Chapter 4

Virtual reality and its opportunities and risks

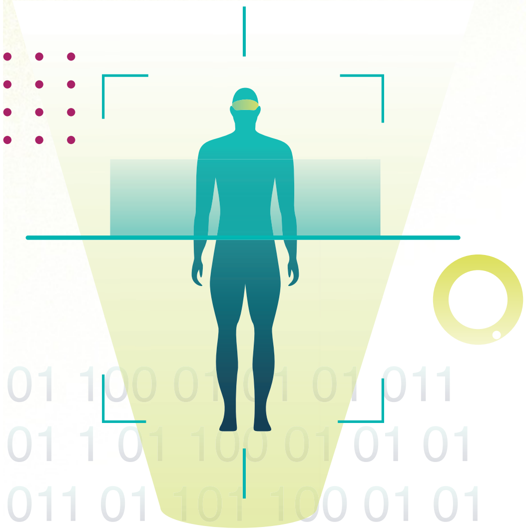
The rise of three-dimensional (3D) technologies is raising questions about the opportunities, risks and impacts of immersive environments on firms, governments, people and society. This chapter disentangles immersive digital environments and focuses on the importance of one immersive medium – virtual reality (VR) – because of its proven ability to scale. It explains the technologies and features of VR, highlighting its benefits and opportunities, as well as its downsides and risks. Concrete use cases help move beyond the buzzwords and hype of VR to a real understanding of when it is exceptionally useful (and when it is not). The chapter also explores the DICE framework, which involves using VR for things that are otherwise dangerous, impossible, counterproductive or expensive, as a useful guide. Key policy issues for VR and immersive technologies include privacy challenges, in particular those associated with tracking data, and safety, especially for children and in moving vehicles.

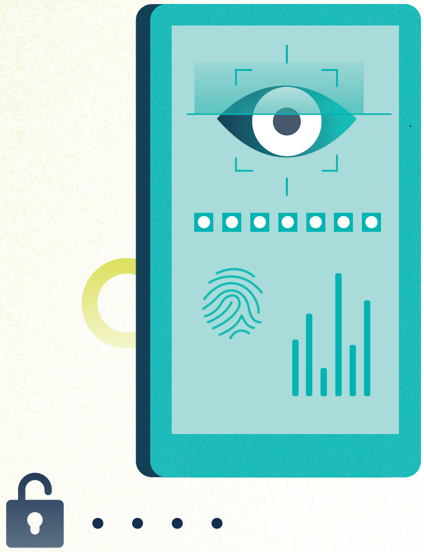
VR opens up new worlds, but user discretion is advised

Mental health and physical safety must be built into VR experiences, especially for children and in moving vehicles.

20 minutes in VR generates almost 2 million unique data points of body language.

Body tracking data makes VR possible, but raises privacy risks.





4. VIRTUAL REALITY AND ITS OPPORTUNITIES AND RISKS

Key findings

The unique features of virtual reality (VR) involve trade-offs

- VR experiences can be self-contained, social or industrial.
- VR consists of a cycle of tracking, rendering and display, a continuous real-time process. Body tracking whereby scenes respond naturally to body movements facilitates "presence" and sets VR apart from other immersive environments.
- VR involves trade-offs on a range of technological features, including tracking level, field of view, field of regard, update rate, latency and image quality.

VR is best for experiences that are otherwise dangerous, impossible, counterproductive or expensive

- The use of VR – rather than two-dimensional technologies – should focus on areas that fall within the dangerous, impossible, counterproductive or expensive (DICE) framework where research has shown that VR is transformational and clearly the best fit for the job.
- VR applies primarily to experiences that fall within the DICE framework such as training surgeons and firefighters, medical rehabilitation (e.g. stroke victims), and having visceral, perceptual experiences (e.g. space exploration).
- Five areas that epitomise the DICE framework and have a proven ability to scale include: teaching empathy; medical rehabilitation; interventions to improve mental health; corporate training; and digital twins.

