Virtual Biomedical and STEM/STEAM Education

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User Manual for VR Platforms

The Short Handbook about Augmented Reality and Virtual Reality Technologies in the Field of Education

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Chapter 1

A general introduction to virtual reality and augmented reality

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General Introduction

General considerations

Among many descriptions defined for Virtual Reality (VR), a proper definition is the one used in *Virtual Reality in Education* [1] as "*…a technology that replaces sensory input derived from the real world with sensory input created by computer simulation." and that "…allows a user to interact with a computer-generated three-dimensional model or virtual environment."*. Indeed, a VR system aims to simulate the experience of being in a virtual (non-real) environment based on three key features: immersion, interactivity and multi-sensory feedback.

Immersion*:* defines the degree to which the computer-created virtual scenario is able to present an *"inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant."* [2] [3].

Interactivity*:* relates with the ability of the user of Virtual Environment (VE) to contact and thus act in the virtually created space and the objects existing there. [2] [4]

Multi-sensory feedback: refers to the process of transmitting to the VE user "*the results of an action or the status of a task"* [3]. This process is fundamental in VR creations as it "*helps to aid understanding of the state of the thing being interacted with, and helps to drive future action"* [3].

Hence, a Virtual Reality system is a 3D visualisation technology based on computer setups that "*…create the effect of an interactive three-dimensional world in which the objects* *have a sense of spatial presence…"* [5] with the aim to allow the user to act in a virtual model as if it was in the real world [1].

History of VR

Despite the popularity boom of Virtual Environments technologies in the recent decades, the development of 3D visualization technologies has already started more than one century ago [6]. Hence, the origins of VR, as formulated in *"The VR Book: Human-Centered Design for Virtual Reality"* [3], can be traced back till nineteenth century with the inventions of instruments as the kaleidoscope [7] [8] and stereoscope [9], two technologies that at present time can be considered as ancient 3D visualization equipment. Still in the 1890s there was the creation of the "Haunted Swing", a 360º VR-style display which produced *"…a purely optical illusion…"* [10].

Later on, the first steps on developing immersive systems that resembled more with the current VR instruments started to be launched in the twentieth century, with the launched of first flight simulator by Edwin A. Link, commonly called as Link Trainer [11] [12] [13]. In the following years, the science fiction literature and filming industry have also started to explore the topic of Virtual Environments with a notable example being the book *"Pygmalion's Spectacles"* [14] of Stanley G. Weinbaum and released in 1935. Later in the 1950s and 1960s several devices focused on VR were patented and launched. Examples of that are the *"Stereoscopic-television apparatus for individual use"* [15] as one the first Head-mounted Displays (HMD), and *Sensorama* [16], both created by Morton Heilig [17], as well as the first glove input device developed by IBM researchers in 1962 [18].

In regard to HMDs, important breakthroughs were achieved due to the extensive work done by Ivan Sutherland and Tom Furness, two of the pioneers in their times [17]. Sutherland's main contributions as the *"The ultimate display"* [19], the *"Head-mounted three dimensional display"* [20], and "Sketchpad-A Man-Machine Graphical Communication System" [21] paved the way to better understanding of computer graphics. Simultaneously, Furness, at the US Air Force Research Laboratories, made significant improvements in the flight simulators field with an "*advanced fighter cockpit (Visually Coupled Airborne Systems Simulator (VCASS)) where the fighter pilot wore a head-mounted display that augmented the out-the-window view with graphics"* [17] [22].

In 1984, Mike McGreevy and Jim Humphries, as part of the NASA Ames team, developed VIEW (Virtual Interactive Environment Workstation), a *VIVED (Virtual Visual Environment Display)* system that was like current VR setups. VIEW was *"a general-purpose, multi-sensory, personal simulator and telepresence device."* [23] [24]**.** The developments achieved in the 1950s and 1960s in the fields of flight and vehicle simulation for military use began to show the variety of uses that 3D visualisation technologies could have. This later led to the definitions of "Virtual Reality (VR)" and "Augmented Reality (AR)" being ultimately coined respectively in 1987 (J. Lanier [25]) and 1990 (Boeing researcher Thomas Caudell [26] [27]) to distinguish the approaches that both technologies can have [28].

Short after both terms started to be widely used, Milgram and Kishino [24] established the concept "Reality-Virtuality Continuum" assuming that reality can take many forms and therefore there would be a "Mixed Reality" approach would be placed between VR and AR [3]. Figure 1 depicts the proposed Reality-Virtuality Continuum.

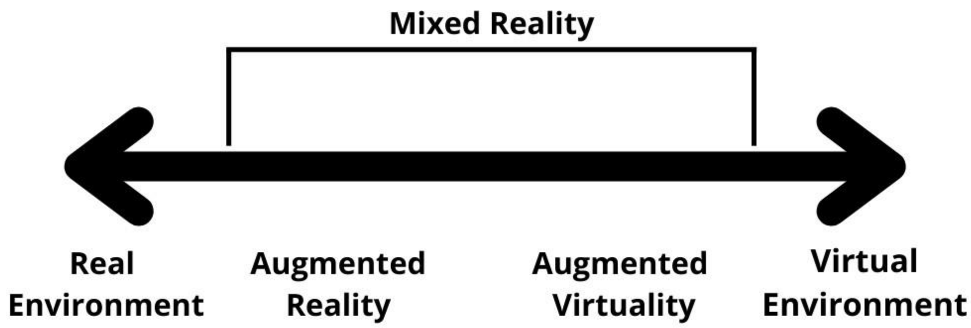
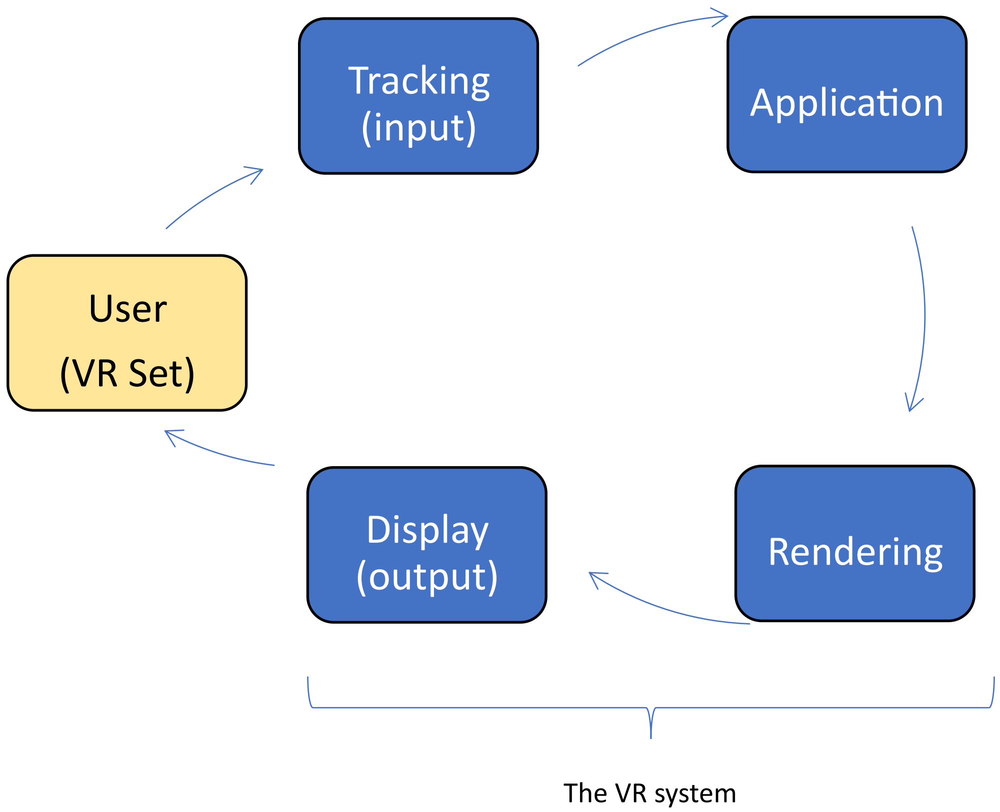


Figure 1 - "Reality-Virtuality continuum" – Diagram based on the model presented by Milgram, Paul & Kishino, Fumio. (1994). A Taxonomy of Mixed Reality Visual Displays [24]

Virtual Reality

The working process of a VR system normally comprises the following four elements in addition to one of the main elements (the user): Tracking, Application, Rendering and Display [3]. Tracking is the input given the human (user) to the system, which can be obtained through a HMD for instance. Application and Rendering are two components of the VR system itself, serving the purpose of compute the inputs received from the user and perform its action and effects on the virtual environment (rendering). Display is thus the final step of the VR computing cycle, ,which embraces the display of the output of the action previously done by the user. The referred VR system structure can be seen Figure 2 - Example of a VR system structure. Adapted from "The VR Book: HumanCentered Design for Virtual Reality" Figure 2.

Figure 2 - Example of a VR system structure. Adapted from "The VR Book: HumanCentered Design for Virtual Reality" [3]



<u>Augmented Reality</u>

As previously referred, in the last decades a clearer distinction of VR, AR and MR have been made by the researchers and developers working in this field. Hence, while for some academics Augmented Reality can simply be considered as an extension of Virtual Reality [25], a more related definition can be taken as the ones given by *"The VR Book: Human-Centered Design for Virtual Reality"* [3] *and "What is AR, VR, MR, XR, 360?"* [29], *as "...augmented reality (AR) adds cues onto the already existing real world..." and "..in augmented reality (AR) the visible natural world is overlaid with a layer of digital content... ", respectively.*

An AR system is thus intended to as the name itself reveals, "to augment" the existing real world, by bringing in virtual objects and a layer of a virtual environment to the physical real world. An AR system is usually planned and designed to be made available through mobile devices, as a smartphone, tablet or for instance special googles [29].

Mixed Reality

Mixed Reality (MR), unlike VR and AR, is perhaps a concept more challenging to define and distinct from the other VR systems. The reason for such is the fact that MR indeed "mixes" the augmented real world with the generated virtual world, leading to a continuum of virtuality/reality where both coexist [29]. As given by the website "The VR Glossary" [30] "*Mixed reality (MR) is similar to augmented reality (AR) except virtual objects are integrated into the natural world".* In the same website there is an evident and easy-to-get example, as having a virtual object beneath a table, which would only be visible until the user bends down to look at it. Mixed Reality and Augmented Reality can often seem to be as the same technology since many share the same features. However, a clear distinction can be made from the fact that in MR all the virtual objects are fully embedded in the real world, making it impossible to differentiate a virtual from a real object as opposed in AR where any virtual object is visually distinct from real-world scene [31].

Types of VR, AR and MR

With the expansion and specialization of Virtual Reality solutions, the definition for the types and formats of Virtual Reality Environments continues to vary among researchers and industry, having often a differentiation based on factors as immersion, display and interaction devices, technology or approach used [32] [29] [30] [1] [33].

Hence, considering immersion as a classification variable, a VR system can be defined as:

- **Non-immersive:** when there is a virtual environment and a degree of control of virtual objects but no direct interaction with the user. This is seen in any traditional videogame for instance. It would also be designated as a Desktop VR (Monoscopic or Stereoscopic) where "*the user seated in front of a desktop* *computer monitor with interaction provided by a controlling device such as a computer mouse."* [32] [29] [30] [1]

- **Semi-Immersive:** when the user is somehow the centre of interaction and with some degree of contact with the VE although without real physical movements portrayed in the VE. [32]

- **Fully Immersive:** when the user is the centre of interaction and feels as if it fully physically immersed in the VE. In such system there is the use of fully-closed display device such as an HMD, Helmet, VR googles, or wide screen, thus being *"the users' field of view is completely obstructed by the visualization display in the form of a helmet worn on the head."* [32] [29] [30] [1]

Considering the display and interaction technologies that a VE system can use, can be:

- **Head-mounted displays (HMD):** such device consists of a visual display and optionally earphones, to which are somehow rigidly attached to the head [3]

- **World-fixed displays:** *"render graphics onto surfaces and audio through speakers that do not move with the head"*. The display setting variesm where for instance the user might be in a room surrounded by displays and thus being immersed in the virtual world or just be using a standard static screen. [3]

- **Hand-held displays:** in this kind of display, the VR device is normally a handheld device as a smartphone or tablet and where the image "*rendering is independent of the user's head and eye"* [3]

As for interaction devices, those are classified into Hand Input and Non-Hand Input, where the former can range from an ordinary joystick, or the common VR tracked handheld controller and hand-worn device to no use of device at all (bare hands). The latter includes HDM, Head or Eye Tracking Input, microphones to Full-body Tracking. Worth to refer that many systems make use of both types of devices, taking benefit from each tool advantages. [3]

Comparison of VR, AR, MR

To summarise the differences and similarities among VR, AR and MR, there is in Figure 3, an analytical comparison concerning six features, as it was already done on *"VR, AR, And MR: What's The Difference?"* [31].

Figure 3 - Table based on infographics written by Todd Jaquith [31]

<table>
<tr><th></th><th>Virtual Reality (VR)</th><th>Augmented Reality (AR)</th><th>Mixed Reality (MR)</th></tr>
<tr><td>Display device</td><td>Special headset or Smart glasses</td><td colspan="2">Headsets are optional</td></tr>
<tr><td>Image source</td><td>Computer graphics or real images produced by a computer</td><td colspan="2">Combination of computer-generated images and real-life objects</td></tr>
<tr><td>Environment</td><td>Fully digital</td><td colspan="2">Both virtual and real-life objects</td></tr>
<tr><td>Perspective</td><td>Virtual objects will change their position and size according to the user's perspective in the virtual world</td><td colspan="2">Virtual objects behave based on user's perspective in the real world</td></tr>
<tr><td>Presence</td><td>Feeling of being transported somewhere else with no sense of the real world</td><td colspan="2">Feeling of still being in the real world, but with new elements and objects superimposed</td></tr>
<tr><td>Awareness</td><td>Perfectly rendered virtual object can't be distinguished from the real deal</td><td>Virtual objects can be identified based on their nature and behaviour, such as floating text that follows a user</td><td>Perfectly rendered virtual object can't be distinguished from the real deal</td></tr>
</table>

Useful links:

An online course on Virtual Reality made available for free by Steven M. LaValle and with various tutorials for different chapters [34]:

http://lavalle.pl/tutorials.html

https://nptel.ac.in/courses/106106138

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Chapter 2

The hardware components of VR and AR

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General information

Augmented and virtual reality systems (AR and VR systems) consist of the following components:

1. Input devices – a camera, IMU (inertial measurement unit) as a movement sensor, and may include joystick(s), GPS module.
2. Processing unit – responsible for scene identification (AR only) and processing (both AR and VR). According to López et al. (2010) and Wagner et al. (2009), the processing unit should consist of a CPU with a minimal clock frequency of 2 GHz that is capable of multithreading and/or parallel processing [1, 2].
3. Output devices – usually consist of a screen (of a mobile device or of a headmounted display) that shows the generated world (VR) that may combined with the nearby environment (AR), speakers (or headphones) that provide auditory immersion and haptic feedback to provide the experience of touch, force, torque, geometry, stiffness etc. by applying vibrations and forces [3].

The generated world may be non-immersive, semi-immersive or immersive (VR).

In general, scene capture devices are physical components that perceive reality to be augmented. These devices can be grouped into two major sets:

- Video-through devices. These devices capture reality irrespective of the device responsible for visualization of the augmented reality (e.g., video cameras and mobile phones with cameras).
- See-through devices. These devices capture reality and depict it with augmented information (e.g., head-mounted displays) [4].

Auditory feedback is an important part of AR/VR systems in providing an immersive experience [5]. The input in the auditory feedback usually consists of microphones and the output is provided by headphones.

Haptic feedback (haptics) is provided by haptic interfaces—programmable systems that reproduce mechanical signals experienced in real life, such as contact forces, torques, movement, mass, stiffness, and geometry of objects. Haptic interfaces rely on mechanical sensors and actuators and consist of the following basic components:

1. Actuators (electric motors) that provide vibrations, forces, and torques.
2. Sensors that measure the state of the system, usually inertial measurement units (IMUs).
3. Power sources and electronics that operate the sensors and actuators.
4. Electronics and control software that communicates with the AR/VR system.
5. Software that controls the haptic system [3, 6]

AR and/or VR systems may use a smartphone because of an embedded camera, IMU, display, and an efficient processing unit. Good examples of such systems are AR games and mobile apps, e.g., Pokémon Go or Flightradar24.

VR hardware development

The development of VR hardware is historically organized to the precursor era, roughly starting in the 19th century, the prototype era spanning between the 1970s and the 1990s, and to the consumer era started with the beginning of 21st century.

The current advanced Virtual Reality technologies are based on stereopsis concept introduced in 1838 by Charles Wheatstone. His invention – a stereoscope – was composed of a pair of mirrors for each angle to each eye to project a single image, creating the perception of depth and a sense of immersion. Wheatsone's stereoscope can be considered as initial prototype of today's head mounted displays (HMD). This discovery from the 19th century may be regarded as the beginning of the VR history [7].

In 1956 cinematographer Morton Heilig developed an experience theatre Sensorama, considered the first VR machine, patented in 1962 [8]. The idea was to simulate real life environment of New York, where the user experienced multisensory ride on a motorcycle. Sensorama machine was cabinet with vibrating chair featured with stereo speakers, a stereoscopic and panoramic 3D display, odor emitters and fans. Heilig was also the pioneer of HDM: in 1960 he patented Telesphere Mask, the first prototype of head mounted display with 140° field of view and stereo sound. One year later, a magnetometer-based head-tracking system was incorporated by Comeau and Bryan in the Headsight, the first motion tracking HMD, developed for military purposes [9].

Another significant milestone in VR development was the utilization of computer hardware to form a virtual world. In 1968, computer scientist Ivan Sutherland created the head mounted display connected to computer rather than a camera, the precursor of today's PC VR systems. Due to its enormous weight the display had to be suspended from the ceiling and received a meaningful name: the Sword of Damocles [7, 10]. The system required a large room area and huge computer hardware to be used. Its production costs amounted to about hundreds of millions of dollars, earning practically impossible for personal use.

From the early 1960s to the late 1990s, the most driving forces that increased R&D interests in virtual reality devices were the military aviation and manned space missions, particularly the need for pilot training in both sectors. The first flight simulator designed for the Air Force was developed in 1966 by military engineer Thomas Furness, who later became entitled "the grandfather of VR" [11]. In 1982 he created the Visually Coupled Airborne Systems Simulator (VCSASS, also known as Darth Vader helmet) [12], which evolved into Super Cockpit [13]. It was the original cockpit replica where the pilot controlled the plane with hand gestures. This project stood out from the earliest by optimal information processing, which lead to real-time interaction between pilot commands and cockpit responding. Gesture recognition was able to arise and be implemented in VR projects through Daniel Sandin and Thomas Defanti's invention in 1977 [14]. They created lightweight, low-cost Sayre gloves, a device for monitoring hand movements. Gloves exploited light emitters and photocells to convert finger movements into electric signals. Based on their invention commercial releases of gloves were created, like VPL Data Glove or Power velove, Mattel (El Segundo, CA, USA). Another example of integrating VR into HMD of those times was the VITAL helmet developed in 1979 by McDonnell-Douglas Corporation (Saint Louis, MO, USA).

Astronauts' training systems for manned space missions were the next big development in VR history. Since 1981 NASA had been working on the Virtual Interface Environment

Workstation (VIEW) [7, 15]. VIEW provided a strong immersive experience. System combined HMD, 3D audio technology, voice recognition and synthesis, data gloves enabling haptic interaction. NASA employees participated also in commercializing Cave Automatic Virtual Environment (CAVE), developed by the researchers from the University of Illinois in 1992 [16]. The prominent technological progress in VR systems induced by the needs of the army and NASA began a new era for VR development- the consumer era.

