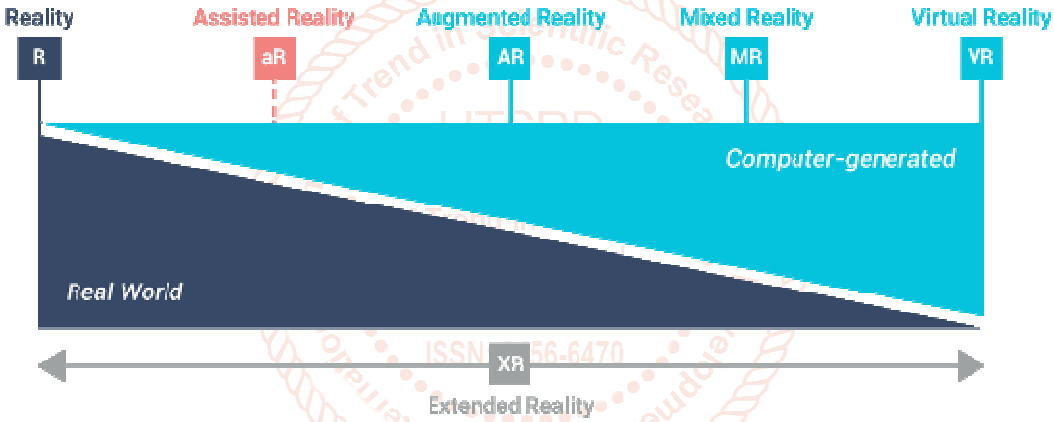

Figure 3 The XR spectrum [7].

Figure 4 Head-mounted displays [9].

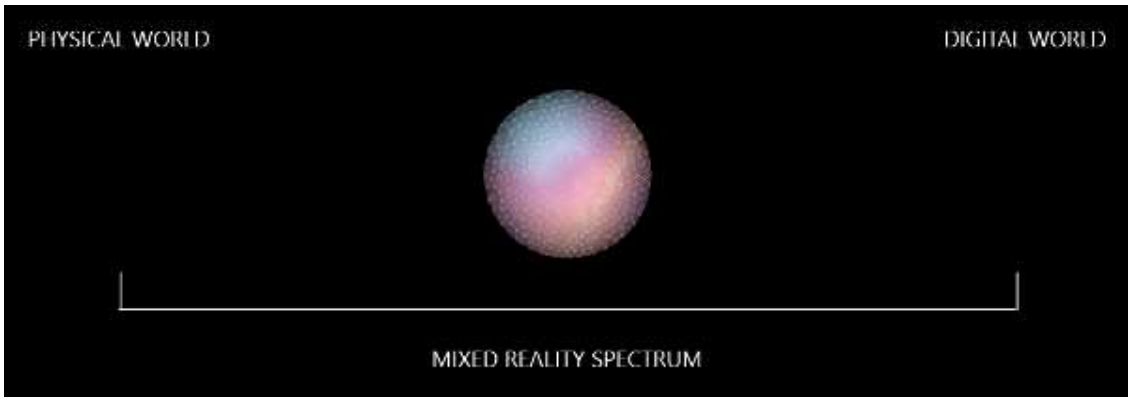

Figure 5 Mixed reality is a blend of physical and digital worlds [11].

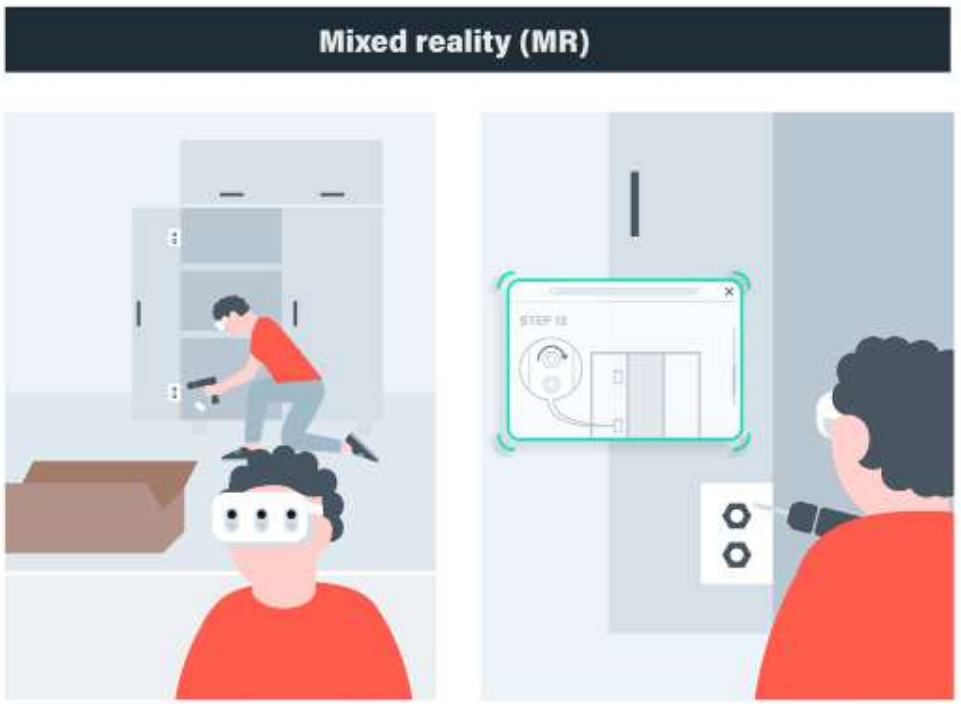

Figure 6 Mixed reality [12].