Considering the downsides and risks of VR from the outset is critical

- VR experiences can be incredible, but if a virtual experience is powerful enough to alter psychological well-being and empathetic views towards other people and cultures, then it must also have downsides and risks.
- Five downsides and risks are: privacy risks, particularly around the tracking of body movements; cognitive development and behaviour of children; simulator sickness; distracted driving; and overuse and addiction.
- Tracking data – which is key to creating VR experiences – also facilitates the generation and potential sharing of highly detailed user profiles, which creates privacy risks.

A mix of existing digital policy frameworks and new policy approaches will shape a positive immersive future

- Policy action on VR and immersive technologies focuses on promoting the domestic VR industry in countries that participated in the *OECD Digital Economy Outlook (DEO) 2024* Questionnaire, but it is starting to expand into specific sectors (e.g. education).
- Countries are beginning to develop "rights" and "principles" for VR and immersive technologies.
- Given there is no way to "opt out" or "go incognito" in VR, new approaches beyond traditional consent-based models will be needed to protect privacy.
- VR mental and physical safety must be carefully considered, especially for children and in moving vehicles, and safety by design can play an important role in this respect.
- VR businesses have begun to develop guidelines, particularly for social VR experiences.

As digital environments evolve from primarily "flat" formats to 3D environments that respond to users' body movements, questions about the opportunities, risks and impacts of such immersive worlds on firms, governments, people and society become more pressing. Applications of immersive environments span a broad range of sectors, including entertainment, manufacturing, education, health care, construction, government services and defence (Kim, 2021[2]; Marr, 2021[1]). While immersive technologies have existed for many years, the ways in which they are combining, the range of emerging applications and the falling costs create a new sense of urgency for policy makers (MIC, 2022[3]).

A cocktail of terms is used to describe immersive environments – augmented reality (AR), mixed reality, extended reality (XR), the metaverse, Web 3.0 and VR. AR, which is sometimes referred to as mixed reality, allows users to see and hear the real world together with a digital layer. With Google Glass, an early example of AR, a pair of eyeglasses allows light in from the outside world. At the same time, through a small window in a portion of the field of view (FOV) of one eye, users can see images, text or video superimposed on the real world. In more advanced systems, such as Apple's Vision Pro, Microsoft's HoloLens or Magic Leap's headsets, objects can be rendered stereoscopically. In other words, each eye receives an image drawn from the proper viewpoint to create depth, and these objects are registered spatially in a real room (Miller et al., 2019[4]). The most popular use of AR is the camera on a two-dimensional (2D) phone or tablet to look at a real-time video of the world with a 2D image superimposed on it (e.g. the videogame Pokémon Go) (Lee et al., 2022[5]).

XR is a relatively new term used to capture the range of different immersive technologies that exist today – VR, AR and mixed reality – as well as related technologies that may emerge. The term "metaverse" (sometimes called Web 3.0) is the overall architecture that includes XR, blockchain technology and virtual worlds that offer real estate, currency and platforms for events and activities. The term metaverse is broad, not well-defined and overused. The term, which came from science fiction, is a future-oriented concept that has spread to video game developers and academia (Ball, 2022[6]). The concept will evolve as technologies develop and expand.

This chapter focuses on one immersive medium – VR – because it is the only immersive environment with proven ability to scale. In 2022, approximately 9 million VR headsets were sold worldwide (compared to 260 000 AR headsets during the same period) (Ubrani, 2023[7]). Almost all of these headsets were sold by companies whose main source of revenue is social media products and services (80% by Meta, 10% by ByteDance and 10% by other firms). VR comes closer to providing an actual experience than a mediated one, both perceptually and psychologically. It offers "presence", the sensation of an experience feeling "real" to users (Sanchez-Vives and Slater, 2005[8]).

This chapter highlights VR use cases that have already demonstrated their ability to scale and return on investment, while minimising discussion of recently overhyped cases (e.g. cryptocurrency-fuelled VR real estate) (Tangermann, 2023[9]). It begins by explaining VR, including its technological and other features. It identifies the benefits and opportunities of VR, as well as its downsides and risks, and provides concrete use cases in a range of areas. The chapter concludes with a consideration of policy issues raised by VR.