Since 1990 developers of the VR devices – mostly VR game platforms – attempted to sell their products on commercial market. Encouraged by the success of the first arcade game Virtuality, and HMD products made by W. Industries (e.g., Scuba, Visette® Pro, Jaguar displays) [7], other companies attempted to repeat the success of the leader. Until 2012, none of these efforts could be regarded as successful. In 1991 SEGA announced their VR headset for arcade games which was never released for the public to purchase, due to its limited processing power and safety concerns [7, 17]. Four years later Nintendo, another key player in the game industry those days, manufactured the first HMD VR console called Virtual Boy [9, 18]. A peculiar feature of Virtual Boy was the red monochromatic 3D display with low-level of immersion. After one year the product flopped, because of the dissatisfaction from the unimpressive experience of VR, health concerns, lack of computer power, colored graphics, comfort and portability.

From the beginning of 21st century, the potential for novel and functional VR ideas expanded as PCs became remarkably more powerful. In 2012, teenage self-taught engineer Palmer Luckey designed the prototype of Oculus Rift for John Carmack, cofounder of id Software (Wolfenstein, Doom, and Quake game developer). Oculus was the first inexpensive HMD that quickly gained worldwide popularity. Eventually, the company was purchased by Facebook for $2 billion in 2014 [19]. After that event, evolution of VR devices speeded up rapidly. Later that year Sony launched the Morpheus project (today's PlayStation VR) [20]. In 2015, HTC collaborated with Valve Corporation announced VIVE [21]. Many other companies like Google, Apple, Intel, Amazon or Samsung began developing their own VR headsets. As a throwback to the first virtual reality set Sensorama, startup OVR Technology is even incorporating smell in VR. In 2021, OVR presented the INHALE Wellness Platform, a VR HMD enriched with the scent cartridge to induce olfactory feelings of calm and well-being [22].

From the year 2016, the sales of VR HMD began to rise. Many people want to experience VR, and many companies across a wide range of sectors are interested in utilizing virtual reality in their business. An illustrative example comes from 2015, when The New York Times distributed widely a million of the DIY Google Cardboards devices [23]. Using a low-cost cardboard viewer, dedicated mobile app, and smartphone utilities like accelerometer, gyroscope, and GPS, users can convert their smartphones into VR headsets. The Times published immersive stories and interactive content, in connection to its massive giveaway of Google Cardboards. It is worth noting here that nowadays smartphones have become an increasingly attractive platform for augmented reality development.

The above-mentioned events in the history of VR devices were selected and compiled into a timeline below (Figure 1).

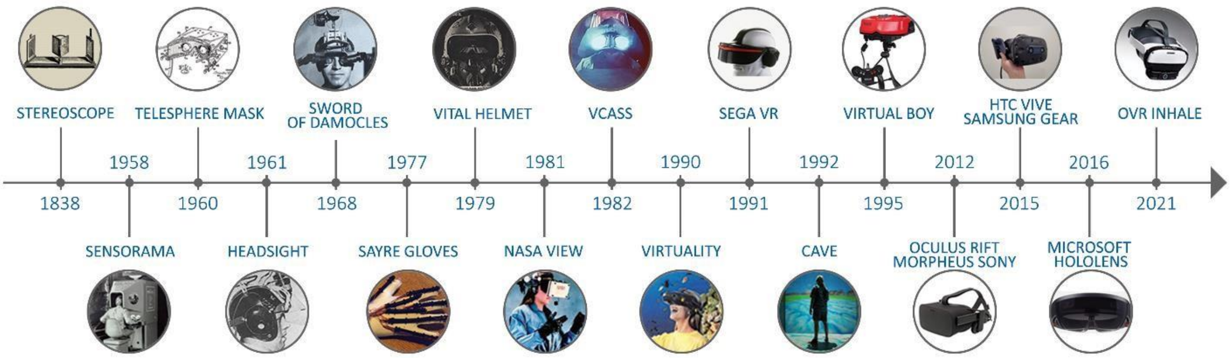

Figure 1. From stereoscope to multisensory VR experience – the evolution of VR devices.

Use cases

Microsoft HoloLens 2

Microsoft HoloLens 2 is an augmented reality (AR) device with a head mounted display that combines waveguide and laser-based stereoscopic & full-color mixed reality [24]. The displays on the HoloLens 2 are simple waveguide displays with a fixed focus of approximately two meters. The fixed focus causes the Vergence-accommodation conflict that causes an unpleasant sensation for the viewer [25].

Figure 2. The side view of Microsoft HoloLens 2 device. Source: https://www.microsoft.com/pl-pl/hololens/hardware. Retrieved 20 November 2022

The technical specification is as follows [24, 26]:

Operating system	Windows 10 Holographic
CPU	Qualcomm Snapdragon 850
RAM	4 GB LPDDR4x system DRAM
Storage	64 GB UFS 2.1
Display	See-through holographic lenses 2K 3:2, 1440x936
Graphics	Adreno 630
Input	Eye tracking: 2 IR cameras Hand tracking: 4 visible light cameras Spatial tracking: 9DoF (9 degrees-of-freedom) Inertial measurement unit (accelerometer, gyroscope, magnetometer); 1-MP time-of-flight (ToF) depth sensor Voice: 5-channel microphone array
Camera	8 MP 1080P30 video
Connectivity	Bluetooth LE 5.0, USB-C, 802.11 2x2 Wi-Fi 5
Platform	Universal Windows Platform
Mass	566 g
Power consumption	2-3 hours of active use

Meta Quest 2 (Oculus Quest 2)

The Meta Quest 2 (former name: Oculus Quest 2) is a virtual reality (VR) headset designed by Meta Platforms, Inc. (formerly Facebook, Inc.). The headset supports physical interpupillary distance (IPD) adjustment at 58 mm, 63 mm and 68 mm, adjusted by physically moving the lenses into each position [27].

The controllers included with the Quest 2 are the third generation Oculus Touch controllers.

Figure 3. Meta Oculus 2 headset with Meta Quest 2 Torch controllers (cropped). Author: KKPCW, source: https://commons.wikimedia.org/wiki/File:Oculus_Quest_2_-_2.jpg. Licensed under CC-BY-SA. Retrieved 21 November 2022.

Technical specification [31-38]:

Operating system	Quest system software (a derivative of Android 10)
CPU	Qualcomm Snapdragon XR2 (a derivative of Snapdragon 865)
RAM	6 GB LPDDR4X
Storage	128 GB, 256 GB
Display	Singular, fast-switch LCD panel with a per-eye resolution of 1832×1920, and a refresh rate of up to 120 Hz (an increase from 1440×1600 per-eye at 72 Hz).
Graphics	Adreno 650
Sound	3 built-in stereo speakers, 3.5mm headphone jack connector
Input	Meta Quest 2 Touch controllers, 6DoF IMU, 4 infrared cameras
Connectivity	Bluetooth LE 5.0, USB-C, Wi-Fi 6
Platform	Meta Quest
Mass	503g

Power consumption	2-3 hours of active use

2.3.3 HTC VIVE Pro 2

HTC VIVE Pro 2 is a VR headgear offered by HTC Corporation with additional controllers from 2021 [39].

Figure 4. HTC VIVE Pro 2 headgear with controllers. Source: https://vrscout.com/news/htc-vive-pro-2-review/. Retrieved 21 November 2022.

Technical specifications [40]:

Screen	Dual RGB low persistence LCD Resolution: 2448 × 2448 pixels per eye (4896 x 2448 pixels combined) Refresh Rate: 90/120 Hz (only 90Hz supported via VIVE Wireless Adapter)
Field of view	Up to 120 degrees (horizontal)
Audio	Hi-Res certified headphones (removable) High impedance headphones support (via USB-C analog signal)
Input	Sensors: G-sensor, gyroscope, proximity, IPD sensor, SteamVR Tracking V2.0 (compatible with SteamVR 1.0 and 2.0 base stations) Voice: Integrated dual microphones
Connectivity	Bluetooth, USB-C port for peripherals
Ergonomics	Eye relief with lens distance adjustment Adjustable IPD 57-70mm Adjustable headphones Adjustable headstrap

Augmented reality with smartphones

The most prominent use of augmented reality with smartphones is Pokémon Go (Niantic Labs, Inc.), a location-based augmented reality game released in 2016 that is one of the most popular mobile games in the world [41, 42]. The objective of the game is to catch virtual characters (Pokémons) mapped to real-world locations and to fight other players. The augmented reality mode of catching Pokémons uses the Internet connectivity, GPS module (for location), camera, and gyroscope to generate the characters (Pokémons) placed in the surroundings of a player visible on a screen [42]. An example of AR mode in Pokémon Go is shown in Figure 5.

Figure 5. The AR mode of catching a Pokémon in Pokémon Go mobile game. Retrieved from https://niantic.helpshift.com/hc/en/6-pokemon-go/faq/28-catching-pokemon-in-armode/ on 22 November 2022.

Another example of the use of AR is the placement of flight information near the aircraft that is visible on the device's screen in the AR mode in Flightradar24, a real-time air traffic tracking website and app based in Sweden. The AR mode in Flightradar24 needs authorization to the smartphone's camera and location [44, 45] besides the Internet connection.

Peripheral hardware for VR

Meta Quest 2 Touch

The Meta Quest 2 Touch (formerly Oculus Touch) consists of a pair of handheld units, each featuring an analog stick, three buttons, and two triggers, (one commonly used for grabbing and the other for shooting or firing), along with the first and third iterations having a dedicated thumbrest [36] and features a system for detecting finger gestures the user may make while holding them [37]. The ring in each controller contains a set of infrared LEDs, which allows the controllers to be fully tracked in 3D space by the Oculus Rift's Constellation tracking system [30] or the Oculus Insight tracking system in later models [31], allowing them to be represented in the virtual environment. Each controller features a rumble motor for haptic feedback and is powered by a single AA alkaline cell.

HTC VIVE Base Station

HTC VIVE Base Station 2.0 improves tracking technology by scanning the room with a frequency of 100 Hz. It uses a laser device to track the VR googles and controllers furnished with photonic sensors. The technology enables us to track the devices with high resolution without a risk of them being hidden behind any furniture. Using up to four base stations it is possible to increase the working area up to 10 x 10 m. The base station is compatible with HTC VIVE, VIVE Pro Series, VIVE Cosmos Elite.

HTC VIVE Tracker

VIVE trackers are additional devices used for further increasing the accuracy of copying position (movement) of any real objects into a virtual reality.

VIVE Facial Tracker

A facial tracker is a device furnished with dual cameras and IR illumination that enable tracking of facial expressions in real time. VIVE Facial Tracker is compatible with VIVE Pro and VIVE Pro Eye.

Virtual Reality Treadmill

One of the disadvantages of VR systems is the limitation of the usage space. This problem can be solved by augmenting the system with a special omnidirectional treadmill, which enables natural physical movement (walking, running, jumping, etc.) and motion tracking, ensuing safety and security for the user. VR treadmill is usually paired with a dedicated footwear and safety harness.

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Chapter 3
The software components of VR and AR

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General introduction

As of the time of writing the software environments of a VR setup consists of the same elements, though their manifestation may differ depending on the platform in question. Setup order, user accessibility and automation of said processes also vary by device, thus this categorization is by function, not by implementation. Basically these are the things a VR system needs to know to place the user inside a coordinate-system that correlates to the real world and keep it that way throughout the experience. Safety and quality of life measures are always implemented by respecting these elements and prioritizing their workings to avoid an unwanted user experience.

1. Identifying the user, the operating system, the possible connection types of the VR device and loading/creating a profile for it. Each and every next step uses this profile. Note that this profile may consist of several different parts scattered throughout a system, and is not necessarily a single file in a specific folder.

2. Checking the availability of a VR devices and ordering a state to it. Here the software environment decides if there is a possibility of a VR device being available yet not seen by the software environment. Usually this state occurs when the device is sleeping or out of the boundaries of sensors while the sensors themselves are awake and working. This way the environment makes sure to wait for any possible devices even if it is not present at the exact moment of powering on.

This is the step being rerun, usually coupled with a power-cycle, when a driver error occurs or when the system is returning from sleep and the devices refuse to show up, or when a new VR device is introduced to the system (ie: body tracker, LeapMotion or such).

3. Checking capabilities of available VR devices. This is the part where the system tries to define what data input it expects to create reference points.

4. Finding the user. This is usually done by finding the HMD, expecting it to be at some point in time on the head of said user.

5. Finding the floor and the height of the user. More specifically calibrating the floor and getting relative coordinates to the HMD. In case the tracking precision is low, or the implementation lacks precision it might be required to enter height manually to have it locked.

6. This step defines the world scale, and the system, if capable to do so, will know how to make 1 meter in virtual space the same as 1 meter in real life. This is usually done based on the previous step with fine-tuning being available later on.

7. Defining usable movement area also known as playspace. This may be done by feeding a 3d model of the playspace and aligning it to the real world or by asking the user to mark it somehow. The first method is used by old, QR-code based cardboard and other 3-DOF VR systems or big VR arcades, where real-life objects may represent other, similarly sized objects in VR. The second method is currently the accepted way to go for consumer grade and non-location specific VR.

8. Tracking: this runs continuously and is a key function of all VR systems: without it any HMD is only an uncomfortable and bulky 3D screen. Tracking applies to all devices and objects which are represented in the VR space. Tracking can be passive or active, and from the point-of-view of the system itself real-world objects are tracked as well to ensure their alignment with their VR counterparts. Since object tracking is computationally intensive it is usually done by using user-defined anchors and playspace-relative positional coordinates.

9. Safety measures: Though completely optional every modern VR system is equipped with some type of guardian mechanism to prevent accidents and property damage. This function is basically piggybacking on the elements detailed previously and has the efficiency of a traffic-sign: since the user is not a digital entity only warnings can be issued and compliance is up to the user’s consideration at the given moment.

10. 3d stereoscopic rendering. Humans usually see with two eyes, each eye perceiving a slightly different image due to their positions and then the brain creates a mental image based on these inputs and interprets objects as 3-dimensional entities. Abiding by this principle the VR software needs to render every frame twice with the slight offset equal to the user’s interpupillary distance, or IPD for short. Usually the same setting is used to

physically position the lenses in an ideal spot in front of the user's eye. Getting this wrong results in a phenomenon called "pupil swim" which is basically the human eye trying to adapt to the new circumstances. Though eye damage is off the table, nausea, eye-strain, headache, dizziness or in case of endangered individuals increased risk of epileptic seizures are not.

11. Spatial audio rendering. VR audio ideally uses ambisonics (aka: sound fields). Every sound source is a mono sound source placed in space and then calculated based on the user's head position. This is different form desktop environments where a stereo mix is adequate and different from a surround sound home theatre setup: it is independent of the playback device and the speaker setup, it simply adds the properties to the sound to make it's vertical position distinguishable.

12. Motion vectors and frame smoothing. Motion vectors are calculated independent of frames for each tracked device. These vectors are then used to keep movement in VR space fluent: when tracking data or frame rendering is late the VR system keeps the last known position which is perceived as stuttering or freezing and causes nausea. To prevent this motion vectors are used to move objects when no tracking data is available, which gives a small, but adequate buffer for the hardware to catch up with the user experience.

13. Body-IK and user-pose estimation. This is pure smoke and mirrors, data created based on only the position of the head and the hands will never be factually correct. Yet immersion often requires the representation of a full upper body or at least elbows and shoulders. Here artistic interpretation is used by the creators to try to adapt the VR firstperson character to the user. The sole purpose is to make it believable, similar to the phantom hand experiments.

From a user's perspective these functions are boiled down to an install procedure as automated as possible and only three levels of access should be considered: 1. Operating system (driver setup, solving Windows compatibility issues)

2. Tracking setup (real world alignment of virtual space)

3. VR/AR app

Fortunately all major manufacturers and platform owners realized that driver installation and tracked space setup can be streamlined to allow users a fast way to access their preferred VR/AR applications. Except for Microsoft.

Now that we have established these requirements and basic functions we can go through some of the major platform setups as examples.

STEAM VR

What is STEAM?

Steam is the largest gaming platform and distribution network in the world. SImilar to the app stores by Apple and Google, it allows game developers to distribute their game easily to users. It also provides features for automatic game updates and other developer-friendly analytics and distribution tools.

What is STEAM VR?

Steam VR is a snap-on application that enables the connection of VR headsets. It includes configuration software that maps VR hardware, their controllers, and tracking.

Steam VR has both generic configuration for VR and direct support for all major VR headset HMDs:

- Valve Index
- Oculus Rift S
- HTC Vive
- Oculus Quest (through Oculus Link)

Windows Mixed Reality

Windows Mixed Reality is a platform introduced as part of the Windows 10 and 11 operating system, which provides augmented reality and virtual reality experiences with compatible head-mounted displays.

Operating System

Mainly the STEAM VR is developed for Microsoft Windows platforms (at least Windows 10 is recommended). Otherwise there are unofficial ways to implement is on Linux[1].

System requirement

MINIMUM:

OS: Windows 7 SP1, Windows 8.1 or later, Windows 10
Processor: Intel Core i5-4590/AMD FX 8350 equivalent or better
Memory: 4 GB RAM
Graphics: NVIDIA GeForce GTX 970, AMD Radeon R9 290 equivalent or better
Network: Broadband Internet connection
Additional Notes: 1x USB 2.0 or newer, HDMI 1.4, DisplayPort 1.2 or newer

RECOMMENDED:

Graphics: NVIDIA GeForce GTX 1060, AMD Radeon RX 480 equivalent or better [2]

Hardware

SteamVR is the ultimate tool for experiencing VR content on the hardware of your choice. SteamVR supports the Valve Index, HTC Vive, Oculus Rift, Windows Mixed Reality headsets, and others. [2]

How to Install Steam VR

- Go to the Steam Website (https://store.steampowered.com)
- Click on the Green Install Steam Button
- Click on the Blue Install Steam Button
- Run Installer EXE
- Allow App to Make Changes
- Continue as asked
- Create a New STEAM Account or Login to Existing
- Enter In Account Credentials (If you are logging in from a new computer, you will have to authorize it for use)

- Complete Computer Authorization
- Enter Code: Enter the code you received in your email
- Go to the Steam VR website. Click on Install Steam (https://www.steamvr.com/en/)
- Do You Have Steam? YES ,if STEAM is installed!
- Install Steam VR [3][4]

Using STEAM VR with Windows Mixed Reality

Windows Mixed Reality for SteamVR allows users to run SteamVR experiences on Windows Mixed Reality immersive headsets. After installing the Windows Mixed Reality for SteamVR, users can launch their favorite SteamVR applications from their desktop or Steam library and play them directly on their Windows headset [5].

a) Get your PC ready

- Make sure you have no pending updates: Select **Start > Settings > Update & Security > Windows Update**. If updates are available, select **Install now**. If no updates are available, select **Check for updates**, and then install any new ones.
- PC requirements vary for the apps and content on Steam. See the minimum requirements per title. A PC with a GTX 1070 graphics card (or equivalent) and an Intel® Core™ i7 processor should offer a good experience for a broad range of titles.
- Set up up Windows Mixed Reality if you haven't already.

b) Set up Windows Mixed Reality for SteamVR

1. Download and install SteamVR.
2. When ready, start SteamVR. The SteamVR Tutorial should start automatically.

Note: For advanced troubleshooting of your SteamVR setup, make sure you have the following software components installed:

1. Install Steam and **login** or **create a new account.**

2. Install SteamVR. With your headset plugged in, launch Steam and you should see a dialog prompting you to install SteamVR. Follow the prompts on the dialog to install it. * If you don't see the popup, install SteamVR by navigating to the *Tools* section of your *library*. Locate SteamVR in the list and then right-click and select *Install Game*.
3. Install Windows Mixed Reality for SteamVR.

Room-scale VR

This is an example how can you define your HTC Vive room setup using SteamVR. Herein we assume that the OS level setups are completed. [6]

- After the Steam application is opened aunch SteamVR using the VR button in the top right corner of the application window.
- SteamVR will launch and attempt to connect all HTC devices
- Turn on both HTC controllers and ensure that all devices are illuminated in the SteamVR menu.
- Once all devices are connected, Room Setup can be accessed by clicking the triple line menu in the top left corner and selecting Room Setup
- Room Setup will now walk you through creating your play area, follow any instructions it provides.