Figure 7 A worker wearing an assisted reality device [14].

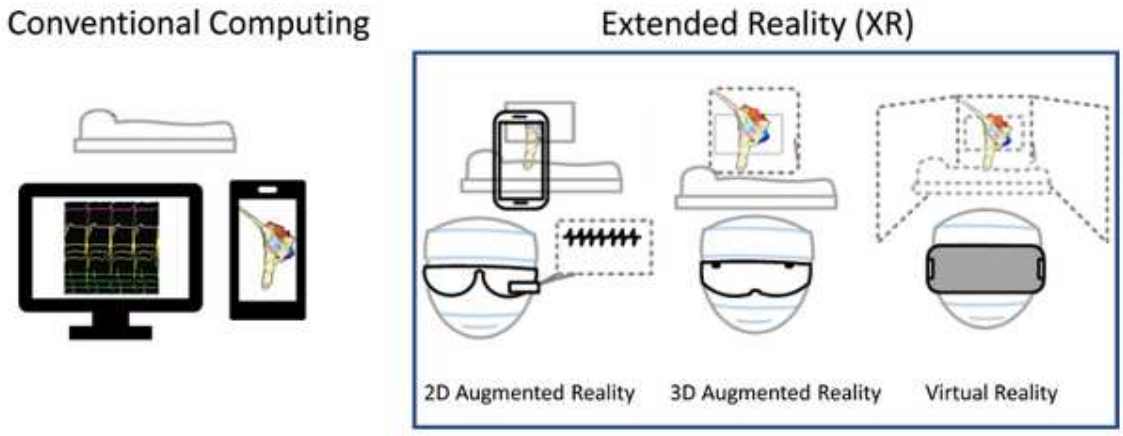

Figure 8 Comparing conventional computing with extended reality [15].

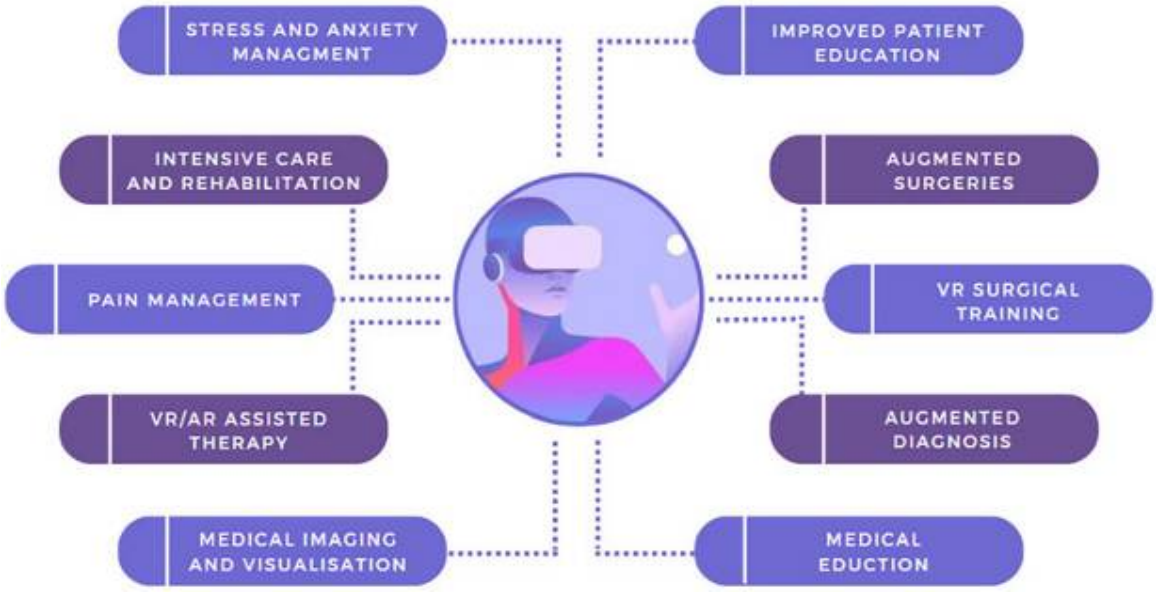

Figure 9 Various uses of immersive technologies in medicine [18].

Figure 10 A specific use of immersive tech in medicine [19].

Figure 11 Use of immersive tech in the workplace [20].