Understanding VR

People often engage in self-contained VR experiences via apps.[1] In self-contained VR, only one live person is in the VR environment at any time, whether to play a game smashing floating boxes with light sabres or to visit Palau to understand how climate change is harming coral reefs. Other examples range from the critically acclaimed blockbuster video combat game "Half Life Alyx" to the smaller-budget experiences that allow users to experience empathy by "walking a mile in the shoes" of an avatar with a different identity. Meta offers VR experiences via the Meta Quest application, while Sony has its own platform for its user group of over 100 million PlayStation console owners (provided they buy the Sony VR headset).

A second type of experience is social VR platforms, which allow people to network as avatars and build and experience VR scenes together. For example, VRChat allows people to create a custom 3D world, embody avatars that can look like them (or not) and share virtual experiences with others who are also wearing headsets. For example, users may play miniature golf or sing Karaoke together. In social VR platforms, users meet new people and form relationships and communities. Horizon Worlds, Meta's current VR social networking app, is estimated to have around 200 000 active monthly users as of the second half of 2022, interacting in more than 10 000 different virtual experiences (Horwitz, Rodriguez and Bobrowsky, 2022[10]).

A third type of experience is the use of VR in industry, including business-to-business use cases that involve immersive solutions. For example, VR technologies can help manufacturers go a step beyond "digital twins" – loosely defined as a dynamic virtual version of a physical place or object (Jones et al., 2020[11]). This allows them to see how a potential product would operate in a realistic setting before physically manufacturing it. The concept of VR digital twins has been used in a range of areas, including the design of complex equipment, highly detailed VR environments of factories and cities, and precision medicine and digital agriculture (Marr, 2021[1]). Use cases exist in a broad range of sectors. To date, however, these applications have been highly customised and only practical for high-value applications (e.g. the design of jet engines, industrial facilities and power plants) (Marr, 2021[1]).

A continuous cycle of tracking, rendering and display enable VR

VR consists ofa cycle of tracking, rendering and display, which takes place continuously in real time (Blascovich and Bailenson, 2011[13]). The cycle starts with tracking, which involves sensors detecting a user's movements and translating them into data that can be used to update the VR content. Historically, tracking used a variety of sensors ranging from mechanical to magnetic, but today's tracking is mostly done with computer vision systems. These systems comprise cameras embedded within a headset that can accurately, quickly (i.e. low latency) and frequently (i.e. high update rate) determine where a user is looking and how their body is moving by constantly filming the room around them. Tracking information is critical because the system needs to know where someone is looking and how their body is situated to display their virtual location properly.

Rendering is how VR creates a virtual representation of the environment based on tracking data. Much in the same way that a GPS system in a car stores a map, a computer powering a VR system stores a 3D digital model of the virtual world. For example, it could store scenes such as a living room and the objects in it or a coral reef and the individual corals. Using the tracking information and data from the digital model, the computer updates the user's viewpoint by rendering the 3D world from that same viewpoint. In an underwater coral reef VR experience, for example, if the user tilts her head and looks down, she may see fish swimming below her. Similarly, in a VR experience in a house, if a user physically turns her head around 180 degrees, she will see the rear wall of the virtual room. Every moment the user moves physically, the tracking equipment detects the movement, causing the computer to render the world appropriately to this new point of view.

In current VR systems on the market, this process repeats itself approximately 100 times per second. When the system is functioning well, everything appears smooth to the user, like moving about in the real world. By dynamically rendering each scene based on the user's position, VR allows a scene to be explored infinitely. In an underwater coral reef VR experience, a user could find a small shell in the periphery, crouch down and look behind it. This contrasts with movies that only offer a single point of view (i.e. when a director films from a particular angle showing the shell). As another example, video games allow users freedom to explore paths and objects but typically only as they relate to the gameplay.