Windows Mixed Reality Portal

Mixed Reality Portal is a Microsoft Windows-based software that allows users to simulate mixed reality (for a definition and more information, see Chapter 1) and to explore as well as customize virtual reality environments. Users can explore the virtual world even without a headset allowing them to get an insight into the possibilities mixed reality provides. In addition, an essential feature of Mixed Reality Portal is that by running a minimum hardware requirements process, it informs the user whether the computer at hand is ready to run Windows Mixed Reality (WMR).[7]

How to install Windows Mixed Reality Portal

- Open Microsoft Store or visit the www.apps.microsoft.com website
- Search for “Mixed Reality Portal”
- Click on the blue download button
- Open the application
- Click on “Start setup and check your PC” in the right bottom corner
- Next, you will see a text explaining what is going to happen: in a nutshell, a software will be installed (2 GB of free space is required), and a system check of your computer will be done
- In case your computer does not meet the minimum system requirements, it is still possible to run the application (see the section below)
- During this process, your computer’s graphic card, graphic driver, CPU, RAM, disk space, USB ports and Bluetooth adapter (it is needed for the use of motion controllers, it is not a crucial requirement) will be checked
- Then, WMR will be downloaded
- Downloading WMR is not always successful when you are on an enterprise managed network (which is possible if you would like to download it on your work computer) – if this is the case, consult your administrator and check whether WMR is enabled [8]
- Alternatively (e.g., if you do not have a VR headset), you can set up a simulation by clicking on the button in the left bottom corner

Running the app if the minimum requirements are not met

If the system requirements are not met, you can still try running the application after making some modifications in the Registry Editor:

- Open the Run box by pressing Windows key + R or by searching for “run”
- Type “regedit” and press enter to open the Registry Editor
- Navigate to the following location: “HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Holographic”

- By default, there should be two items here: “(default)” and “FirstRunSucceeded”
- Right click on the empty space and create a DWORD item with the name “AllowFailedSystemChecks”
- The value of AllowFailedSystemChecks should be set to 1 (hexadecimal)
- The value of FirstRunSucceeded should also be set to 1
- You are now able to run WMR [9]

Room-scale with Windows Mixed Reality

Before starting the room scaling procedure, make sure the space around you is clear (i.e., no objects on the floor and above you). Make sure your VR headset is connected to your PC.

- Open the application
- In the top right corner, there is an icon called “Boundary”
- Navigate the cursor over it and choose “Run setup”
- There are two options to choose: the first option (recommended) will create a Boundary, while the second will not and therefore will require you to stay put
- Hold your VR headset towards the screen
- Click on the “Trace” button and walk around the perimeter of your area, while aiming your headset toward the screen [10]

Simulation

The Simulator is a built-in function of WMR Portal that allows the user to run VR application without a VR headset. To set up a simulation, you have to first navigate to Windows settings and select Update & Security. Then, on the left side, select “For developers” and click on “Developer mode”. You can set up a simulation right after the system checking process or later by clicking on the “For developers” icon in the left bottom corner and switching on the simulation. The simulator can be controlled by a keyboard, a mouse, or an Xbox controller.

MetaStore – Meta (formerly: Oculus) Quest 2

Virtual reality and augmented reality solutions have become essential tools in the field of healthcare education, as well as in teaching disciplines of STEM. In order to visualize and demonstrate biological processes, cell functions or different anatomical structures, pathologies or even complex medical procedures, VR and AR goggles, headsets can provide an excellent, immersive learning experience for both students and teachers, supporting both vertical and horizontal educational programs.

As it is demonstrated in previous chapters, selecting the proper equipment is important, based on the desired use cases, and similarly, choosing the right software solutions play a key factor in the proper teaching material development and training programs.

Generally, „virtual reality" based learning materials can be displayed using several platforms – from „regular" computers and screens to complex, HMDs (head-mounted displays), there is a huge variety of commercially available devices. For each device, it is a must to have the necessary software environment to run the different contents in. There are several products on the market, and one of the most widely known platform is called Meta, which is generally used with Meta Quest 2 VR platform recently.

Basic user guidelines:

The Meta Quest 2 (formerly Oculus) can be referred to as an "all-in-one" or "standalone" VR system, which includes all the necessary hardware components (VR headset, 2 manual controllers) to run VR based software on the platform. After charging and turning "ON" the platform, the next essential step is to download the Meta Quest Mobile app. Finally, it is recommended to adjust the lenses and straps for the perfect fit for the user, and the system is ready for use. Make sure, the device is connected to the local WiFi, and the media access control (MAC) address is found.

Basic tutorial:

Wait for the end of the initial visual introduction. After the demo ends, the user will be introduced to the Guardian System. It is a virtual "grid wall", which represents the borders of the virtual space. It is not recommended to move or reach beyond the highlighted (red) lines – since in the physical reality, it can be a real obstacle! This whole process is supported by a room-scale mechanism. It is recommended to have an at least 2 meters by 2 meters safe, unobstructed area when the system is being used.

When the user is more familiar with the virtual space, it is time to get a closer look at the controller devices. The virtual representation of the hands and the controllers have a tutorial, where the user needs to press specific, highlighted buttons, which is an excellent way to learn basic manipulation with the system. Also, another tutorial guides through the hand-gestures which can be mimicked in the virtual space, using different buttons of the controller. The virtual hand gestures are widely used in different applications, it is beneficial to learn them.

Use cases

There are numerous applications that can be used for teaching STEM or biomedical disciplines using the Meta Quest system. Since it is considered as a user friendly and affordable VR device, it can be widely used by teaching institutions or individuals as well.

For example, the lessons of STEM can be taught on a novel, innovative way, using FutuClass. It is designed for 5^{th}-9^{th} graders, and it contains several subjects within the field of physics and chemistry. Interactive laboratory practices have been modelled, and all the teaching materials also contain the necessary theoretical information for the experiments. Each module ends with an assessment.

VR teaching materials on Meta Quest are not only applicable in elementary or middle school. With the concept and trend of "serious gaming", developers have created teaching materials for dental education as well. A recent study have reported, that researchers have modeled tools used in dental treatment, also, they have created scenarios to practice drilling. However, it is mentioned, that future research and tests are needed to further develop the platform.

Maybe the most well-known use case of VR in healthcare and medical education is the visualization of different anatomical structures. For example 3D Organon aims to create models, based on a multi-user VR module, which offer shared anatomy learning experiences, involving teachers and students in the same virtual space, at the same time, which can greatly enhance student engagement and provides a continuous feedback for the tutors.

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Chapter 4

Virtual reality simulation in healthcare education: an introduction

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Introduction

Healthcare workers are constantly learning during their work. Nowadays, when medical devices undergo faster, often revolutionary development than ever before, it is crucial that these professionals have up-to-date knowledge of the latest innovations. If an institution does not pay enough attention to this, falling behind will eventually cause it to be unable to provide the best possible services to its patients. Virtual reality is an extremely effective training tool at the forefront of technology. The use of augmented reality (XR) as an innovative simulation-based learning method is the most revolutionary initiative in education in recent years. It is present as a high-tech development solution in medical education and in the health sector itself. Virtual Reality (VR) has also revolutionized the way healthcare professionals are trained and offers many new uses that can benefit the healthcare industry. By offering personalized learning experiences, it brings undeniable benefits to both students and educational institutions.

Increasing demands on the nature and amount of material to be learned, the decreasing frequency of bedside teaching experiences, and the need for authentic learning experiences have resulted in new and innovative uses of educational technologies in medical education. These new simulation education technologies offer the opportunity to acquire knowledge that is closer to real practice, but at the same time safer, more accessible, and more cost-effective. Simulation became an important cornerstone of medical education even before this; however, invaluable manikin-based simulators are often only found in the most highly equipped medical education centers. In addition to geographical limitations, their installation and operating costs and human resource requirements are also high, and they take up a lot of space, so their number and thus their access possibilities are necessarily limited. Dummy-based simulations require significant preparation, staffing, and scheduling, as well as the physical presence of students—with physical and time constraints similar to bedside exercises in terms of educational organization. With increasing pressure for accessibility and the need for a regulated learning environment, augmented reality (XR) has emerged as a new way to create simulated experiences more cost-effectively, which can complement or in some cases replace traditional simulation modes. What is no longer in dispute is that VR, AR, and MR technologies have significant potential for use in medical education and training. Recent experiences with COVID-19 have also highlighted how fragile health professions education can be with widespread restrictions on clinical and academic activities. The importance of XR technologies is also reflected in the opportunity to continue experiential learning in the face of such limiting factors, enabling remote development of clinical skills and knowledge. [1] [4]

Examples of the applicability of virtual reality in medical education

Surgical simulations

One of the most invaluable uses of VR in medical education is surgical simulations. By being immersed in a realistic 3D environment, surgeons can perform complex and delicate procedures with less risk to patients.

Emergency simulations

In addition to traditional medical education, VR can also simulate emergency situations where students must react quickly and accurately. By allowing medical students to experience these scenarios in a safe environment, they can become more prepared and confident when facing similar challenges in real life.

Preparation for patient care

Virtual reality technology creates opportunities for doctors and nurses to learn more about patient care. It increases access to interactive health education content, allowing them to explore complex subjects such as anatomy or pharmacology from multiple perspectives. VR scenarios also provide valuable insight into how different treatments affect disease outcomes, allowing healthcare professionals to make ethical decisions before treating real patients. VR can also play an important role in improving doctor-patient interaction, especially for those who need special care, such as consultations in addition to hospital treatments. With this technology, patients can enter a simulated environment that allows them to feel more comfortable in the doctor's office even before the in-person consultation, which, in addition to a more positive experience, leads to greater overall satisfaction and, due to preparation, more successful treatment during the in-person visit.

Prevent human error

VR is used in many ways by educational centers and hospitals around the world to reduce human error due to fatigue or stress. By placing medical staff in realistic 3D simulations of operating rooms or intensive care units, they can practice emergency procedures and hone their skills while reducing the potential risks associated with working under pressure in real-life situations. It can also facilitate greater collaboration among healthcare teams on complex cases by allowing members of different departments to collaborate virtually with each other, rather than relying on long-distance communication methods such as phone calls or email. In addition, the recording of treatments using VR technology can serve as evidence in connection with procedures related to malpractice, so it can also be an important part of quality assurance related to care.

Practicing rehabilitation

Virtual reality, as well as augmented reality, can help patients regain mobility and strength after injury or surgery by providing an immersive environment where they can practice therapeutic movements while being watched and guided by a trained professional. In addition, virtual reality offers the opportunity for the patient to immerse himself in realistic scenarios that cannot be experienced in a traditional environment, such as rehabilitation or physical therapy clinics - e.g. virtual forest walk. This allows professionals to tailor the experience to individual needs, thereby inspiring patients to make efforts towards recovery and better preparing them for real-life situations. In addition, VR also provides feedback on how well the patient performs certain activities, allowing professionals to evaluate them and make adjustments if necessary. By tracking progress over time, improvement becomes measurable and treatment plans can be modified accordingly.

Practicing the use of medical equipment

In the healthcare market, VR technology can provide hands-on experience with medical equipment, allowing trainees to gain exposure to devices they may not have access to in their everyday lives. This allows them to be comfortable using complex equipment and increases their confidence when dealing with patients. Taking advantage of virtual reality, healthcare professionals can more easily stay up-to-date on the latest technologies while improving their knowledge without putting patients at risk.

Overall, virtual reality has made great strides in revolutionizing medical education since its introduction more than two decades ago. With its immersive capabilities and interactive features, it offers a wide range of uses for medical educators and practitioners alike, offering unique opportunities to achieve better patient care outcomes and greater safety. [2]

Good practices for the use of VR simulations in medical education

Incorporating virtual reality into medical education does not replace theoretical education in the classroom, nor does it replace an expert teacher if their supervision is required. In connection with the simulation component, it should be emphasized that certain pedagogical goals are more appropriate in a real context, while others do not require indepth study of a complicated situation. In general, while hands-on learning usually replaces home learning (when possible), the teaching of certain concepts would benefit from being transferred to virtual reality. This is the case, for example, with anatomy classes, which this technology can present in a much more precise, global and attractive way than traditional media. Thus, instead of having to learn from a two-dimensional image, VR allows the student to explore different parts of the human body in 3D at will and see the metabolic processes in action. [3] [4]

It is important to note that these are very powerful computer programs that allow you to create specific 3D images by combining two-dimensional images from MRI machines, ultrasound images and CT scans. It is even possible to create a patient's "digital twin" in virtual reality based on their imaging results and clinical data.

One of the great strengths of VR in medical training is that it offers optimal conditions for maximizing the competence of professionals without compromising patient safety. Remember that we learn best through practice, and the right to make mistakes is fundamental to this process (see Neuroscience: learning in 4 steps). In this sense, this technology represents an ideal testing ground: not only does it allow the learner to make mistakes and practice as long as necessary to master a given skill and develop good reflexes, but it also corrects mistakes in real time. Thanks to neuroscience, we now know that this immediate feedback and error correction is a crucial step in effective learning. In addition, VR has the advantage of collecting data on user behavior and performance, allowing tasks to be fine-tuned and personalized. It is important to emphasize that this function is also relevant for assessing the skills of a future practitioner or reassessing the skills of a practitioner. VR can therefore be used in certification, recertification and hiring processes.

Virtual reality is ideal for learning technical movements, such as certain surgical procedures, as well as learning how to operate various tools and medical devices. It is also very useful in allowing practitioners to familiarize themselves with new equipment or use new care techniques.

VR is also suitable for developing non-technical skills, which are also essential in diagnostic and therapeutic interventions. To this end, it is possible to recreate different care environments and situations in which the intervention of healthcare professionals is requested. For example, a virtual ward can be created in which the learner has to interact with several avatars – patients, colleagues and family members of the patients – in scenarios where the typical activities and rhythms of the hospital can be reproduced. Such training allows the student to practice all stages of his future activities: ask the patient about his condition, assess, diagnose and then treat. These types of exercises aim to sharpen the student's clinical reasoning, interpersonal and communication skills, critical thinking, and decision-making abilities, while helping to better manage stress and increase confidence in such contexts.

Finally, by allowing the learner to take on the role of another avatar—the patient, the patient's family member, or a colleague—VR can help the learner develop greater empathy for those they encounter in their professional environment and thus better they can understand the problems they face. In medicine, empathy is increasingly seen as a communication skill that should have a central role in the patient-doctor relationship.

VR simulation in healthcare - therapeutic uses

The healthcare use of virtual reality is not limited to education, in fact, its use in specific medicine is expanding every year [5]. The use of VR can be very effective in pain relief, physical therapy, rehabilitation and mental health therapies.

VR technology and hypnosis are two possible alternatives to medication for pain. The use of VR technology for distraction has proven to be a relatively effective method of pain relief. VR can influence pain perception in an immersive virtual environment by occupying finite attentional resources and blocking external stimulation and painful stimuli associated with the real environment. Because distraction interventions work by competing for attention to otherwise painful stimuli, pain tolerance and pain threshold are increased under VR conditions. In addition, pain intensity, anxiety, and time spent thinking about pain also decrease following VR distraction. Although research findings support the hypothesis that VR devices can reduce pain, the neurobiological mechanisms still need to be determined. The current state of VR as a tool for pain relief is still in its early stages of development, and VR technology may eventually emerge as a promising first-line intervention and adjunctive therapy for patients mainly suffering from chronic pain.

VR technology can also play a role in the treatment of psychological diseases. Virtual reality exposure therapy and virtual reality cognitive behavioral therapy can be effective options for patients with anxiety disorders and other phobias such as fear of flying, claustrophobia, acrophobia or general social phobia. Treatment for many psychological disorders usually requires patients to face situations they fear. This type of approach, also known as exposure therapy, helps patients accept their anxious emotions and consequently change their beliefs about the perceived catastrophic nature of the consequences. Exposure therapy is very effective, but difficult to implement, as it is very challenging to recreate complex situations such as social situations, natural phenomena (e.g. lightning), injuries and other phobic stimuli under controlled conditions, and exposing individuals to them in a real environment is also may carry dangers.

Consequently, the virtual environment created by VR simulators can be a valuable option for exposure therapy.

Both patients and therapists can benefit from this type of treatment, especially with advanced VR technology becoming increasingly available. In addition, VR technology can be used as self-treatment to some extent, VR devices can be used in private practices and even private homes, which is very important as it can further help patients cope with unwanted feelings in an "emotionally safe environment". Since the treatment of mental illnesses is very time-consuming, VR devices that provide abundant and lively content can be of great help to patients going through difficult periods.

Virtual models and environments designed for medical therapies vary depending on the patient's specific symptoms. Every patient's symptoms are different, every VR platform has different working conditions, and the therapeutic procedures depend to a large extent on the decisions of the individual therapist, so a general description cannot really be given, but in general it is possible to define guidelines in the form of good practices regarding the practical issues of applicability.

Best practices in the use of VR simulations for medical purposes

Virtual reality (VR) technology has advanced significantly over the past few years, with these developments the clinical use of VR is rapidly increasing as the VR experience can be very effective in pain management, physical therapy, rehabilitation, and mental health therapies. Currently, there are no generally accepted guidelines for the appropriate application and acceptance of VR technology for clinical use. At the same time, to exploit the full potential of clinical VR, it is important that such guidance is also available, as it helps and even enables the selection and application of the tools.

Below is an extract from the article “Virtual reality (VR) health care: best practices for clinical implementation" [6]. The authors collected best practices and relevant experiences for the most successful clinical implementation of VR. Based on the principles of "Do no harm in any way", they created a framework for those who are considering the adoption of VR in their clinical practice, or who want to use and develop VR therapy applications and technologies. Their recommendations are based on decades of practice and rigorous, evidence-based research in the field of VR health. The article focuses on the patient-centered, patient-involved therapeutic use of VR instead of obtaining medical training or medical practice, but their advice can be interpreted in general in these areas as well.

Their simplified, commonly used definition of VR is a computer-generated experience that tricks the senses into thinking the experience is real. "As an example of tricking the senses in VR, imagine a virtual world where you see a virtual table, bend down to look under the table, then extend your real hand to hold yourself upright on the virtual table top."[6]

In keeping with the primary rule of all medicine – do no harm – VR therapy should aim to cause little or no negative side effects to the patient. In general, negative effects such as headache, nausea, or fatigue often result from a mismatch between the VR system and the human sensory or cognitive system. Some effects are obvious and immediate, such as sickness from riding a virtual roller coaster, while effects such as eye strain and dizziness can result in a more undifferentiated feeling of being physically or mentally "off". Therefore, it is the duty of VR software and hardware developers to take all measures to reduce potential harm to patients and to vigilantly test for potential negative effects of VR therapy.

Use the best possible VR system available: Using the best possible VR hardware system is essential to ensure the best possible experience with minimal risk of harm. Without going into the preferences of specific VR hardware products in the current market, a good VR system is one that matches human sensory and cognitive systems as closely as possible. The closer the match between human, machine and VR content, the better the VR experience, the fewer side effects and the better the clinical outcomes. Matching the complex and finely tuned human sensory system is no small task for VR hardware or software. Good VR systems provide a high-quality graphical and interactive experience with excellent image quality, brightness and low latency.

Ease of use and the physical ergonomics of the equipment can also have a major impact on the quality of experience and effectiveness of clinical outcomes. For example, the VR controller you use can have a big impact on the quality of immersion, usability, and physical strain of using VR. An easy-to-use system is essential: this means that not all patients can be assumed to know how to use video game controls or conventions, nor do they have the knowledge of young adults. Choose a system that has simple control functions. The collection of positive features listed above is called professional VR. We strongly recommend the use of professional VR systems for all clinical applications. The use of a professional VR system becomes even more important during longer or more clinical trials, as high-quality systems maximize comfort, ensure the highest efficiency and reduce adverse side effects.

For VR headsets, we recommend headsets that are designed to **meet safety and EMC standards for information technology equipment**. Choose a VR headset that has been successfully tested against electromagnetic interference. Look for hardware that is IEC/EN-60601-1 and -2 series approved, not just tested. Clinical Protocols The clinical implementation of VR is in some ways very similar to any other clinical equipment. For example, it must be sterilized for use between patients. Most off-the-shelf VR headsets are not easily sterilized and have too many recessed parts and bacteria-friendly materials to clean properly. To maintain a standard level of clinical infection control, choose equipment that can withstand repeated use of bactericidal wipes, has no open cell foam, and has a replaceable or disinfectable face pad.