Finally, VR systems display the virtual environment to users in real time, allowing them to experience the environment as if they were physically present. This display is typically achieved through a VR headset, which provides a stereoscopic view of the virtual environment and spatialised sound via multiple speakers synchronised with the user's movements. Other display systems include 3D laptops using lenticular autostereo to show 3D models, or projection systems such as the Cave Automatic Virtual Environment in which all surfaces are screens.

VR has been evolving since the publication of "The Ultimate Display" by Ivan Sullivan in 1965, which explained the concept of VR well but not the manner of implementation (Sutherland, 1965[14]). Indeed, the potential of VR has changed dramatically over the past few decades. In Sutherland's early implementations, headsets could not render scenes stereoscopically or in more than a single colour. Today, headsets can mimic how people see and hear in the real world. However, VR systems vary in quality. A high-end system powered by a costly headset that displays images and a separate (powerful) computer for rendering produces much better sight and sound than less expensive, standalone VR headsets that both display images and render simultaneously.

The technological features of VR

As noted by previous scholars (Cummings and Bailenson, 2016[15]), there is no standard implementation of VR; instead, it combines various features and technologies. These features can be prioritised (or not) to achieve specific goals.

Tracking level refers to the number and types of degrees of freedom by which a user is tracked in VR. One can manipulate the tracking level by adjusting the quality of the input method. For example, more natural movement tracking can simulate how the body moves versus abstract controller input such as buttons or joysticks. Tracking also refers to the number of degrees tracked, such as the position of heads, hands, feet and facial movements.

Head tracking is arguably the most essential feature of VR (Lanier, 2017[16]). Without head tracking, VR is reduced to a 3D movie. Research suggests this active navigation through scenes is what makes VR uniquely effective (Markowitz et al., 2018[17]). Body tracking allows users to manipulate their hands and legs and walk around, and has been shown to significantly increase presence (Zanbaka et al., 2004[18]). Some applications require more tracking than others. For example, VR used for stroke rehabilitation requires an elaborate system to follow arm and leg movements accurately (see subsection on medical rehabilitation).

FOV is typically associated with more presence and engagement in VR (Hendrix and Barfield, 1996[19]). FOV is roughly a proxy for how much of an environment a person can see at once. It is often increased by changing the size of the screens close to a user's eyes. This feature is different from field of regard, which is the total amount of possible area that one can view. For example, the typical FOV of a VR headset is a window about the size of a large piece of paper held at arm's length. By moving one's head around, one can typically move that window, examining objects and spaces in every direction (in which case the field of regard is 360 degrees).

However, the field of regard is often reduced. VR video content creators often shift to 180-degree content by limiting the field of regard to avoid rendering content beyond the user's starting FOV. Some applications do not require a large FOV. For example, in a one-on-one conversation, a person rendered across a desk does not take up much space in a user's visual field. On the other hand, scenes designed to inspire awe, such as a virtual moon landing, benefit immensely from the increase in spatial presence depicted by a large FOV (Brown, Bailenson and Hancock, 2023[20]).

Stereoscopic rendering refers to rendering a scene twice so that each eye receives a slightly different virtual camera location, similar to how humans see in the real world. Most virtual reality designers consider stereoscopic vision – that is, seeing depth – to be one feature that truly sets VR apart from other media. However, people rely on stereoscopic vision primarily for objects nearby (i.e. within a range of about 6 metres) (Ono and Comerford, 1977[21]). Stereoscopic vision is critical for some use cases, like trainee surgeons learning to use scalpels and sharp tools on a body. However, for scenes with critical content in the distance – for example, an educational demonstration of the solar system – seeing depth is not as important.

Update rate (how often a scene is rendered each second) and latency (how long a frame takes to render given one's tracked movement) are different constructs. However, they work similarly to contribute to the overall impact of VR. In general, the ability of a VR system to render objects and scenes quickly increases presence, and this is most readily seen in a high-latency environment (Waltemate et al., 2016[22]). Reducing latency and increasing the update rate are important for reducing simulator sickness, one of the main downsides of VR (see subsection on downsides and risks).