Patient preparation: One of the keys to success is proper patient preparation. Clinicians should ensure that patients understand the risks and potential benefits of VR. It is good practice to ask the patient about any previous physical conditions, such as getting seasick or carsick easily. Before patients put on the VR headset, they are told how long the VR therapy session will last and what they need to do when it ends. Provide a way for the patient to report problems. Take the time to fit the VR headset to the patient (not too tight or heavy), let the operator know all the settings the hardware and software are capable of. The most important component of visual comfort is the ability to adjust the interpupillary distance (IPD).

The patient needs a safe space. Because the VR headset "blocks" or covers the patient's view of the physical world, the space where VR is used must be free of potential obstacles that patients could easily trip over, bump into, or hit their heads with. A stable chair (not on wheels) is especially important.

Clinician preparation: One of the most important factors influencing the clinical success of VR is how familiar the healthcare provider is with the system and how comfortable they are with using it. When the clinician is comfortable presenting and handling the equipment, the patient will feel more relaxed and benefit the most. Clinicians are strongly encouraged to spend some time using the VR system themselves. Before using VR with patients, familiarize yourself with the system setup and how to use the equipment. We also recommend that providers familiarize themselves with the history and science of applied VR therapy; so they can share their knowledge with patients.

Prepare repeatable and clear instructions: Where possible, before placing the VR headset on patients, show them what the virtual environment looks like and describe the experience and how they will interact with it. Demonstrate how to use VR controls. Allow patients to try out the controls before putting on the VR headset and no longer being able to see or observe what is happening around them in the room.

Duration is important: The duration of VR therapy depends on the type of therapy, clinical conditions and patient characteristics. As a rule of thumb, we recommend testing the success and tolerance of the patient's cooperation with VR during an initial examination of no longer than 15 minutes. Further treatments are recommended to be adapted to the patient's needs and the clinical requirements of the treatment. For longterm repeated use, the maximum working time of 60 minutes is the recommended upper limit. Breaks of at least 10-15 minutes are recommended between sessions.

Shifting care from the clinical to the home environment: Perhaps the biggest potential benefit of VR is that it shifts the focus of therapy and wellness from the clinical context to helping patients at home.

Stay up to date: Monitor the topic, look for improvements, new knowledge and build on the experiences of others in future articles.

Basic concepts (AR/VR/XR) and animation environments

VR/AR technology supplements the physical environment with new layers of information, or even a completely new virtual environment can be created with its help; augmented reality (XR) is an umbrella term for all such technologies, including virtual reality (VR), augmented reality (AR), mixed reality (MR) and others such as those using head-mounted displays (HMDs). computer generated realities. XR technologies enable wider accessibility, it is not necessary to provide or transport surgical dummies, and there are no expendable devices or parts to replace. XR can also provide greater standardization and reproducibility of experience. It can be distributed widely, and it does not necessarily require the presence of a live instructor. Immersive augmented reality provides an opportunity to increase students' involvement in the learning process through better spatial representation and learning contextualization.

Wearable technologies such as HMDs (head-mounted VR displays, smart glasses, haptic gloves) are key tools for the application of XR simulations. HMDs (Head Mounted Display) are devices with an optical display that can be worn on the head as part of a helmet and allow the user to project images in front of them or to see through them, while they display additional information in the field of vision in a spatially perceptible way.

Smart glasses realize the latter in such a way that they do not hinder the movement and orientation of the wearer. At the same time, HMDs enable full immersion in a 3dimensional (3D) space, displaying stereoscopic views of the scene (pairs of images projected in front of both eyes).

Therapeutic and diagnostic applications of wearable VR displays are also being sought, especially in the fields of cognitive disorders, pain management or psychological therapies.

In addition to providing new, immersive ways to learn complex medical content, VR-, AR-, and MR-based HMDs and haptic devices can alleviate the financial, ethical, and supervisory constraints of traditional medical learning methods such as cadaver and you need to develop practical skills related to the use of special laboratory equipment.

Several potential uses of XR have been described, including in anatomical learning and training in practical skills and procedures in a variety of medical and surgical specialties. AR is increasingly being used in emergency medical education and training, and may have greater relevance in emergency medical applications as it displays information in an individual's field of view, allowing information to be shared and used in real time [1].

The types of XR technologies and the depth of simulations they can create

Computer Generated Virtual Reality (VR or CGVR)

CGVR is an interactive 3-D simulation that enables full real-time interaction and immersion in computer-generated virtual environments that can stimulate multiple sensory modalities, including visual auditory or tactile experiences that simulate sights, sounds, orientation, and movement. This virtual environment is displayed through an HMD, which allows the user to exclude the environment and interact with virtual objects in the simulated environment. This artificial world can mimic and simulate the real world, or it can be a completely imaginary, artificially created world. In some VR environments, students may be able to interact with virtual, graphical characters called avatars.

360° virtual reality video

A 360° VR video is created with the help of special video recordings and processing of real scenes, which enable a completely realistic 3D experience using a virtual headset. These 360° film images follow the recorded movement, but at the same time they make it possible for the user to explore the displayed environment through the 360° camera, i.e. they can look in front of, behind and above the recorded objects. Studies comparing twodimensional (2D) and 3D movies have shown improved learning, and like other XR modes, 360° video allows users to experience an immersive environment. However, unlike VR and AR, users cannot move freely within the objects in the virtual environment, nor can they directly interact with them, since a fixed event forms the basis of the projection.

Augmented Reality (AR)

Augmented reality is an improved version of reality perception, in which digital additional information about the real world (text, graphic images or 3D content) is placed in the user's direct field of vision with the help of technology. AR allows the user to see the real world, but it is overlayed in real time by these layers of digital content. AR headsets use transparent screens and reflective lenses to project digital information into the real world in the wearer's field of vision. This seamless addition allows the user to see and interact with the physical world normally while working with the displayed digital objects and information. AR differs from VR in that user interaction takes place in a more realistic environment compared to a virtual one, due to the fact that the objects being viewed are actually real, while allowing the user to interact with the virtual information in the context of their own goals. with the real environment.

Smart glasses and HoloLens

Smart glasses are a type of HMD and a technology that can be worn during normal activities, which, in addition to being able to display a variety of information, includes a video camera that records what the wearer is currently looking at. Google Glass is an example of an optical HMD that can record and display audio and video images in real time as the wearer interacts with their environment. The use of smart glasses is particularly recommended for video recording, remote skills training, and remote monitoring, for example, video-based assessment of trainee performance has been found to be as reliable as in-person, real-time assessment to assess various medical and procedural skills. Some models have been shown to have significant potential to advance the development of telemedicine and serve as a means of sharing time-sensitive medical expertise in physically inaccessible areas [7]. It is also reported that Google Glass can be used as a telementoring tool, allowing trainees to convey their views to supervising physicians and vice versa. Other uses for smart glasses include photography/video recording/live streaming for learning, teaching and training; to communicate with doctors, nurses and surgeons outside the operating area, to assist with teleconsultation during surgery, and to review patients' medical records and imaging findings (e.g. CT scan, MRI, ultrasound, X-ray). One of the latest and most advanced implementations of smart glasses is the Microsoft HoloLens [8]. Hololens is an advanced form of smart glasses that has all the features of previous generations and is able to superimpose hologram-style stereoscopic 3D graphics onto the real world, which is perceived as 3dimensional to the wearer.

Modeling interactive (3D) environments

About 3D modeling in a nutshell

3D design is an activity that requires a high degree of creativity and intuitive thinking. Before we get down to it, perhaps the most important thing is to have some idea of what we want to achieve with 3D design and illustration. There are many different career paths in 3D design, each requiring slightly different skills and training, such as 3D illustration (for visual design, product design, advertising campaigns, websites, billboards, flyers, animation or interactive content), game design (in games, 3D real-world requires details, the characters are modeled after specific people and their movements), the creation of visual effects (films and television) and, of course, the design of physical objects (production, industry, architecture) can be relatively well separated from each other in terms of the "end product". The operating logic of the software required for this differs depending on the application area, and for certain types of tasks there is a transition between them (e.g. the design of 3D printable objects can be implemented with the help of parametric, solid-state modeling software or with 3D visual design programs, but just as a visual design made in 3D can be made suitable for 3D printing if necessary , a visual design can also be created from a 3D design of an industrial product), it is generally true that it is advisable to select the software for the given type of task. The question is further colored by the fact that there are many software with very similar capabilities and functions for specific types of tasks, and for individual problems, there are also many solutions with almost identical results - in many cases, the price of these software will not be a secondary consideration.

3D modeling can be quite complicated at first glance, it's easy to get lost in the details right from the start. However, it is essential to understand the basic concepts of 3D modeling, 3D environments, types of modeling and how they work together to create the final product; without it, any intention to learn or find a solution will very quickly run into limits. The basics of 3D can be learned in many ways. Some designers are self-taught, others take courses, targeted courses aimed at a given problem, or there are even graduate courses in 3D modeling that give an accredited degree (e.g., visual design and creating visual effects for films). Which of these works best is up to the individual, but it is important to be aware that the learning curve of 3D design is steep and requires persistence and a lot of practice. 3D design is an activity that requires a high degree of creativity and intuitive thinking. The support of a work environment and/or a mentor that best suits the future work is invaluable, and it is also possible to solve and evaluate practical problems.

If what has been described so far does not necessarily support this, 3D design is not as scary as anyone would think! What decades ago, as cutting-edge technology transformed many industries, due to the development and commercialization of computer technology (both software and hardware) is more accessible than ever. In fact, 3D is a very convenient design method in which the computer does the most complicated part of the work for us. In the last few years, an entire industry has emerged based on this, which is heavily dependent on the use of 3D. Whether it's new digital product interfaces, dashboard automotive design, smart home interfaces or VR and augmented reality, 3D is an integral part of everything. Despite its popularity, the 3D job market is not saturated, on the contrary, there is still a huge need for 3D designers, and the demand will probably only grow [17]. With a slight exaggeration, today even a refrigerator has enough computing power to run a simple 3D engine, which means that the application possibilities are growing exponentially. This naturally drives the development of design tools, so that what was previously only possible with own software and hardware costing five figures, can now be done with a web browser, with little exaggeration [9] [15] [16].

Input and/or creation of the 3D environment

In a very simplified way, the creation and finalization of the 3D environment can be imagined as the detailed design of a house, but this time from the foundation to the possible movement of its inhabitants. We have to dream where the walls will be, where the furniture will go, and finally where the residents will walk, what happens when they move around the spaces. The simulation will finally be made up of these steps.

For the simulation, it is absolutely necessary that either the displayed object (or person) or the environment in which it is placed is also available in the form of 3D information, whether that environment is virtual or as an augmented reality supplement to the real world. The "preparation" of this can be done in many ways, I put the word "preparation" in quotation marks for the first time, because it can really be made from "0", as a scratch, say, based on on-site measurements and some characteristic images in a design software or as a result of some imaging process, which can be, for example, 3D scanning or 3D photogrammetry, but 3D images of organs and bones can also be produced based on data files obtained from medical imaging devices (CT, MRI). Creating a model completely from scratch is an effective tool when creating a prototype or archetype, while 3D scanning is a more effective tool for existing objects. 3D scanning is now used in many areas and sizes. The spectrum ranges from small objects, such as the surface of a coin, to cars, buildings, and even "scanning" the surface of the earth or the seabed. For accurate modeling of real environments, due to the time spent and accuracy, there is no better alternative to inputting data obtained by scanning, and although its technological requirements do not suggest this, it is far simpler than drawing a complex, exact size and shape object ourselves, so let's start with that.

3D scanning

During 3D scanning, a real three-dimensional object is transformed into a digital model, which can (and usually should) be worked on further. The model obtained in this way can then be used as a template in three-dimensional design, printing, or for quality control (e.g. to look for discrepancies in industrial production) or for digital archiving (e.g. historical statues or objects). In addition, 3D scanning is often used in the entertainment industry (animation, digitizing objects, even persons into virtual reality) or geodesy. It is also often used in medicine, perhaps currently the most well-known is its use during dental or maxillofacial surgery (for example, when modeling teeth, jaws or joint replacements).

3D scanners can be touch readers or operate on optical and laser principles, i.e. either a camera lens detects the light reflected from the object (non-contact scanners), or the device receives the information about the object from a probe passing through the surface of the object (contact scanners). The obtained data are then converted into a digital model using special software [10].

Contact scanners

During touch scanning, the object to be scanned must be fixed in relation to the scanner, the scanning itself is done using a pressure-sensitive spherical probe. The scanner determines the position of the object by describing the coordinates of the scanned surface in space (CCM - Coordinate Measuring Machine), thus creating a spatial point cloud.

Touch scanners can be small, movable devices attached to a mechanical arm (for example used in animation studios), they can be part of a robotic arm (automated, repetitive processes in industrial production), or larger units with a scanning table. The big advantage of touch readers is that they can scan transparent and shiny objects, which traditional optical technologies have a hard time dealing with. The biggest disadvantage of touch readers is that it is difficult or impossible to scan larger (and distant) objects - due to the technology - and that they must definitely come into physical contact with the object to be scanned.

Optical scanners

Optical scanning (photogrammetry) represents a reasonable compromise between price and scanning quality. The devices are not as expensive as laser or touch scanners, but they are not as accurate. They use reflected light, they work in practically the same way as a camera or the eye. Therefore, before a three-dimensional model of the desired object, building, vehicle or even person is created, photographs must be taken from as many angles as possible, and a dedicated software converts the photograph into a digital model. It is important that the overlap between the photos (files) is as large as possible, so that the program can more easily find common points in space. The overlapping points of the images that can be recognized by the software, as well as the angle and calculated distance of the photograph, form the basis of the spatial model creation.

In photogrammetry, the virtual 3D model is composed of hundreds or even thousands of image files of objects, objects, and buildings that exist in real space with the help of photographic tools used for image creation. The simplest optical scanners have a single lens, for example, you can even use a smartphone to scan with the photogrammetric method. Data processing, on the other hand, requires serious graphic computing power from the hardware side due to the high computing demands.

A condition for successful optical (and laser) scanning - similarly to photography - is an empty space between the lens and the scanned object, and accordingly distance is less of an obstacle in this case (see later LIDAR). ("Útmutató a 3D szkennerekhez," n.d.)

3D laser scanners

Extremely precise models can be obtained with 3D laser scanning, which is why its use has now spread widely in the industry in the already mentioned quality control processes. Laser scanners work on the same principle as optical sensors, they assemble the model based on the scanned image. The main difference is that here the scanned object is illuminated with a laser beam. The light reflected from the surface of the object is recorded by a high-speed camera, and the resulting model is created by a special application. Cheaper laser scanners only use a spot light, but by using better equipment, we can achieve more accurate results, using the advantages of laser distance measurement. Laser scanning does not depend on external lighting and can operate from tens of kilometers away under certain conditions. These so-called LIDARs, optical radars, can be used to scan buildings, terrain or even the seabed. Whichever method is chosen, the input data is displayed as a set of points with spatial coordinates. A special program uses this data to create a 3D skeleton of the object, which is a rare point cloud, and then as a next station a mesh based on this is created, on which the appropriate details (texture) of the photographs (or graphics) taken of the object can be added.

Furnishing and animation of the virtual environment

Once the basics of the virtual environment are ready (using what was described earlier), this environment needs to be provisioned. There are many sources available for obtaining ready-made objects, but of course, choosing the more difficult path, we can create them ourselves. The characteristics of the used rendering engine also determine the depth at which other parameters of the given object must be entered (e.g. the "physical" properties experienced in virtuality - hardness, mass, transparency, etc.). Scenes can then be created in the resulting environment (rendering), either in real time (e.g. moving in it) or based on a scenario, like shooting a movie. In general, there are two main ways to get an image from a 3D scene. Real-time rendering is used in games and in interactive applications, and ray tracing is usually used to create film or photorealistic images. Ray tracing means that an algorithm simulates the path of light rays (just like in the real world) and calculates the resulting color (shadow) for each pixel in the final rendering. This obviously requires time and computing power, but the result is the realistic appearance of materials, lights and shadows, and the realistic display of depth perception.

Real-time engines, on the other hand, have functions that allow the movement of 3D objects and their relationship to each other and their appearance from a given point of view to be calculated with the help of graphics cards. Creating visuals with real-time engines usually requires less computing power. Most of the time, these technologies work well in addition to each other, and due to the rapid development of the performance of computing devices, the need for resources is much less of a problem today than it was even just a few years ago.

Huge industries like movies, visual effects, full-featured animation, or AAA games all depend heavily on their specialized technologies, and each has very specific and timeconsuming workflows with a specific set of tools. Real-time rendering brings interactivity into the mix. You don't have to become a game developer who wants to develop further in this direction, since interactivity is a growing demand in almost every field. Interactive 3D visualizations are being used more and more to improve user experiences, and to create them you need some knowledge of how real-time rendering engines work. [11]

Softwares for 3D modeling and their application possibilities - a brief overview

Before someone jumps right into learning 3D, it may be useful to find out which part of this versatile technology interests them or applicable to her/him the most, and how can later incorporate these elements into the desired workflow. For example, 3D illustration can be a good way forward for those who already have knowledge in graphic design, as 3D illustration can serve as an extension of the graphic toolbox. For those coming from the engineering field, the use of CAD-CAM is now almost essential, this is mostly the world of parametric and solid-state 3D design softwares. The two directions mentioned as an example are suitable for quite different things compared to each other: an object created in a visual design application is less suitable for 3D printing, and the reverse is also true that solid-state design programs are less suitable for creating photorealistic visual elements.

Once someone has a rough idea of what kind of end result they want to create in 3D, the next step is to find the right set of tools - usually this means software. In fact, there are not many 3D packages on the market, and with the goals in mind, some of them can be selected immediately. Evergreen, industry-standard tools like 3dsmax and Maya, which are behind most of the multi-million-dollar productions seen in movies and games, are a reliable choice. These are stable software with a strong support base, which manufacturers continuously develop and test based on needs. Of course, this can be seen in the goods as well. It is important to highlight that a single software package is rarely used for an entire manufacturing process. There are tools that are particularly powerful for certain tasks, such as ZBrush for sculpting, Houdini for complex simulations and procedural modeling, Substance tools for textures, and many others that are exceptionally good in a particular area [12].

If the cost of software cannot be high, a software called Blender can be a very good choice - which is an open source and therefore free software. That's not all that makes Blender special. Due to its open source code, it can be developed freely – for example Linux has been built around a similarly loyal and in many cases very professional community. After about two decades of development, it has reached the maturity of professional-quality devices in many areas, and due to its popularity, major hardware platform companies such as Nvidia, AMD, and Epic also support it. Blender has a wide range of features, including powerful non-destructive modeling, sculpting, animation, and a built-in photorealistic rendering engine. It even includes features that most out-of-the-box tools don't have - such as a real-time EEVEE rendering engine that allows you to preview and work on the scene as close to the rendered result as possible in real-time. This is the result of very diverse community development. The only drawback of this is that its user interface is therefore not standardized, meaning that it is more complicated to learn compared to other tools. In return, it offers unbeatable value for money (free) and incredible versatility (one tool for all types of tasks). For these reasons, Blender is by far one of the best choices for designers who want to enter the world of 3D [13].

For games, working interactive prototypes and XR (AR & VR), using Unity is the most common choice. It's probably the most popular and accessible game engine out there, with extensive support and tons of documentation and tutorials. Unity offers many modeling and animation options directly in its program package - so for certain projects it is sufficient to use only Unity, but in practice some modeling tool is used to create the 3D objects involved in the animation and the animation is entrusted to the Unity engine [14].

Such application as Vectary, Tinkercad, Spline-3D, SkechUP, Womp-3D and alike are examples of how you can create 3D work from a web browser. Vectary for example allows you to model, layout and render scenes online [15]. There are browsers that already have plug-ins for similar tasks, which can be useful for presenting 3D models on a website - e.g. a web shop selling 3D models. For example, Mozilla Firefox version 54 or newer (WebGL 2.0) Google Chrome version 59 or newer (WebGL 2.0) Microsoft Edge 40 or newer (WebGL 2.0) Apple Safari (WebGL 1.0) [16].

How to start learning 3D design and illustration?

Since the world of 3D has many layers, my first suggestion is to invest in a well-structured course that covers your chosen area of 3D and closely matches what you want to achieve visually, if you can. This way, you can achieve instant success that motivates you. This is especially important due to the relatively steep learning curve mentioned earlier. With the help of a course or an experienced instructor, you can immediately start building up the necessary knowledge during your own projects and fill in and learn the missing basics as you go. Without experiences of success, it is easy to give up when someone constantly encounters difficulties or seemingly unsolvable problems. It's a good idea to do a bit of research not only on 3D applications, but also on the learning opportunity you might have, it's useful to consider the options, recommendations and opinions, but it's important not to let yourself be put off. The famous writer Robert Heinlein was once asked what advice he would give to those who want to become a successful writer, and he replied: "Start writing!". I can say the same about 3D: Let's start creating! If a certain area of 3D has caught your eye, get the software you want and start learning. Is there a panacea? Just an experience: being able to co-create on a creative project with experienced designers, educators and other motivated people in a space that allows for uninterrupted focus can be a real magic for personal development.

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Chapter 5

VR and AR Technologies in gradual medical training, focusing on basic sciences

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Introduction

Medical education is continuously improving field since the number of medical professionals are increasing each year and the training is diverse, long and traditionally based on lectures require practical and applied knowledge necessitating high number of hospital or cadaver based practices which are complicated and impractical in many cases however fundamental to gain the knowledge needed for practicing medicine.[1]

In gradual medical teaching the preclinical, basic subjects are often huge in extent and either interpret advanced and complex structures eg. in anatomy or multilevel and complex mechanisms eg. in biochemistry or physiology. Traditional medical training aids are based on drawn or written graphs or figures which inevitably simplify the described processes and mechanism frequently leading to fragmented knowledge and missing pieces for the holistic understanding for example in case of dynamic mechanisms of physiology or pathophysiology. Whereas in case of anatomy the two-dimensional demonstrating figures are impractical, while the currently used hands-on cadaver based trainings are limitedly accessible and morally questioned leading to difficulty for students to transform 2D lexical knowledge to 3D applied knowledge. Previous studies proved that contrary to traditionally used memorization-based learning, the active learning which encourage students to use skills beyond remembrance such as evaluation and analysis enables the students to learn via experience resulting in more comprehensive knowledge.

To overcome this difficulties, technical advancement provided virtual reality (VR) and augmented reality (AR) environment could be implemented as digital training to undergraduate medical education. VR technology has three main types namely, the nonimmersive-, semi-immersive and immersive VR. In case of non-immersive VR, the user has no direct interaction with the virtual environment and the situation could be controlled over a computer, whereas in immersive VR provide extensive feeling with quasi transmission to the virtual environment and interaction with the artificial world is enabled by VR goggles, gloves and body detectors. The semi-immersive VR is in-between the abovementioned ones, the participant enjoys the virtual reality in the real physical situation. Due to the COVID pandemic caused need for distance learning appliances from 2020 the VR based solutions and teaching materials have improved extensively.

Physiology with Dr. Christian. Source: https://www.youtube.com/watch?v=8FkyI5912w8

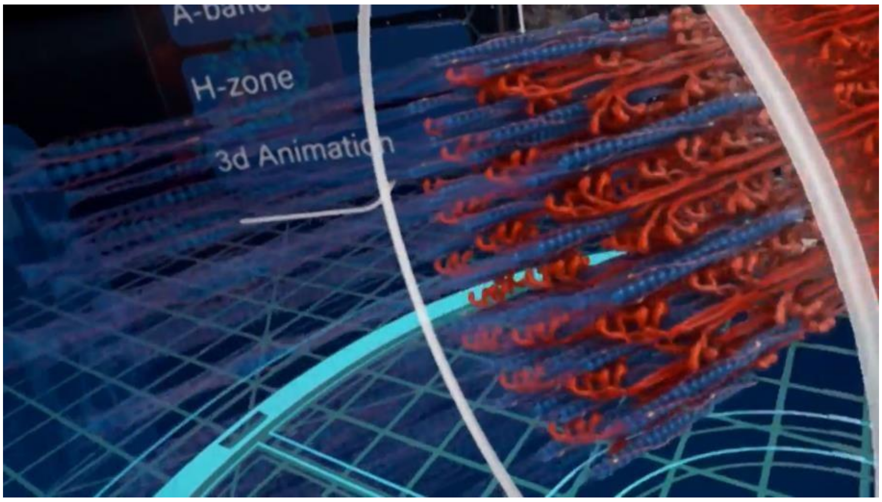
The first few years of medical training includes basic sciences such as anatomy, cell biology, physiology and biochemistry. VR technologies has been implemented to the education of these subjects in the last decade to improve the better understanding, holistic view of the complex mechanisms as well as having an insight to the complex structures and further improved with eg. gamification to increase the engagement.

Physiologiy training

Several applications are available on the market, even with free source codes. In the field of physiology teaching, a variety of the VR and AR modules are accessible covering cardiovascular system, spine, intrauterine development, muscle or central nervous system physiology. Apart from free software, many different licensed VR applications are available to medical education, such as “The Physiology of the Eye”, “3D Organon”, “Brain Vis” or “Sharecare VR”. [2]

The Virtual Reality Anatomy & Physiology Lab | George Fox University
Source: https://www.youtube.com/watch?v=s8mwz0_VVUY

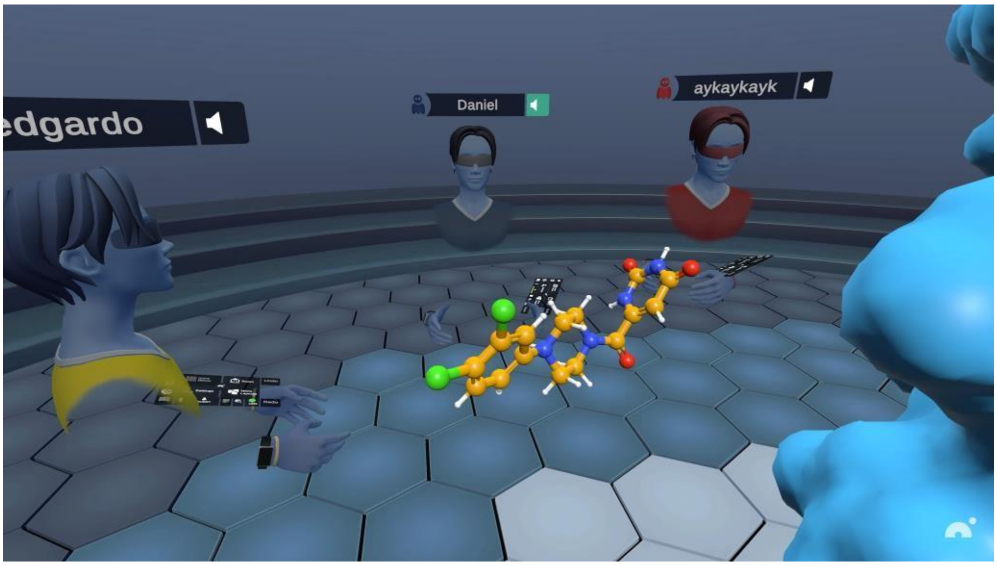
Apart from subjective impressions from the students, the use of immersive VR muscle contraction physiology application (Skeletal muscle contraction VR App; Blausen Medical, United States) was objectively evaluated and tested by Ma et al with medical, healthcare and biomedical engineering bachelor students aiming a better understanding of the muscular contraction with 3D models, annotations and verbal explanations.[3] The students impressions were analysed both quantitatively by the Technology-Enabled Active Learning Inventory (TEAL) and qualitatively based on individual feedbacks.[3] Based on the TEAL inventory the students responded positively to all of the questions (median points were 5 out of 7) with more effective learning impression for students who already had experience with VR technologies.[3] Data showed positive results regarding interactive engagement, deeper learning with better knowledge understanding mainly due to the complex 3D visualization with free control and manipulation by that resulting in extensive participation in the learning curve and increased curiosity. Underlying the positive results, students claimed: “It helps me get a more holistic and microscopic view” and “Gained a better perspective in understanding how different components physically interact in 3-D space, e.g. how the muscle fibers are arranged and how the actin and myosin move against each other.”. Based on the results, the lowest points were given for the feedback satisfaction questions but still receiving overall positive grading. The main concern during the trial was the dizziness and headache due to the VR system, but stable and neutral backgrounds could reduce this concern.



Blausen VR Experience, muscle model. Source: https://www.youtube.com/watch?v=OutDwNbGZhk

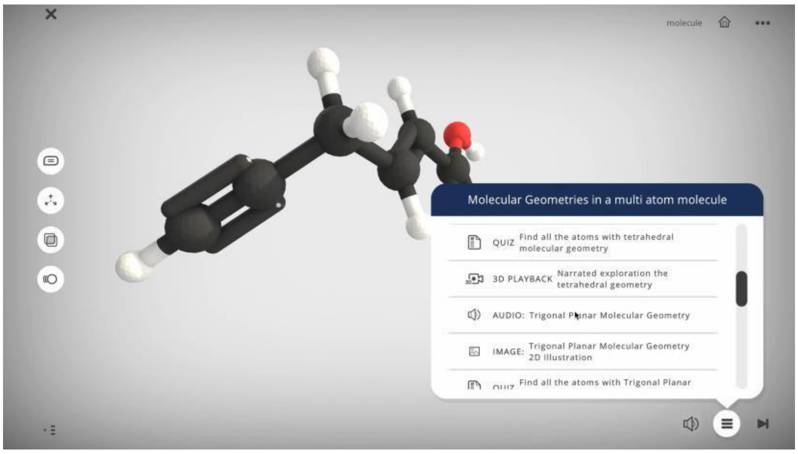
Biochemistry

In the recent years VR solutions were developed to serve the understanding of complex 3D biochemical structures and processes which is obligatory to medical and pharmaceutical professionals. The teaching of complex chemical constrictions is very challenging since the visualisation of torsion angles, bonding, stereochemistry and general conformation is unattainable with traditional 2D solutions, whereas these throughout knowledge is needed to understand drug interactions, storing, action mechanisms etc. Recently developed "MedChemVR" is an application based software which is compatible with head-mounted displays aims to implement visualization of chemical structures combined with gamification approach.[4] MedChemVR is a complex solution which contains comprehensive information about chemical materials, navigate in the 3D model of chemical substances combined with gamification to further increase the engagement and enrich learning experience (eg. after revision of a complex structure, the key elements are eliminated and the user could rebuild the complex structure).[4] The prototype has been tested on 41 pharmacy students by questionnaires and showed generally positive results, especially regarding memorizing and understanding chemical structures, applying the knowledge and engagement in spite of some students' had technical difficulties during the course.[4]



MedChem Tool in Nanome. Source: https://www.youtube.com/watch?v=DG2UIJ4KrAw

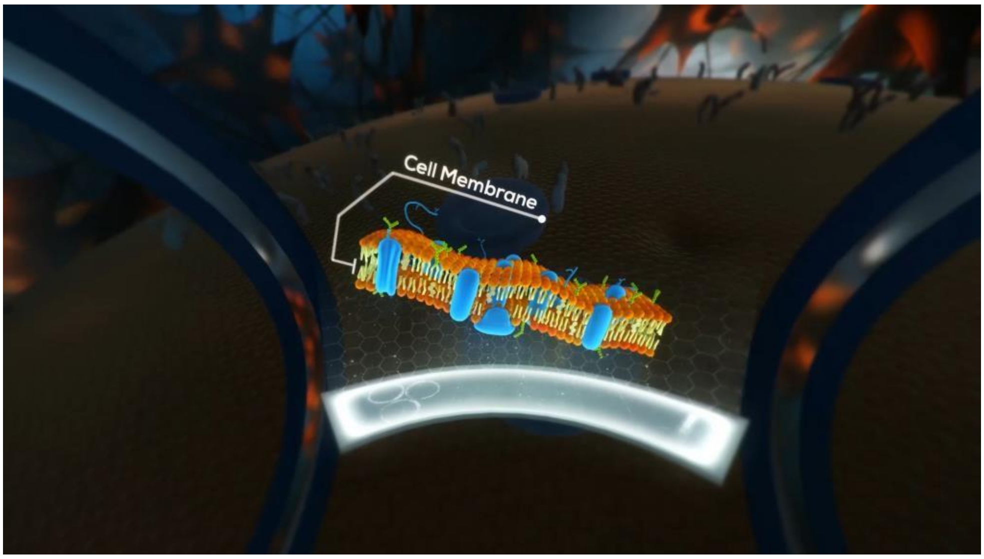
Further VR solutions are available on the market, aiming to increase the understanding and application of biochemical structures and related physiological processes, such as citric acid cycle.[5] In this application structural and biochemical background of citric cycle is presented in 8 steps in virtual laboratory environment with additional sounds and calming background music.[5] The application was tested on 10 undergraduate medical students and had convincing results especially regarding the usefulness, better understanding and greater engagement measured by both subjective questionnaires, Kirkpatrick evaluation method and monitoring the physiological reactions.[5]



Using AR, VR, XR for Teaching Chemistry. Source: https://www.youtube.com/watch?v=0QC1rRXKdmo

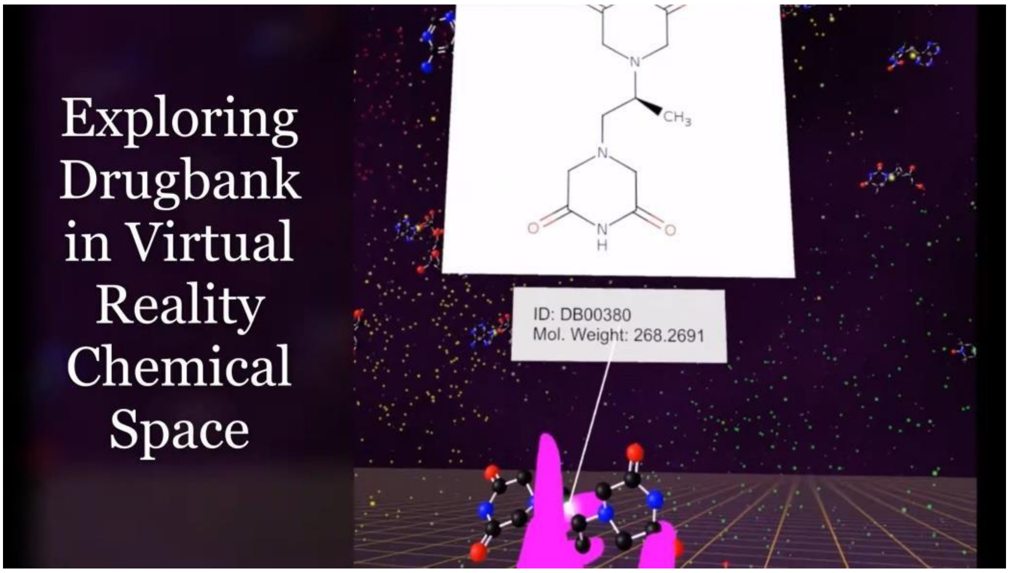
Cell biology

Freely accessible "Journey Inside a Cell" VR solution offers an enjoyable and fascinating insight to cell biology.[6] The application was tested on 62 undergraduate students and 93% of them agreed on that, the VR experiment increased their learning experience mainly due to better understanding, increased interest and opening new perspectives eg: "It allowed me to better understand the cell as a 3D structure. It provided me with a better understanding of how the different parts of the cell interact with each other." or „It was a new, interesting way to learn about the cell etc. I thought it was very helpful to see things "in person."[6] It helped me remember the material in a SUPER cool way.". During the testing course, after the VR presentation of the cells structures, students were challenged with "cell-sorting" allowing them to review the gained knowledge, increase engagement and apply it to build a cell in VR environment, which again showed very positive results and convinced the students about the benefits of innovative learning tool applications in education. [6]



The Body VR: Journey Inside a Cell. Source: https://www.youtube.com/watch?v=YL2bGEfiACg

DrugBank is an extensive collection of chemical structures which is available on web based 2D and 3D platforms and in 2018 has been implemented for VR application to enable more effective analyzation of chemical space with detailed information about the molecules to enhance precision medicine.[7] To avoid VR sickness, an independent visual feedback was used with movement of the object instead of more distressing method of moving the user in the VR space.[7]

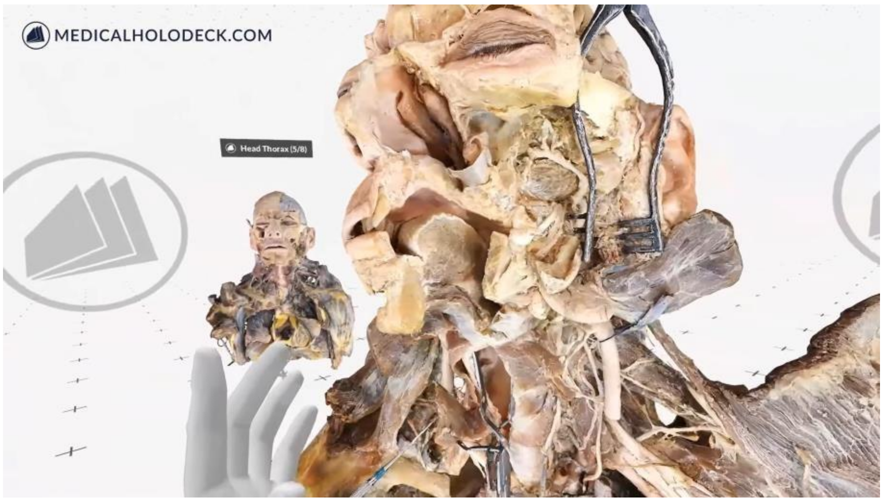


Exploring DrugBank in Virtual Reality Chemical Space.
Source: https://www.youtube.com/watch?v=FZWV50aFftc

Anatomy

VR, AR and mixed reality (MR) software solutions are particularly favoured in anatomy education both in medical and healthcare training, even in postgraduate education, aiming a comprehensive 3D knowledge of human structures which is incredibly important for mastering manual skills eg. for operation.

The complex structure of the skull and the multilevel organization of the central nervous system is exceptionally challenging for students, therefore visualisation technologies gained attention recently, leading to many different VR platforms in this field, such as: Dissection Master XS, Medical Holodeck, 3D Organon etc.



Study Human Anatomy in Virtual Reality: The Complete Human Body in VR

Source: https://www.youtube.com/watch?v=HzLszH2jfic

Surgical Theatre is an immersive VR platform compatible with Oculust Rift HMD system offering healthy neuroanatomy of the brain for medical education purposes. Stepan et al. performed a randomized trial to evaluate the platform objectively by questionnaires related to the teaching materials in three different time period and subjectively by Instructional Materials Motivation Survey (IMMS) which access the four main features of motivation as attention, relevance, confidence, and satisfaction evaluated by Likert scale involving 66 medical students.[8] This was the first study analysing VR technology implementation in clinical anatomy, and found no significant different on the pre-posttest knowledge of the students compared to traditional methods (control group) however, based on the subjective evaluation VR group had significantly higher point on the motivation survey moreover, among the students who were more satisfied with the system, reached better scores on the tests, meaning the importance of encouragement and attention in gaining better lexical knowledge.[8]

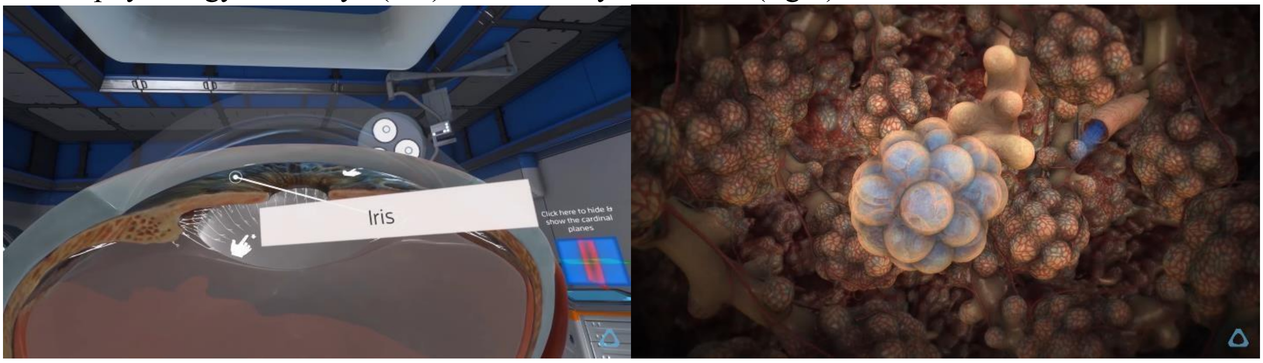
A Precision VR™ Voyage with Dr. Neil Martin. Source: https://www.youtube.com/watch?v=lkGnTwqHf9o

Beyond medical training, Surgical Theatre offers opportunity to assemble materials based on real CT (computer tomography) and MRI (magnetic resonance imaging) showing pathological structures, which could be incredibly important for surgical planning or training surgeons to perform a complicated non-routine surgery and also very useful for patient information and education purposes.