Image quality combines several technological features that contribute to the general quality, realism and fidelity of visuals in VR. There are several ways to improve image quality, including screen resolution, flicker rates, lighting types and texture mapping quality. Improving the general level of detail also increases the number of polygons, which allow objects to have smooth portions and not appear as if they are made of blocks.

The VR ecosystem is complicated as one can only do so much, technologically, on a device worn comfortably on the head. This is especially true with standalone VR that does not link to an external computer or cameras. The features discussed above are necessarily zero sum and so trade-offs are important.

The choice of headset has consequences. A headset with high resolution and a wide FOV could maximise the visual awe or scale of a scene. However, such headsets will usually have high latency. If computers are rendering large and complex scenes, they cannot render as often (i.e. lower update rate) and take longer (i.e. higher latency). Consequently, visual fidelity trades off with the naturalness of navigating through the experience.

Scenes in which users naturally look around frequently are often more effective with headsets that maximise low latency and a high update rate, as opposed to the size and quality of an image (i.e. FOV and resolution). More elaborate tracking – for example, large spaces to walk in and hand and feet tracking for self-avatars – adds value to a scene in terms of presence at the expense of scale and ease of use. Consider a situation in which 30 students are using VR in a classroom. There is no space for all of them to walk around with room-scale VR simultaneously. Instead, teachers tend to use "3DOF" VR, which only tracks and renders head rotations. In this way, the students can sit in their chairs and look around.

Many believe that VR has not become more mainstream due to hardware limitations. However, most VR headsets cost about half as much as a typical smartphone. Researchers point instead to the lack of engaging content specific to VR (as opposed to a 2D screen) as the reason for low adoption rates (Mado et al., 2022[23]). Unlike typing a social media post or recording a video, which anyone can do relatively quickly, building a successful VR scene is difficult. Moreover, as the hardware system increases in complexity, it becomes more challenging for users to learn the system and for physical spaces to support multiple users concurrently.

Touch and smell are complex to render in VR

For sight and sound, the cycle of tracking and rendering is straightforward – objects are rendered bigger and louder when one approaches them. However, touch and smell are more complex. The tactile output of a user's VR experience is typically rendered by simple vibrations in a user's hand controllers. In a VR experience in a coral reef, for example, users receive a slight vibration in their hand when they reach out in the physical world to "touch" the place where a piece of coral is rendered spatially. In this sense, touch in virtual reality can contribute to the overall realism of a VR experience (Kreimeier et al., 2019[24]).

Scholars have also studied interpersonal virtual touch, which is enabled by the networking of multiple haptic devices[2] to allow two people to touch each other (Bailenson and Yee, 2008[25]). For example, when two avatars touch hands, each hand controller can vibrate simultaneously to provide a haptic representation of the mutual grasp. Studies have shown when people can touch one another – like shaking hands virtually – they like one another more than in social interactions without touch (Bailenson and Yee, 2007[26]).

The sense of smell is compelling when rendered in VR. One of the most researched use cases of smell is exposure therapy for soldiers with post-traumatic stress disorder (PTSD) (Herz, 2021[27]) (see subsection on mental health). Specific smells, such as diesel fuel, can act as a trigger for traumatic events. Therapists can use those triggers to help patients develop skills and strategies to undo the associations between particular smells and trauma (Mozgai et al., 2021[28]). Over the past few years, olfactory devices have become portable. They are now light enough to attach to the bottom of a head-mounted display.

The benefits and opportunities of VR

VR is most often associated with the entertainment industry where it has achieved modest success.[3] However, VR has more potential if developed and used responsibly. This section presents a framework, based on decades of research, that guides people for when to choose VR over 2D technologies. The DICE framework helps identify experiences for VR that would be "dangerous", "impossible", "counterproductive" or "expensive" in the real world. Training firefighters, rehabilitating stroke victims, learning art history via sculpture museums, and having a visceral, perceptual experience of the Earth's future to understand climate change, for example, all fit squarely in DICE. Alternatively, checking e-mail, watching television and general office work do not earn their keep in a VR headset. Such applications work far better on 2D screens. By not putting such use cases needlessly in VR, society can avoid some of its challenges (see subsection on downsides and risks). Instead, research should focus on areas where VR is transformational and clearly the best fit for the job.