Brain Surgery to the Playground - Kobe's VR Journey.
Source: https://www.youtube.com/@surgicaltheater1903

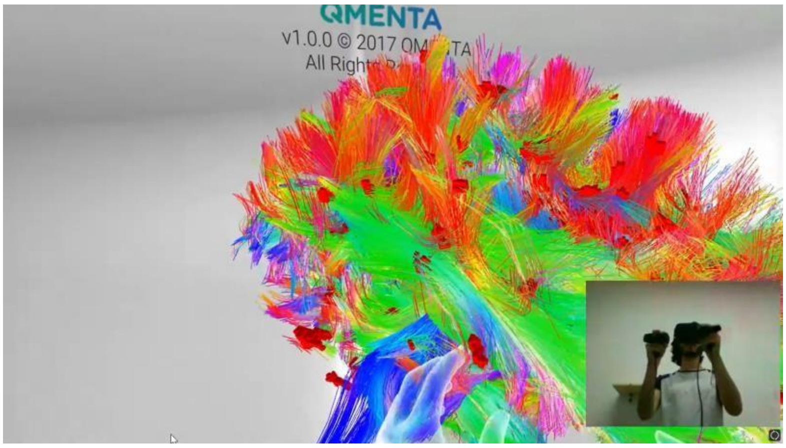
In the following years, many different studies were conducted to evaluate the VR based anatomy teaching compared to traditional paper-based or desktop-based methods regarding effectivity and subjective impressions among medical students. The objective analysis revealed increase in anatomy knowledge in all of the cases, and showed at least as effective learning tool as traditional ones. [8-10]

The physiology of the eye (left) and YOU by Sharecare (right). Source:



https://www.youtube.com/watch?v=CWB8HMFGf94,
https://www.youtube.com/watch?v=CFXpZ0xeJQ8

However, the students were more engaged and enjoyed the VR or AR based anatomy learning compared to other methods, although a subsequent group of students experienced dizziness or vision alterations during VR classes, whereas it was subsequently less on AR applications.[9-11] The majority of the students favoured VR over paper-based methods and agreed on that, VR based teaching should be implemented to anatomy teaching, and gave feedback regarding the technology as: “Really good! Extremely helpful to visualize bones and to be able to see/choose which bones to look at. The audio was informative. I learned so much by doing this activity— definitely feel I learned a lot more doing this than learning from a lecture."[9;10;12;13] Overall, VR is valuable and effective tool to help the spatiotemporal understanding of the complex anatomical structures, especially in neuroanatomy and with the interactive approach, the general fear of neuroanatomy, so called "neurophobia" could be diminished resulting in more confident and enthusiastic students.[12]



Brain Vis VR demo. Source: https://www.youtube.com/watch?v=UOxkIdeFtuU&t=43s

Conclusions

In conclusion, technology such as AR and VR implemented education facilitates learning and stimulates arousal leading to increased motivation. Immersive technology based training has a positive effect on learning, especially by changing the traditional memorizing learning curves to interaction and experience-based learning, which enhances cooperation, problem solving and encourages project based, collaborative learning.[3;14] VR, AR and MR solutions are capable to simulate situations, which could be stressful (eg. lifesaving procedures) in real environment in a smooth way, therefore able to decrease the stress and fear of these conditions, with hands on experience leading to more stable and confident professionals. Even with the clear benefits, the VR sickness is an important issue, which needs consideration and to avoid neutral background or mixed reality solutions which incorporates both the physical environment and virtual objects should be preferred. With the technical improvement, VR headsets are small, compact devices, which are getting affordable for more and more institutes enabling the technology to reach wider population. Considering the characteristics of alpha generation, who is familiar with technology even in very young ages, it would be important to implement the technology such as immersive platforms to the education systems as a supplement to traditional teaching methods with appropriate pre-training practice and technical support to ensure positive experience leading to joyful and comprehensive learning.

Using technology and holograms in health sciences and medicine: Anatomy, Science, Physiology labs Source: https://www.youtube.com/watch?v=8FkyI5912w8

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Chapter 6

Medical and health care uses of VR and AR technologies - use-case collection

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Introduction

As technology reshapes all sectors of healthcare, the need for innovation in learning and professional development is also increasing. The use of technologies similar to virtual reality allows for increased interactivity, practice of clinical procedures, refinement of related skills and more efficient patient care.

VR - virtual reality - is a computer-generated simulation of a three-dimensional image or environment, with which the user can interact with a feeling of reality using special electronic devices, such as a helmet with a built-in screen or gloves with sensors. With the VR headsets available today, we can enjoy a truly immersive virtual experience for the first time in history [1] These technologies are now being adapted to medical training and health care [2]

Augmented reality (AR) is an interactive experience that combines the real world and computer-generated content. The content can span multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory. AR can be defined as a system that incorporates three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects. This experience is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment. In this way, augmented reality alters one's ongoing perception of a real-world environment.

Wound care

Wound care training is essential to ensure that healthcare professionals are able to accurately identify, diagnose and treat wounds, providing safe and effective care to patients. However, healthcare professionals working in a busy clinical environment may find it difficult to attend training, mainly for logistical and scheduling reasons. It is also a big challenge to be able to provide training that has practical utility in real practice situations – without putting patients at risk.

VR-based training in wound care offers a safe and effective way to educate healthcare professionals in a way that can be applied to real-world practice without putting patients at risk. The use of VR technology also provides a more flexible form of training for busy healthcare professionals [1] New VR-based wound care training programs introduce an innovative approach to the world of wound care training, using VR simulation to provide healthcare professionals with a more immersive, interactive and intuitive learning experience.

With VR-based devices, a kind of "checklist-style" assessment method can also be used, which can be used to measure professional proficiency objectively, so that the results are not distorted by human bias; in this way, VR-based training tools provide a more accurate picture of what the healthcare professional is doing correctly and in which areas he still needs to improve. [3]

In the field of wound care, VR can provide an extremely safe training method in clinical practice, using realistic situations and wounds without compromising patient safety. In addition, VR-based training can minimize the necessary resources for both healthcare professionals and departments and institutions – e.g. the clinician's time commitment, high costs, the need for patient(s) to be present – which are usually required in traditional clinical practice training.

VR technology can also be an important element of "real" wound care, as it can effectively reduce the pain sensation of patients and the perceived intensity of pain during wound care, thereby reducing the need for pharmacological pain relief related to wound dressings [4]

In addition, it has been shown that the "gamification" of education (gamification, i.e. the introduction of elements with which the user can "win" during individual tasks and improve their skills to a noticeable extent) - which can be implemented in virtual reality

- is suitable for increasing the involvement of students, thereby it develops their skills and optimizes the learning process for them [5]. VR can provide a unique and memorable training experience, which enables more effective learning. In this wound care training, the VR experience promotes learning, recall, and increased satisfaction and pleasure (which further increases learner motivation) by having them all successfully achieve wound closure to complete the training.

The newest VR-based wound care courses provide a unique learning experience based on a virtual reality simulation, providing a realistic clinical experience in wound care. The learning algorithm offers a three-dimensional experience and provides a realistic clinical experience in the field of wound care. The user can see the patient and the wound and select the appropriate treatment for that patient. You can then track the wound's evolution over time to see if you've selected the right treatment, perform dressing changes, and choose from additional treatment options at each stage, thereby determining the final outcome.

It is extremely important that VR-based training offers healthcare professionals the opportunity to make bold decisions, take safety risks, make mistakes, and learn by trial and error without compromising patient safety. This helps increase the confidence of clinicians, while the novel experience of using VR technology makes learning memorable. The application of VR technology in the field of wound care helps to increase the rate of experiential learning in training, thereby making it more useful in terms of application in real practice.

VR modules provide the opportunity for remote, collaborative learning, which both enriches the independent, peer-to-peer and group learning experience of healthcare professionals in the field of wound care. The training format encourages interaction with fellow learners and provides new opportunities for collaboration between industry players and healthcare professionals.

The technology is modern and easy to use, requiring only a headset and controllers. VRbased training scenarios allow health professionals to evaluate the patient's medical history, examine and diagnose the type of wound, and select bandages that are considered the appropriate therapeutic solution for the given healing phase. Focusing on situation assessment, clinical judgment, and decision-making, VR-based training is therefore designed to reflect real-world practice. Clinical judgment and decision-making skills are improved, and the user's hand movements and possible mistakes made during the application of bandages are corrected by the system. With the help of training, users can more easily and correctly identify specific wound types with greater accuracy and confidence, and select the appropriate treatment options for those wounds.

VR technology has now become a powerful tool in healthcare training as it allows for greater interactivity, practice of clinical procedures and refinement of related skills [2]. These new, innovative technologies provide a three-dimensional experience and realistic clinical experience simulation in the field of wound care, thereby complementing existing traditional or more modern digital education forms and training plans as an effective educational tool. Furthermore, they create a risk-free environment for learning and provide the opportunity for a "checklist-style" assessment, so we can get a detailed picture of what the healthcare professional is doing correctly and in which areas improvement is still needed [3]. This ground-breaking new approach to educating healthcare professionals improves clinicians' skills, increases their confidence, and provides an overall more positive treatment experience and better patient outcomes. It helps healthcare professionals to assess, identify, diagnose and treat wounds, select treatment options and track results based on the patient's medical history and described symptoms.

Elderly Care and Cognitive Stimulation:

The European population is aging, and while many remain vital growing older [6], there is an increasing number of European Union citizens that experience age-related diseases [7] and cognitive [8] and physical decline [9]. Indeed, dementia is the second largest cause of disability in individuals over 70 years of age [10]. Dementia affects a broad range of cognitive functions, including long-term memory, executive functioning, and spatial orientation [11]. The deterioration of these functions has a detrimental effect on the execution of activities of daily living (ADLs) [12]. The subsequent decrease in autonomy has been associated with a lower quality of life [13]. No intervention has yet fully succeeded in halting the cognitive decline elderly experience.. Developing interventions that slow down cognitive decline would greatly benefit the autonomy of these elderly, as well as their caretakers. A novel and promising tool to improve cognitive functioning is immersive virtual reality (VR).

The VR environment is highly flexible and allows for the training in settings that are either impossible in real life or too dangerous. It allows for the practicing of a task's constituent parts, before tackling the task in its whole complexity. For instance, a doubleblind, randomized controlled study showed that in adults with hemiparetic stroke, isolated aspects of walking, namely weight shifting and stepping, can be subsequently trained and improved [14]. VR can also be used to provide a simplification of reality by removing elements such as gravity [15]. As a participant's skill level increases, these factors can easily be reintegrated into the virtual world, showing VR can cater to the participant's physical abilities, taking into account physical limitations [15]. Next to training in settings that do not exist in real life, VR is especially suitable for providing an environment where situations conceived as potentially dangerous in real life can be trained safely [16]. Many age groups, including elderly, can benefit from such a safe environment. For example, VR enables blind participants [17, 18] and wheelchair users [15, 19] to practice their visuo-spatial orientation safely, without bumping into their surroundings. Similarly, elderly [20], stroke patients [21], and children [22] can practice crossing the street before doing so in real life. Other examples of executing ADLs in the VR world include preparing food [23, 24], going to the supermarket, or walking through a city [25].

The flexibility of VR also means that training settings can be tailored to the participant's individual needs and level in a dynamic fashion. A wide variety of variables can be adjusted such as which [15] and how many [26] stimuli are presented, the size and closeness of these stimuli [27], as well as their speed and order [27], while engaged in the training. This use of immediate feedback on performance can ensure the tight fitting of the difficulty setting to the subjects capability [28]. This personalization of VR has proven to be of value in a wide variety of populations such as the blind [17], wheelchair users [15], children [29], stroke patients [30], and is of special relevance for the elderly population [31].

To conclude, VR training can be adjusted to the changing abilities of elderly, helping them to train complex tasks step by step and allowing for the training of potentially dangerous situations that are relevant for autonomy. Moreover, VR can be highly personalized. These factors may help prevent training-related injury. This is of special relevance given the increased frailty of elderly and its associated risks, such as falling.

Commonly, rehabilitation and other training programs are time-consuming for elderly and their informal caretakers, as they require visiting a professional, and are labor extensive for care professionals, as they require individual instruction and guidance. The randomized controlled study by Yang et al. [29]shows that VR rehabilitation of elderly within their community setting is in fact feasible and effective.

VR enables a wide variety of data to be gathered with a high temporal resolution, aiding the detection of subtle changes within and between subjects. For example, kinematic data can be gathered, such as stride duration, step width, and mass trajectories [32]. Moreover, the motions tracked can be compared to the ideal execution of a movement. This so-called “motion matching” can help the participant finetune their actions to the desired movement through immediate visual feedback [33].

Lastly, VR can be combined with other techniques such as fMRI, making brain functionality trackable while in the VR environment, giving more valuable insights into VR’s effects [34].

The measuring of a wide variety of parameters with a great time resolution is not only of relevance for measuring physical performance, but is also becoming increasingly informative for cognitive performance of functions such as working memory and sensorimotor integration. Being able to measure subtle cognitive changes may help diagnostic as well as training and rehabilitation settings, warranted the data obtained are valid and reliable.

Immersive VR for cognitive training of elderly shows great potential due to its unique characteristics. It can be tailored to the individual, which is important given the heterogeneity of the elderly population and the need for safe training environments.
Moreover, VR’s high level of automation can potentially lower the burden conventional interventions pose on caretakers and medical staff, and increase the elderly’s feeling of autonomy. In addition, VR provides a very rich dataset and allows for a tight tracking of progress and adjustment of treatment focus.

Postoperative care

Postoperative pain is a highly prevalent clinical problem and continues to be a significant challenge in the management of surgical patients [35,36]. It is defined as an unpleasant physical and psychological experience associated with actual or potential tissue damage caused by the surgery itself [37]. Postoperative pain is a cause of delayed recovery and discharge after surgery, as well as increased risk of respiratory and cardiovascular complications [38,39]. Therefore, effective management of postoperative pain is clearly of primary concern to the patients and essential to the health care workers.

From now on, pharmacological treatments remain the cornerstone in the field of postoperative pain management [40]. However, commonly used drugs like opioids often have certain side effects, including nausea, vomiting, urinary retention, and respiratory depression [41]. As a result, more and more non-pharmacological methods of pain relief have been used to relieve postoperative pain for reducing the use of opioids, such as music therapy [42] and hypnosis [43].

With the continuous development of technology, virtual reality (VR) serves as an emerging non-pharmacological treatment for pain relief. It is a computer-generated depiction of a 3D immersive environment that can make patients feel as if they are a part of the virtual environment [44]. VR can create a sense of presence and combine interactive scenes to engage the patients in the virtual environment to divert the attention of pain.

Numerous studies demonstrated that applying VR during the perioperative period resulted in a greater reduction in postoperative pain when compared with usual care. The current mechanisms of VR to relieve postoperative pain are not unified. Distraction is one of the main mechanisms, because attention is required for postoperative pain perception and exists in limited supply. Therefore, diverting attention can reduce the resources available for processing postoperative pain [45]. Furthermore, VR is thought to be more effective than traditional methods of distraction, because its immersive property makes the patients actively interact with the vivid virtual environment, which in theory demands more attention [46]. Moreover, emotion regulation is another important mechanism. Common negative emotions such as fear and anxiety in postoperative patients can make them more susceptible to pain perception and unpleasantness, because these emotions will evoke more brain activities in emotion-related medial pain system. VR can usually alleviate these negative emotions, thereby reducing the pain intensity and discomfort of patients after surgery [47].

However, the use of VR and AR technologies is not limited to postoperative pain relief, they can be used in other circumstances. Piskorz et al. [48] pointed out that VR could relieve the children's pain during the puncture process by constructing some imaginative games. Tanja et al. [49] found that the peaceful seaside scenery presented by VR could better relieve the pain associated with dental treatment than the urban landscape, which thus appears that particular VR environments could provide more significant benefits for patients' pain experiences.

Simultaneously, given the serious side effects of opioids use, VR should also be used as an adjunct to opioids to reduce the dosage of opioids [50]. In a word, VR can be a viable analgesic intervention or a complementary intervention to some pharmacological analgesia.

Except for postoperative pain scores and physiological parameters, postoperative satisfaction is also a vital aspect of illustrating the pain intensity. Inadequate treatment of postoperative pain can influence the level of satisfaction among patients because pain is defined as an unpleasant sensory and emotional experience [51]. McNeill et al. indicated that the reasons for patient dissatisfaction with postoperative pain management were related to insufficient perioperative education and a lack of communication between patients and health care workers [52]. However, VR could offer patients more understandable perioperative education compared with routine care, and it also created an immersive environment to interact and communicate with the patients, which would enhance the perioperative experience so that the patients' postoperative satisfaction was improved [53,54]. This gives an implication that is VR can be employed in other medical scenarios except for painful situations further to enhance the patient's whole medical treatment experience.

VR/AR in pathology

Virtual Reality (VR) and Augmented Reality (AR) technologies have shown promising applications in the field of pathology. Primarily, the use of these two technics are typical in the field of various detection devices, including microscopic examinations.

The augmented reality microscopy (ARM) is an Olympus microscope with an Augmentiqs AR device attached between the microscope’s objectives and eyepiece unit and an inbuilt camera to capture high-quality images. The images can be viewed through the microscope’s binocular lens or displayed on the monitor of an attached computer. It can overlay additional information (whether computer-generated data or the pathologist’s manual annotations) onto the original microscopic field of view (FOV) in real time, without having to first digitize a glass slide.

ARM even enables real-time image analysis on the glass slides by integrating AI algorithms to generate a composite FOV that can be used for advanced data collection without altering the traditional manual pathology workflow or the optical quality of the microscope. This modified "smart microscope" can be used for a variety of diagnostic purposes, including:

- simple measurements (e.g., size and depth of tumor or lymph node metastasis)
- immunohistochemical stain quantification (e.g., Ki-67 proliferation index)
- diagnosing non-neoplastic diseases (e.g., myopathy and non-alcoholic steatohepatitis)
- cancer diagnosis (by integrating AI such as deep machine learning algorithms)

The high-quality digital images the microscope produces can be used for telepathology, tumor board presentations, frozen section peer reviews, teaching, and research.

Augmented reality – and ARM in particular – has a lot to offer in the lab as well. Its benefits include:

- AR devices can be attached to any conventional light microscope to convert it into a "smart microscope."
- Real-time image analysis on glass slides by avoiding the time-consuming process of digitizing glass slides prior to image analysis. This decreases the disruption to routine workflow in a busy pathology practice.
- Minimal technical skills required to operate ARM, unlike whole-slide scanners that require special technical expertise.
- More affordable than a conventional whole-slide scanner.
- Not associated with simulator sickness, which is known to occur with wearable AR/VR devices.