This section focuses on five areas that epitomise the DICE framework: Teaching empathy; using VR as a tool for medical rehabilitation; interventions to improve mental health; corporate training; and VR digital twins. These use cases are chosen for two reasons. First, they all use VR to solve hard problems in the real world, as opposed to simply doing something "cool" with technology. Second, they have already demonstrated their ability to scale. These five areas have all demonstrated how VR can be used in an applied context and extended that application to thousands of people around the world.

Teaching empathy

Doing something in VR that is impossible in the real world – to occupy another body – is a classic DICE use case. VR allows people to experience the body of another person from a perceptual standpoint. Perspective-taking tasks can more effectively promote empathy, improve attitudes and increase prosocial behaviours than less immersive tasks such as watching a video or reading a story. For example, previous studies have asked participants to take the perspective of people with schizophrenia (Kalyanaraman et al., 2010[29]) and the elderly (Yee and Bailenson, 2006[30]) through VR. Other studies have had people transform virtually into animals to understand where beef comes from (Ahn et al., 2016[31]) or cut down virtual trees to feel the consequences of not recycling (Ahn, Bailenson and Park, 2014[32]). VR is uniquely able to enhance understanding of marginalised groups and produce changes in attitudes and behaviour that can last months after the VR experience (Herrera et al., 2018[33]). Such experiences can facilitate the sense of ownership and identification with an avatar even if the avatar does not look like a user's body.

Academic studies of VR and empathy are gaining a foothold in corporations. Sprouts Farmers Market, a US retail chain with about 35 000 employees, created a set of VR experiences to exemplify their core values, some of which were related to empathy. For example, an employee might teach an anxious mother how to buy gluten-free food for her child or deliver a watermelon to an elderly sick customer who cannot drive to pick up his favourite food.

Instead of teaching rules about empathetic behaviour, Sprouts Farmers Market implemented an "Exemplar Model" (Smith and Medin, 2002[34]). Such a model highlights salient experiences that are different on the surface but which all show empathy. These work in tandem to build a particular view of the world organically. In one study, a subset of about 300 employees was tested on its conceptual understanding of the firm's core values. Half were trained through VR, while the other half took PowerPoint training (Bailenson, 2020[35]). Of those trained through VR, 48% learnt all six concepts perfectly, compared to only 3% of the trainees who learnt through PowerPoint.

Another example of VR empathy at scale is the film "Clouds over Sidra". Produced in part by the United Nations, "Clouds over Sidra" is an 8.5-minute, 360-degree immersive film. It takes viewers inside the Za'atari refugee camp in northern Jordan, which was then home to over 80 000 Syrians displaced by civil war. The user hears a young girl named Sidra describing the camp, where she explains that her family lives in a small, converted shipping container. The film has been heralded as one of the most effective pieces of VR content ever made. According to the United Nations, the film doubled the number of people who donated to relief efforts for Syrian refugees (Gaudiosi, 2016[36]).

Medical rehabilitation

Medical rehabilitation can be expensive, and a home VR system can often replace a visit to a physical therapist, improving both comfort and efficacy. Therapeutic VR applications already exist to rehabilitate patients suffering from stroke, traumatic brain injury, cerebral palsy and more (Weiss et al., 2021[37]). Repetition and practice are important for the motor learning component of rehabilitation, and patients need feedback about the success of such repetitions. Additionally, participants must be motivated to practise movements, which are often painful or boring.