Because AR devices can be attached to multi-headed microscopes, educators can use ARM to annotate important pathology features, such as mitotic figures. Some devices even have a stage-tracking facility that students can use to follow the educator's exact movements in reviewing the slide – helping them learn to navigate difficult cases. Manual counting of Ki-67 or H-score for breast biomarkers is time-consuming and shows interobserver variability – whereas ARM can make the process faster and more accurate so that trainees can focus their time on difficult cases.

ARM can save time and improve trainees' educational experiences by integrating different features, such as more accurate measurements and automated stain quantification. AR is really effective for education, as it offers learning that is more engaging, fun, helps explain abstract concepts, and can reach more people.

Pregnancy

Pregnancy is one of the most significant and stressful events in women's lives. Anxiety and fear during pregnancy have adverse medical, mental, biological, and behavioral effects on the mother and her child [55, 56]. One of the main concerns of pregnant women is their delivery process and they fear its pain [57]. On one hand, VR technologies provide information about the operating room and delivery process within an artificial environment similar to that of the real world and help reduce anxiety in pregnant women by allowing mothers to artificially experience childbirth before it actually happens, so mothers are much more ready. On the other hand, VR could be used to decrease women's focus on her surrounding environment and calm them. One of the other uses of VR in pregnancy is exercise training. Exercise during pregnancy could help to control gestational diabetes, reduce cesarean surgery rates, and ensure good fetal and maternal weight gain [58]. Following an exercise course schedule provided by healthcare centers may be time-consuming and boring for some women. Therefore, it is sufficient to use VR technology instead as it encourages pregnant women to do their exercise at home and at any time they would like [59].

Some hospitals have already used pre-designed relaxation videos such as dream beaches, cliffs, dolphins and whales swimming, castles, and forests [60,61,62,63,64,65]. These natural landscapes can calm pregnant women and distract them from the events taking place around them and as a result reduce their fear and pain.

In addition, there are VR videos that contain all aspects of cesarean delivery to increase the understanding of pregnant women of the event and eventually decrease their anxiety

[66]. Moreover certain hospitals use VR videos in which there are trainings to different exercise activities which are quite useful for pregnant women [59]. Last, but not least a 3D model of the fetus from ultrasound images was also developed for VR haptic and visual contact of the mother with her fetus [67].

In, conclusion, VR technology has different applications in pregnancy, from reducing anxiety and pain to exercise training. VR technologies can decrease the anxiety of pregnant women and their pain of delivery by informing the mothers about the operating room and delivery process in an artificial setting before women encounter the situation in reality. Also, VR helped to distract women from the events taking place around them which inturn helped to decrease their stress and anxiety. (Although studies have shown that VR is an effective method in helping pregnant women, it is essential to take the available guidelines into consideration to ensure a successful implementation of this technology in the future.)

Anatomy education

Anatomy education has historically been facilitated by cadavers, anatomical models and drawings in anatomical atlases [68]. In line with this, the anatomical assessment is based on the ability to recall spatial relationships between structures, both in two-dimensions (2D) and three-dimensions (3D) [69]. However, with an increasingly cramped curriculum for medical students, anatomy educator have been searching for engaging and interactive teaching methods based on state-of-the-art technologies [70].

Anatomy education has been greatly enhanced through the use of Virtual Reality (VR) and Augmented Reality (AR) technologies.

Through a software (HoloAnatomy) instructors can lay out anatomical content in the manner they wish to present the subject. Maintaining the instructor as the expert, HoloAnatomy Software allows them to:

- Customize the shared view with thousands of detailed illustrations including the entire cardiovascular system, lymphatic system, thorax, heart in isolation, or any combination of anatomical structures.
- Include side-by-side comparisons of the male and female anatomy.

- Activate automatic labels or create custom labels and highlight or isolate particular structures to call attention to detail.
- Decide whether the body is presented in the erect, prone, or supine position
- Display the body at a human scale (100%) or mini scale (75%) or large scale (150% and 200%) helping students to observe small and gross anatomical structures.
- Display instructor's notes or key points that could heighten the learning experience for students.
- Inclusion of 2D images that could help students learn or match concepts within subspecialities (i.e., embryology, histology and pathology)
- Design 3-D "slideshows" and "publish" in minutes to large groups of students, so they can explore the content together in class.
- Lead their own curriculum in-person or remotely.

The HoloAnatomy Software suite includes:

<u>Designer Tool</u>

The Designer Tool is similar in concept to PowerPoint, loaded to the course instructor's computer. This allows educators to develop custom presentations using the library of anatomical art. The instructors could apply automatic or custom labels, highlight features, change body positions and sizes, include notes and 2D images, and compare male and female anatomy side-by-side. Once the 3D "slideshow" is designed, course instructors can click "publish" and deploy the content to multiple HoloLens headsets where students can start exploring content together in class.

<u>Dashboard Tool</u>

The Dashboard Tool makes class and exam management even easier for both faculty and technical support. Upon launch, it allows users to view the status of any HoloLens connected to class to gain a clearer understanding of what participants are experiencing and have control over the testing environment, including: monitor dropouts, administer an exam, assign different questions to different students, and much more.

The Anatomical Hologram Library

A library of digital 3D anatomy art assets with more than 9000 intricate illustrations of the human body. Static male and female models represent average healthy middle-aged adult anatomy.

The Viewer App

The Viewer App is an app to HoloLens, allows the display of holographic content created in the Designer Tool.

The HoloAnatomy Network

Networking framework enables multi-user classroom interactions for large and small groups using traditional classroom Wi-Fi.

Conclusions

In conlusion, the use of VR and AR in anatomy education offers students a more immersive, interactive, and engaging learning experience. It enhances their spatial understanding, critical thinking skills, and retention of anatomical knowledge, ultimately preparing them for clinical practice.

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Chapter 7

Using virtual reality to improve medical students' communication skills

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Introduction

The previous chapters in this book predominantly focused on the use of virtual reality (VR) with regards to the physical world. However, the exploration of the social world through VR is an equally fascinating adventure that has its own benefits as well as challenges. Designing a social environment in VR in order to simulate social interactions may strongly differ from other VR environments that were designed for the exploration of physical, biological etc. phenomena. For example, while VR's capability of making microscopic objects visible to the human eyes and\or manipulable is highly valuable for disciplines like chemistry or biology, while for the training of social skills, it is usually of little use. For a social VR environment, much more important are other features, for example, realistic, customizable avatar creation, spatial audio, the implementation of networking etc. [1-3] Privacy and safety issues may also get more focus when users are in a social virtual environment interacting with other users or the computer as the interactions might include private, sensitive information too. [3-4]

Challenges of designing social environments in virtual reality

Social VR environments have been developed for research and education alike [56]. A typical educational aim is training medical students or health professionals to improve their social and communication skills. VR is particularly useful in teaching such skills as we can simulate any kinds of situations (e.g. emergency care) or patients (e.g. patients with different mental disorders) without the risk of causing any harm to an actual patient. Besides being safe, VR is also capable of presenting highly realistic environments with people and equipment, which will make the training process feel real and trainees might therefore find it easier to get engaged [7].

Thus, to make the best out of VR, the simulation of medical environments must be as realistic and immersible as possible. To achieve these goals, the designer of such VR simulations should consider several functions and characteristics. (1) Both the visual and auditory representation of the room, the medical equipment and the patient and doctor\nurse avatars should be very realistic as it enhances immersion [7]. (2) The interaction between the avatars should also be realistic[7], which requires the designer to put much effort into the synchronization of visual and auditory elements, proper timing, careful design of mimics, gestures, vocalization etc. Adding extra features like being able to show emotions via actions (e.g., smiling, showing concern) might also be helpful. (3) The person training through VR should, of course, be also able to interact with the medical equipment in a realistic manner. (4) For certain scenarios, it is also important to be able to connect multiple users. For example, emergency care scenarios might be simulated in multi-user mode, which therefore require a couple of additional features [8]: the users should be able to communicate with each other via text messages or voice chat, see each other's actions in real time with the lowest latency possible. In these cases, the selection of an optimal engine is especially important as engines that support networking such as Unity or Unreal Engine (see Chapter Y) are preferred. Finally, (5) if a specific subpopulation of patients (e.g., a patient with aphasia who therefore finds it hard to communicate properly) is involved in the simulation, the realistic presentation of symptoms, communicational and social limits is also a key aspect. In an ideal case, the virtual patient should also show other special characteristics that are typical of that particular patient population, for example, a virtual patient with autism might frequently avoid eye contact as it is often observed in real autistic patients [9]. To sum up, the above presented features, when properly designed, are suggested to enhance user experience, lead to higher levels of immersion and are therefore important to consider when designing a medical simulation that involves social interactions.

Besides designing a realistic environment, there are other factors to consider too. To help the user in the virtual world, it is recommended to include real-time feedback about their actions and give them further instructions at different time points of the simulation if needed. The ability to manipulate time within the virtual environment is also very useful when our goal is to teach social skills. Thus, users are supposed to be able to stop, rewind or even fast-forward situations. Some extra time for problem analysis and thinking about potential solutions can be very useful while acquiring or improving certain skills. In addition, having a large database of cases for patient representation is also an asset because it enables the simulation to be more variable. In an ideal and probably too optimistic case, the variance of virtual cases available in the virtual simulation should closely resemble that of the variance of real cases in terms of basic patient characteristics (e.g., age, sex, BMI), severity of symptoms etc.

Despite the challenges presented above, teaching social and communication skills through VR based patient simulations have captured the attention of many [10-11]. It is, of course, no surprise as this method certainly seems to be one of the best ways of teaching these skills for medical students without having to face actual patients. VR gives medical students and professionals the opportunity to practice how to communicate clearly and sensitively, conduct motivational interviews, deliver bad news (e.g. sharing a lethal diagnosis or telling relatives that a patient has passed away) and help them to acquire the ability to gain trust, demonstrate empathy and influence the patient's behavior [13;12;11]. In the following sections of this chapter, we are going to describe previous studies that tested the effects of VR on social and communication skills and synthetize previous findings.

Enhance compliance by developing Motivational Interviewing skills using Virtual Reality

Motivational interviewing (MI) is a powerful technique that has become increasingly important in healthcare. It involves a collaborative conversation between the healthcare provider and the patient, with the aim of identifying and addressing any factors that may be impeding the patient's progress towards better health. MI has been shown to be effective in a wide range of healthcare settings, from addiction treatment to diabetes management [14]. It is particularly useful in cases where the patient may be resistant to change, or where the provider is struggling to engage the patient in the treatment process (e.g. vaccination uptake). Given its potential to improve patient outcomes, it is essential that healthcare providers receive training in MI techniques. This is especially true for medical students, residents, and other healthcare workers who are just starting their careers. By incorporating MI into their practice, these providers can help their patients achieve better health outcomes and improve the overall quality of care [15]. Furthermore, healthcare providers who are trained MI can help to reduce the burden on the healthcare system by improving patient adherence to treatment plans and reducing the need for costly interventions.

In the followings, we review the existing research on the use of VR in developing medical communication and compliance, with a particular focus on the application of motivational interviewing skills. VR technology has the potential to revolutionize the way healthcare providers are trained in MI. One of the main advantages of using VR for MI training is the ability to create a wide range of scenarios that cover different patient populations, health conditions, and treatment contexts. Virtual patient simulations may also be useful in clinical scenarios that are difficult to replicate with standardized patients, such as communication with patients who have rare conditions, speech disorders, and neurological diseases [12]. Overall, the use of VR technology in MI training has the potential to make this valuable technique more accessible and effective for healthcare providers. By providing realistic scenarios, instant feedback, and the ability to train large numbers of providers, VR can help to improve the quality of care and outcomes for patients, while also reducing healthcare costs and improving access to care. The further potential specific features, benefits and limitations of VR technology in this context are discussed. Through a comprehensive review of the literature, we found a total of six studies that investigate the use of virtual reality in enhancing medical communication, with four of these studies focusing specifically on pediatricians and three of these focusing on specifically vaccination uptake (see table x).

Table 1. Summary of studies investigating the effects of VR in motivational interviewing

REFERENCE	NUMBER AND TYPE OF PARTICIPANTS	FEATURES OF THE INTERVENTION	OUTCOME VARIABLES	RESULTS

REAL ET AL, 2017	resident pediatricians; int[1] (n=24); ctrl[2] (n=21)	3 suitable simulation sessions of about 15 minutes, immediately followed by professional feedback on communication tools (open questions, empathy, avoiding jargon) from a facilitator in person.	vaccine refusal rate at 3 months postintervention	vaccine refusal rate ↓ compared to control group (27.8%-37.1%; p=0.03)
REAL ET. AL, 2022	resident pediatricians: int (n=93); ctrl (n=30)	4 VR simulation scenarios; approx. 25 minutes	HPV[5] vaccination uptake rates before and after VICTORI in the intervention and control groups; MEC Spatial Presence Questionnire (to measure attitudes towards VR)	MEC confirmed that the VR experience was as if they had actually participated in the action of the presentation. HPV vaccination uptake rate ↑ (int: 54.3-72.4%; p<0.001; ctrl: 59.5%-63.4%; p=0.609)
REAL ET AL, 2023	resident pediatricians; int (n=35); ctrl (n=20)	Four 15-minute lessons (BHAG and MI) per month, followed by a VR simulation for practice	observation sheet ABCS[9] to assess BHAG and MI in a twomonth postintervention simulation	praise ↑ (p=0.03) further control ↑ (p<0.001) use of open questions ↑ (p=0.04) MI adherent behaviours ↑ (p=0.04) consequences, asking for permission, emphasis on control, reflection, confrontation n.s.[10]
REGER ET AL, 2020	HCW[11] int (n=61); ctrl (n=59)	two 45-minute VR simulations, 3 months apart	MI Treatment Integrity coding system pre-, post- and 3month postintervention	technical skills ↑ (p=0.02) relationship skills ↑ (p=0.001) reflectivity ↑ (p=0.001) changes were maintained in the 3-month

				postintervention phase
SCHOENTHALER ET AL, 2017	hospital staff providing primary care (n=35) and low-income minority patients (n=34)	15-minute simulation in one session; SDM and antibiotic use improvement; patient and doctor participate in the simulation and a virtual coach gives feedback in a short video at the end of the simulation	Antibiotic perceptions and knowledge questionnaire - *for patients only* - PPOS[15] to measure attitudes towards shared decisionmaking - decision making subscale from the MMCS[16] - for *patients only*	Patients: beliefs about appropriate antibiotic use ↑ (p=0.001); knowledge at one-month follow-up n.s. -SDM n.s. Staff: SDM ↑ (p=0.01); one month follow-up n.s.
ZHENG ET. AL, 2022	first-year medical students (n=20)	pre-intervention: one-hour smallgroup training with two VR scenarios (child's perspective on receiving an injection; receiving dental care) TBH: 5 scenarios in small groups for 10 minutes with children.	JSE[18] prepost and one year postintervention TBH impact questionnaire	JSE ↑ (pre/post: p=0.026; pre/annual post: p=0.002; post/annual post n.s) subjective confidence, interaction ability ↑

Note: [1]*intervention group* [2]*control group,* [3]*nonrandomized control trial,* [4]*Virtual Immersive Communication Training on Recommending Immunizations,* [5]*Human Papillomavirus Vaccination,* [6]*randomized controlled pilot trial,* [7]*Promoting Resilience and Emotional health through Virtual Education iN Training* [8]*behavioural health anticipatory guidance* [9]*assessing behavioural communication skills* [10]*not significant,* [11]*healthcare workers,* [12]*Motivational Interviewing Novice Demonstration,* [13]*virtual standardized patient,* [14]*shared decision makink* [15]*Patient-Provider Orientation Scale,* [16]*Medical Communication Competence Scale,* [17]*Teddy Bear Hospital,* [18]*Jefferson Empathy Scale.*

Real and his colleagues (2017) showed that immersive VR can be an effective method for training physicians in communication skills related to influenza vaccine hesitancy [16]. The VR curriculum consisted of three scenarios in which residents counseled graphical character representatives (avatars) who expressed vaccine hesitancy. The scenarios presented different reasons for influenza vaccine hesitancy commonly reported in the literature (In the first scenario, the caregiver expressed feelings of the vaccine as ineffective. In the second scenario, the caregiver presented beliefs regarding the vaccine as unnecessary and injurious. In the third scenario, caregivers expressed spiritual objections to vaccination as well as misconceptions regarding contraindications.), and the residents had to demonstrate several best-practice communication skills including open-ended questioning, exhibiting empathy, and providing education without medical jargon. Feedback about the residents' use of bestpractice communication skills was provided by the facilitator after each scenario, and feedback was periodically assessed for consistent messaging by a physician author. The impact of the curriculum was assessed by comparing the rates of influenza vaccine refusal between the intervention group (who underwent the VR curriculum) and the control group (who did not undergo the VR curriculum) in the three months after the VR curriculum. The study found that residents in the intervention group had a decreased rate of influenza vaccination refusal in patients aged 6 to 59 months compared to the control group.

In a further study [15] the authors also attempted to demonstrate the effectiveness of the method on HPV (human papillomavirus) vaccination. In this study the Virtual Immersive Communication Training on Recommending Immunizations intervention (VICTORI) included 4 VR simulated scenarios during which participants had to counsel caregiver avatars hesitant to accept the HPV vaccine for their child. The scenarios were designed to scaffold learning and present participants with more challenging cases over time. In each scenario, participants had to consistently demonstrate high-quality recommendation skills, such as using presumptive announcements, endorsing vaccination during the clinical visit, bundling HPV between other standard adolescent vaccinations, and providing a strong personal recommendation for vaccination. Additionally, participants had to effectively address sources of hesitancy by using MI skills, such as asking open-ended questions, reflecting on patient statements, and asking permission before providing information. MI skills were included in VICTORI given their importance in establishing rapport while exploring and resolving ambivalence and evidence-based relevance to addressing HPV vaccine hesitancy. Facilitators used standardized simulation flow sheets and performance rubrics to conduct training and ensure adequate demonstration of learning objectives before training completion. The intervention group completed the VR simulations and a smartphone application on recommendation behaviors, while a comparison group completed only the application. The study found a statistically significant increase in patients' HPV vaccine initiation rates after training within the intervention group.

Finally, their recent comprehensive PREVENT (Promoting Resilience and Emotional health through Virtual Education iN Training) program [17] was developed to increase the overall BHAG (Behavioral Health Anticipatory Guidance) and MI competencies of resident pediatricians using VR training. A randomized control trial showed that PREVENT resulted in enhanced BHAG skills among participating residents compared to a control group. The intervention group received four 15-minute, monthly didactics on BHAG and MI followed by VR simulations to practice delivering BHAG by verbally counseling avatars. The VR training included brief didactics and three simulated scenarios during which participants verbally counseled caregiver avatars with concerns related to their child's behaviors. The control group received didactics on assessing pediatric respiratory distress. Two months post-VR training, all residents participated in a unique VR behavioral health scenario which was recorded and coded by pediatric psychologists via an observation instrument to assess residents' skills. The primary outcome variable in this study was the change in BHAG counseling skills, measured by a pre- and post-intervention comparison of the residents' performance in a virtual behavioral health scenario. The secondary outcome variables included changes in openended question asking and MI-adherent behaviors. Thus, the authors concluded again, that VR may be an effective educational strategy for residents to acquire BHAG and MI skills through deliberate practice.

Another strong evidence for the effectiveness of VR comes from the study of Reger and his colleagues (2020) who investigated the effectiveness of a computerized training program called the Motivational Interviewing Novice Demonstration (MIND) application, which uses virtual standardized patients (VSPs), on improving MI skills of health care professionals in order to make positive health changes [18]. Participants completed an online course on brief motivational interviewing for veterans, which included instructional content and videos. After the online course, half of the participants practiced their skills using a virtual patient (VSP) named Mike. They engaged in two scenarios with Mike, discussing his home problems and substance use. During the virtual patient encounters, participants selected response options, and the VSP provided feedback based on their choices. The software tracked performance and generated detailed reviews for each participant. The control group studied a summary document of the computer training. All participants completed three study visits over approximately 3.5 months, which included surveys, interactions with a standardized patient, and assessments of their motivational interviewing skills. The study found that participants who underwent VSP training had significantly greater post-training improvement compared to those who received academic study of the course content. The differences were maintained after the 3-month additional training session, with more improvements achieved after the 3-month training for the VSP trainees on the reflection-to-question ratio. The study concludes that VSPs have the potential to facilitate dissemination of MI and may be useful for training in other evidence-based skills and treatments.