An early study used VR to rehabilitate motor performance in stroke patients (Holden, 2005[38]). This VR system trained patients how to perform a variety of arm movements to overcome stroke-induced deficits. A patient would practise activities to elicit movements, such as placing a letter in a mailbox. Motion trackers captured the patient's movements and provided feedback within the virtual simulation on how to improve the trajectory. The system outperformed other types of rehabilitation in terms of the patient's experience, leading to improved motion in the real world (Holden, 2005[38]). A recent systematic review that describes 27 quantitative studies using VR in similar ways highlights consistently positive outcomes (Khan, Podlasek and Somaa, 2021[39]).

One promising area for medical rehabilitation involves transforming the virtual representation of physical movements. Scholars have researched how much effort is needed to act virtually by increasing the gain between participants' movements in real life and their avatars' movements in the virtual world (Won et al., 2017[40]). In other words, if patients bend a knee 20 degrees in the real world, they see their virtual avatar bend its knee 40 degrees in VR. The aim was to give the patients a "can do" visualisation, to let them see the gain in mobility that could be possible.

Psychologists call this "self-efficacy" – the idea that believing in a goal is essential to achieving it. Positive visualisation can be a powerful aid to healing. However, when a patient is suffering, it can be hard to overcome agonising pain to visualise good form in physical therapy. Still, early clinical results are promising (Won et al., 2015[41]), and using VR to show movements that are currently impossible for patients remains a unique benefit of VR.

Over the past few years, VR stroke rehabilitation has scaled beyond academia. For example, Penumbra medical devices implement a full body tracking system used by thousands of war veterans across the United States for rehabilitation (i.e. the REAL System) at scale (Bailey, 2023[42]). This use case epitomises the DICE guidelines, and patients are reaping huge benefits from just a few short sessions each week.

Mental health

Negative behaviours in digital environments are associated with mental health risks (e.g. cyberbullying and harassment), and they become potentially even more dangerous in immersive environments (Danaher, 2018[43]) (see also the Spotlight "Mental health in digital environments"). Phenomena such as presence, emotion and immersion mean that emotionally charged content, including violent threats, can make users feel the effects more deeply because VR goes beyond abstract words to present content in three dimensions (Cummings and Bailenson, 2016[15]; Cadet and Chainay, 2020[45]).

However, there is also evidence that VR can play a positive role in mental health. For example, clinical studies across the globe have examined the impact of VR in domains ranging from anxiety reduction and treating phobias to connecting people and decreasing social isolation. Over the past few years, a number of systematic reviews analysed the state of the field of research in mental health in VR (Cieślik et al., 2020[48]; Hatta et al., 2022[47]).

Exposure therapy is one of the most validated VR treatments for mental health. It has been defined as a scientifically proven psychological treatment developed to help patients confront their fears, decreasing avoidance to feared objects, situations or activities through desensitisation (APA, 2023[49]). There are many forms of exposure therapy. In vivo exposure refers to direct interaction with fears in the real world. Imaginal exposure refers to the vivid imagining of feared objects or situations. Today, the American Psychological Association explicitly lists VR exposure therapy as an evidenced-based form of this therapy to treat anxiety disorders.

Rothbaum et al. (1995[50]) produced the first evidence that VR was an efficacious treatment, demonstrating that VR exposure therapy could help patients overcome their fear of heights. In some ways, VR works like traditional in vivo exposure therapy because it elicits presence. If a patient is afraid of heights in the real world, then standing on the edge of a virtual building is scary in VR. Hence, it can be used to help treat this phobia.

VR in this context has four unique advantages. First, it drastically reduces costs. Treatment for fear of flying, for example, commonly involves a physical trip to an airport, spending time in a boarding area and eventually boarding the plane. Given today's airport security protocols, patients often need to purchase plane tickets for treatment, which is expensive. Second, VR allows the therapist to simulate extremely rare events, such as bad weather and turbulence, at the touch of a button. In so doing, the therapist can use VR to evoke the patient's fears in a way that is not possible in an actual flight. Third, with VR, the therapist can reduce a patient's exposure to experiences that are psychologically dangerous or potentially re-traumatising. If a patient fears driving across gorges, for example, the clinician can alter the height of the gorge, the speed of the car or the weather conditions. Finally, VR protects the patient against any risk of physical harm. In VR, for example, spiders do not actually bite and a flying object unleashed by turbulence on a flight cannot actually hit a patient.