In addition, Schoenthaler and his colleagues (2017) used a 15-minute simulation to help healthcare providers and patients practice effective communication about antibiotics overuse [19]. Participants were involved in a simulated conversation focused on improving collaborative patient-physician communication and shared decisionmaking regarding antibiotic use. Healthcare providers acted as Dr. Wei and had to navigate the conversation with the patient, Laura. A brief movie was shown to participants at the start to establish their objectives in the conversation. Providers had to engage Laura in discussing her condition and health goals, and together, they had to develop a treatment plan that Laura understood and was motivated to follow. Throughout the conversation, providers needed to demonstrate empathy, use plain language, ensure understanding, and address Laura's requests for antibiotics. A pre-post repeated measures design was used to assess changes in patients' and providers' self-reported communication behaviors, activation, and preparedness, intention, and confidence to effectively communicate in the patient-provider encounter. Changes in patients' knowledge and beliefs regarding antibiotic use were also evaluated. The simulation resulted only in short-term positive benefits for patients' beliefs about antibiotic use and a positive impact on patients' knowledge about antibiotics, but the changes were no longer significant at the one-month post-intervention measurement. Short-term improvement in SDM was also observed among the staff.

Finally, in Zheng's study (2022) the authors discuss the challenges medical students face in empathizing and understanding how young children feel during medical treatment [20]. To address this issue, the authors propose using the Teddy Bear Hospital (TBH) and VR to help medical students learn how to communicate and empathize with children. The study involved first-year medical students who participated in TBH sessions and completed pre- and post-intervention empathy assessments. The students also completed a one-year post-intervention quantitative and qualitative survey about their experience. Prior to the TBH session, the students participated in a one-hour small group teaching session that included viewing two VR scenarios. The scenarios depicted a child's point of view in the setting of getting an injection and visiting the dentist. The students were also briefed about the different scenarios in the TBH session during this session. The results showed a significant increase in empathy scores for both post-intervention and one-year post-intervention compared to pre-intervention. More than 80% of the students believed that participating in TBH improved their confidence and ability to interact with children, and 50% felt that the VR scenarios helped prepare them for the TBH. The authors note that both VR and TBH are immersive interventions that can potentially increase the empathy of medical students and improve their learning experience. However, each intervention has its own limitations. VR scenarios are scripted and do not allow for real-time interaction, while TBH is resource-intensive and cannot be conducted in situations such as a pandemic.

In conclusion, according to the reviewed studies the use of virtual reality in developing MI skills has the potential to enhance compliance and improve healthcare outcomes. VR technology allows for the creation of realistic scenarios that cover different patient populations and treatment contexts, making motivational interviewing training more accessible and effective. Research has shown that VR-based motivational interviewing training can lead to positive outcomes, such as increased vaccination rates and improved communication skills. Furthermore, VR simulations provide instant feedback and the ability to train large numbers of providers, contributing to the improvement of patient care and reduction of healthcare costs. While VR has its limitations, such as the lack of real-time interaction, it offers a promising educational strategy for healthcare professionals to acquire and enhance their motivational interviewing skills.

Teaching communication skills using virtual reality

Research confirms that communication is the most important component of the doctorpatient encounter highlighting that poor clinician communication skills are associated with lower levels of patient satisfaction, higher rates of complaints, poorer health outcomes, and an increased risk of malpractice claims. The following research studies utilized VR technology to target training general communication skills for medical education.

In 2017 Kron et al conducted a blinded, multisite mixed methods randomized controlled trial study by assessing the advanced communication skills of 421 second-year medical students by randomizing the participants to the MPathic-VR intervention versus the current standard multimedia training for computer-based learning (CBL) [21]. Students had to face two scenarios, the first emphasizing an intercultural, the second scenario providing an interprofessional communicational challenge. The intervention group had an introduction to the system and general communication principles, and then took a readiness assessment quiz. After the first run-through scenario they received an AAR (after action review) with personalized feedback then had the chance to repeat the first encounter. They transitioned into the second interprofessional-focused scene, then having completed an AAR they had a second-run as well. The session concluded with a 12-item attitudinal survey and a reflective essay conducted by the participants. The control group received an introduction to communication principles embedded in a multimedia presentation followed by a quiz and they finished with the same attitudinal survey and a short essay regarding their experiences. Several days later all students were assessed at an OSCE station based on four domains: openness/defensiveness, collaborative/competitive, nonverbal communication, and presence. Attitudinal scores towards verbal communication were more favorable for MPathic-VR. Differences in quantitative attitudinal scores confirmed the qualitative analysis in all domains except the self-assessment of improved clinical skills. Significant differences were noted on the nonverbal communication scale, suggesting that MPathic-VR was particularly valuable for acquisition of nonverbal skills. Additionally, MPathic-VR-trained students were rated higher than the control group students on all four ratings scales, and a global composite created from the four OSCE rating scales revealed a significantly higher mean for the MPathic-VR students.

In 2019 Guetterman et al. also conducted a similar multisite, mixed-methods, randomized control trial study involving 417 second-year medical students utilizing MPathic-VR technology to target teaching empathy and interprofessional communication skills [22]. This research study initially followed its parent study implementing the OSCE to test the learned skills. The control group experienced a CBLmodule, while the intervention group faced 2 scenarios having to interact with 3 VHs. After completing each full scenario, the system provided automated feedback, and the learner repeated the scenario, then they wrote qualitative reflections about their experience. . The students in each condition completed a reflective essay on their experience. Students were randomized to 1 of the 5 reflective questions about (1) human interactions, (2) understanding nonverbal communication, (3) most important things learned, (4) how to improve the simulation, and (5) functional aspects. 1-2 weeks later they all completed the OSCE examination. However, the primary aim of this study was to focus on only those 206 intervention students exposed to the MPathic-VR simulation and investigate differential effects of the simulation. Based on the comparison between high, middle, and lower performing individuals according to their posttraining OSCE communications performance scores the researchers identified 3 major positive themes for the MPathicVR group: gaining useful communication skills, learning awareness of nonverbal skills (as well as verbal skills), and feeling motivated to learn more about communication.

Current study's merging of qualitative and quantitative databases revealed confirmation of findings investigating effects on nonverbal communication skills with promising outcomes. The research results raise questions regarding the need to incorporate instructional design principles that could potentially help motivate students skeptical about improving their health care communication while concluding that virtual humans are a promising strategy for improving empathic communication in healthcare.

In 2019 Sezer at al. in Turkey similarly researched the implementation of VPs in a quasi-experimental pilot study to examine the feasibility of VP teaching methods in Turkey for the teaching of communication skills to medical students [23]. The researchers aimed to fill a niche in Turkey by developing a structured healthcare communication skills training incorporating a 3D VP application with the SP interviews through a quasiexperiment involving a pre-test post-test control group design. 92 academics speicializing in medicine and -among others- medical students participated in the study with both groups undertaking two hours of theoretical communication skills training and after having completed the academic achievement test the control group played a scenario with an SP while the other participants experimented with the VP receiving instant feedback followed by a two-hour communication evaluation and academic achievement test sessions. After having developed the VP of a 55-year of male patient suffering from a headache the VR answers were translated into Turkish, then piloted among students, who reported that the strengths of the simulation included the opportunity for repeated practice animated visuals, 3D, lip sync, a comprehensive scenario, and instant visual feedback provided by the application to students after every question they ask. According to the authors, although they have their own limitations, VPs were found to be at least as effective as SPs based on the advantages they offer, and should therefore be considered for use in affective skills training.

Liaw et al. in 2020 conducted a RCT on team communication and teamwork attitudes by comparing VR vs conventional live simulations through effective and interprofessional team communication trainings involving medical and nursing students' communication skills performances [24]. 120 students participated in the study, who were randomly assigned to undertake team trainings using either VR or live simulations. Prior to their three-hour long training their teamwork attitudes were evaluated using interprofessional attitude surveys (Attitudes Toward Interprofessional Health Care Team (ATHCT) and Interprofessional Socialization and Valuing Scale (ISVS) questionnaires). The authors developed a computer-based virtual reality known as CREATIVE (Create Real-time Experience and Teamwork in Virtual Environment). In both groups, the participants in each team were randomly paired up (1 medicine student and 1 nursing student) and took turns role-playing and observing to participate in two simulation scenarios. First scenario included a postoperative patient with sepsis conditions, while the second scenario involved the same patient in septic shock. Each scenario lasted about 15 to 20 minutes and was followed up by a 30-minute debriefing. After the study intervention, the participants from both groups were brought in for team-based simulation assessments, where they were assigned to work in pairs (medical and nursing) based on their earlier simulation teams. The team-based simulation lasted about 15 minutes and the entire process was recorded (the recorded videos were sent to a clinician for evaluation blinded to the groupings, when the assessors rated the team communication performances independently using a validated team communication scale). The same surveys were administered immediately after(posttest) and 2months follow-up after the simulation training. The outcomes in this RCT study did not show the inferiority of computer-based virtual reality on teamwork attitudes and communication skill performances when compared with live simulations. One advantage of virtual reality over live simulations was its ability to allow anonymous social interactions in its environment, which may cause less social anxiety and stress for students.

Overall it can be stated that all major research outcomes included finding significant differences on the nonverbal communication scale, suggesting that utilizing VPs and the implementation of MPathic-VR were particularly valuable for acquisition of nonverbal skills thus suggesting that VPs could therefore be considered for a wider use in affective skills training.

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Chapter 8

How Virtual Reality Can Enhance Computer Science and Programming Education

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Introduction

Programming is not an essential skill even in the modern days, and it's not easy to learn or to teach. Traditional educational methods, such as lectures, textbooks and online courses often fail to engage students, motivate or provide them with effective guidance and sufficient feedback. Moreover, these methods do not allow students to experience the real-world applications and challenges in topics, for example creating immersive environments, solving complex problems and collaborating with others [1].

Virtual Reality (VR) is a technology that can create realistic and interactive simulations of various scenarios and environments. It can offer a new and innovative way to teach and learn computer science and programming by providing students immersive and collaborative experiences that can enhance their understanding, motivation and skills. In this chapter, I will discuss how VR can help to solve the issues of traditional education methods, what kind of benefits can be offered for both teachers and students, and some examples of existing VR applications and games which can be used for computer science and programming education. I will also review research articles in the topic and use references to support my arguments and ideas about what methods could be used in these VR environments and why.

How VR Can Solve the Issues of Traditional Education Methods

One of the main issues of traditional education methods is that they are often boring and passive for students. Students have to listen to lectures, read texts or watch videos without much interaction or feedback. This can make them lose interest and motivation, as well as reduce their retention and comprehension of the material.

VR can solve this issue by providing students with active and engaging learning experiences. Students can interact with the VR environment using controllers, gestures or voice commands and receive immediate feedback from the system or the teacher. For example, students can manipulate 3D models of data structures or algorithms in VR and see how they work in real time. This can help them visualize abstract concepts, deepen their understanding, and improve their memory.

Another issue of traditional education methods is that they are often limited and isolated from the real world. Students must learn computer science and programming in a classroom or a computer lab without seeing how they can be applied to real-world problems or scenarios. This can make them feel disconnected from the relevance and usefulness of the subject, as well as limit their creativity and problem-solving skills.

Virtual Reality can help by providing students with realistic and immersive simulations of various real-world scenarios and environments. Students can explore different domains and contexts where computer science and programming are used, such as gaming, art, medicine, engineering, etc. They can also create their own VR applications or games using programming tools or platforms in VR. This can help them to see the connection between theory and practice, increase their interest and motivation, and enhance their creativity and problem-solving skills [2].

What Benefits VR Can Offer for Both Teachers and Students

VR can offer many benefits for both teachers and students in computer science and programming education. Some of these benefits are:

Personalization: VR can allow teachers to customize the learning content and pace according to the needs and preferences of each student. Teachers can also monitor the progress and performance of each student using analytics tools in VR. Students can choose their own learning goals, paths and styles in VR, as well as receive personalized feedback and guidance from the system or from the teacher.

Collaboration: VR can enable teachers and students to communicate and collaborate with each other in a shared virtual space. Teachers can create collaborative learning activities or projects for students in VR, such as coding challenges, hackathons or game jams. Students can work together in teams or groups in VR, using chat tools or voice chat to communicate with each other. They can also share their work or ideas with other students or teachers in VR.

Accessibility: VR can make computer science and programming education more accessible for everyone. Teachers can reach more students who may not have access to quality education or resources in their physical locations. Students can access VR education from anywhere using portable devices such as smartphones or standalone headsets. They can also learn from diverse sources of information or inspiration in VR, such as experts, mentors, peers or online communities.

Fun: VR can make computer science and programming education more fun for everyone. Teachers can design more engaging and enjoyable learning experiences for students in VR using gamification elements such as points, badges, levels, rewards, etc. Students can play games or create games in VR that can teach them computer science and programming concepts or skills in a fun and interactive way. They can also express their creativity and personality in VR using avatars, animations, sounds, etc [3].

Interaction Methods

One of the challenges of using VR for computer science and programming education is how to input and visualize code in a VR environment. There are different methods that can be used for this purpose each with its own advantages and disadvantages.

Input examples

VR keyboard using VR controllers: This method uses a virtual keyboard that can be displayed on the screen or in the air and the user can type code using VR controllers that act as pointers or fingers. This method is similar to the traditional keyboard input but the keyboard can be cumbersome(clumsy) and slow, especially if the user has to switch between different keyboards or symbols. To avoid these issues and speed up the process code snipets or premade code sections can help the users in each method.

VR keyboard using hand tracking: This method uses a virtual keyboard that can be displayed on the screen or in the air, and the user can type code using their own hands that are tracked by the VR system. This method is more natural and intuitive than using

VR controllers, but it can also be inaccurate and tiring, especially if the user has to move their hands a lot or hold them in awkward positions.

AR (augmented reality) **keyboard with controllers or hand tracking:** This method uses an AR system that can overlay a physical or virtual keyboard with virtual symbols or hints and the user can type code using either VR controllers or hand tracking. This method combines the benefits of both physical and virtual keyboards, but as drawback, it may also require additional hardware and software and it can be affected by external factor such as lighting.

Hand tracking with gestures and helper UI (user interface): This method uses hand tracking to detect the user's hand movements and gestures and a UI to display the code or commands. The user can use their hands to select, insert or edit code using gestures such as pointing, tapping, swiping, etc. Another UI can provide code snippets, variables and pre-made code sections to choose or modify. This method is more natural and intuitive than using VR controllers or keyboards but it can also be less precise and reliable, especially if the hand tracking system is not accurate.

Voice recognition can convert the user's speech into code. This method is fast and easy but it can also be prone to errors and misunderstandings, especially if the user has a strong accent or uses complex syntax or terminology.

Visual programming with connecting nodes in 3D world in VR: This method uses a visual programming language that allows the user to create code by connecting nodes that represent different functions, variables or values in a 3D world in VR. For example, the user can create a game by connecting nodes that control the movement, sound or graphics of the game. This method is very creative and fun but it can also be confusing and messy, especially if the user creates too many nodes or connections, so the graph should be well separated and easily accessible for each function.

AI (artificial intelligence **/VI (**virtual intelligence) **assistant:** This method employs an artificial (or more likely a virtual) intelligence assistant that can understand the user's commands or questions and generate code accordingly. The user can interact with the AI assistant using voice commands (extending the voice recognition, speech to text technology), text input or even gestures and the AI assistant can provide feedback, suggestions or corrections in real-time. This method is highly interactive and flexible but it also requires advanced AI technology and may not be suitable for many coding tasks.

Visualization

Showcasing algorithms with 2D world UI: It can demonstrate how different algorithms work in a VR environment. The user can see the steps and results of the algorithms on the screen or in the air and interact with them using VR controllers or hand tracking. The user can also choose different algorithms or parameters to compare their performance or efficiency. For example, the user can see how a binary search algorithm finds a target value in a sorted array or how a merge sort algorithm sorts a list of numbers.

Showcasing algorithms with 3D objects: This method uses 3D objects that can represent different data structures, algorithms or concepts and the user can manipulate them using code or VR controllers or hand tracking. The user can also apply the algorithms to different scenarios or challenges that require them to use their logic and problem-solving skills. They can create an array of cubes and get or change their color or position using code. For example, in a 3D world the user can have a list of 3D objects that are placed on the floor, and they need to separate them in ascending order by their weight or any other properties to open a door to the next challenging room. This method is very interactive and immersive [4].

Data Visualization uses 2D UI or 3D graphs, charts or diagrams to visualize the data that the user's code is processing or generating. The user can interact with the data visualizations such as rotating a 3D graph to view it from different angles, zooming in on a specific part of the chart or selecting a data point to see its details. This method can make complex data more understandable and engaging [5].

VR Simulation allows the user to create a VR simulation using their code. For example, the user can write code to simulate the physics of a bouncing ball, and then see the ball bouncing around in the VR environment according to the physics rules they coded. This method can provide a powerful and immersive way to learn and to experiment with coding.

Interactive Code Debugging allows users to step through their code in a 3D environment. Each line of code could be represented as a 3D object or symbol, and the user can navigate through them using VR controllers or hand tracking. As the user steps through the code they can see the changes in the variables or data structures in real-time, which can help them understand the flow of the code and identify any errors or inefficiencies [6].

Examples of interactions

Direct Manipulation allows users to interact directly with objects in the VR environment using VR controllers or hand tracking. For example, users can grab and move 3D objects that represent different variables or data structures, or they can draw lines to connect different nodes that represent different functions or operations [4].

Haptic Feedback devices to provide tactile feedback to the user. For example, when a user selects a piece of code or moves a 3D object, the haptic device can generate a vibration or force feedback, which can enhance the user's sense of presence and immersion in the VR environment.

Gaze-Based Interaction to select or interact with objects in the VR environment. For example, users can look at a specific line of code to highlight it or they can look at a specific button or menu item to select it.

Eye Tracking to detect where the user is looking in the VR environment. This can be used for selecting objects, scrolling through code or controlling the user interface. It can also provide valuable insights into the user's attention and cognitive load, which can be used to adapt the VR environment or interaction methods to the user's needs [9].

Teleportation allows users to quickly move or teleport to different locations in the VR environment. This can be useful for navigating large or complex codebases or data visualizations.

Collaborative Interaction allows multiple users to interact with the same VR environment at the same time. Users can see and interact with each other's code, visualizations or 3D objects, which can facilitate collaboration and peer learning.

Brain-Computer Interface (BCI) to detect the user's brain signals and use them to control the VR content. For example, the user can think about a specific command or action, then the BCI system can interpret the brain signals and execute the command or action in the VR environment. This technology is still in the early stages of research and development, but it has the potential to provide a natural and highly intuitive interaction method [7].

These are some of the possible methods that can be used for code input, visualization and interactions with the results in VR. Each method has its own strengths and weaknesses, and the choice of the best method may depend on various factors such as the type of code, the level of difficulty, the learning objective, the user preference, etc. Therefore, it could be beneficial and also possible to combine different methods to create a hybrid system that can provide a more efficient and enjoyable coding experience in VR. For example, a user could use voice recognition to input code quickly, an AI assistant to check for errors and provide suggestions and a 3D visual programming system to visualize and manipulate the code in a more intuitive and engaging way. The possibilities are endless and the future of VR coding looks very promising.

Conclusion

In conclusion, VR is a promising technology that can enhance computer science and programming education by providing immersive, interactive and collaborative learning experiences that can solve the issues of traditional education methods, offer various benefits for both teachers and students and inspire them to create and explore. VR can also be used to teach and learn computer science and programming using existing VR applications and games that cover various topics and skills. Multiple different methods can be used to generate code and visualize the problem-solving tasks step by step. However, VR also poses some challenges and limitations that need to be addressed, such as technical, pedagogical, ethical and social issues, and as technology advances, more and more options are available. Therefore, more research and development are needed to improve the quality and effectiveness of VR for computer science and programming education.

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