In the years since Rothbaum's first study, a large body of work has focused on treating PTSD. In 2002, scholars used VR therapy to treat a first responder of the 9/11 World Trade Center attack who subsequently developed PTSD (Difede and Hoffman, 2002[51]). Traditional therapies relying on guided imagery techniques did not work for him. Through VR, he was gradually exposed to a virtual environment in which planes flew overhead and crashed into buildings, explosions occurred and skyscrapers collapsed. Following treatment, the patient reported a reduction in acute PTSD symptoms. This case illustrates how VR safely immersed a user in simulations of traumatic environments.

In the decades since, there have been hundreds of studies in this area. One meta-analysis, for example, examined the efficacy of VR for PTSD. It concluded VR outperformed conditions of controlled trials, and that positive effects remained after treatment (Wenrui et al., 2019[52]).

As with other uses of VR discussed in this chapter, academic work on PTSD shows it can successfully scale to the world at large. In 2007, Rizzo, Rothbaum and Graap (2007[53]) developed a VR exposure therapy system for veterans with PTSD that incorporated feedback from returning soldiers from the Iraq War Studies. Over the next few years, the treatment showed clinical efficacy. Today, a commercial system called Bravemind features exposure scenarios, including cities and villages modelled after actual ones in Iraq and Afghanistan (Rizzo et al., 2010[54]). Bravemind is in use at scale in clinics and veterans' hospitals across the United States.

Training

Training can be dangerous, expensive and the rare events that are often teachable moments are hard to replicate. Consequently, soldiers, surgeons and astronauts have trained for decades in VR (Bailenson, 2018[55]). People learn best by doing, and by getting feedback when they make mistakes. Thus, training for high-stake activities is a natural application of VR. For example, research shows that VR increases the confidence of trainee surgeons, improves their understanding of anatomy and gives them a low-risk arena to practise difficult surgical techniques (Paro, Hersh and Bulsara, 2022[56]). Today, thousands of surgeons are training in VR. Even consumer-grade VR helps them become more skilled and efficient at their jobs (McKinney et al., 2022[57]).

There are also academic studies on procedural training, with the literature mature enough to include several meta-analyses. One such analysis, for example, compares VR surgical training to other techniques (Su et al., 2023[58]). Findings generally support the advantage (or equivalence) of VR training to face-to-face training, the economic savings of VR and the decreased time needed to train with VR compared to traditional techniques.

Over the past decade, VR has expanded into corporate training (Bailenson, 2018[55]). "The Pickup Tower", one of the most frequently used corporate modules, is basically a large kiosk that lets customers pick up online orders. Walmart has trained over a million of its associates in this module. Trainees receive step-by-step instructions on how to operate the machine with immediate feedback when they make mistakes. Before the VR training module was developed, every employee spent an entire day training inside special stores. VR reduced training time to 15 minutes, as well as eliminating the time and expense of travel. Given that all Walmart associates in the United States need to train on The Pickup Tower, VR has saved over a million full days of work, while maintaining efficacy (Bailenson, 2020[35]).

Within the training realm, human resources have also adopted use of VR. A recent study examined methods of training bystanders to intervene properly in situations involving sexual harassment (Rawski, Foster and Bailenson, 2022[59]). The study demonstrated that practice scenarios for bystander intervention training were more effective with VR than with 2D video; VR allowed trainees to develop skills in a more realistic environment.

Since the development of the flight simulator in 1929 by Edmund Link, flight training has proven a perfect use case of VR. It checks all the factors in the DICE model, and continues to be the driving force for VR as a medium, both for businesses and consumers. Indeed, personal training is one of the most popular use cases of standalone VR (Eakin, 2018[60]). In one case, Walmart associates had been trained in emergency response to an active shooter. The training used a digital twin of the store and enabled associates to rehearse critical survival skills, such as how to hide, what to say to the shooter and to practise nonverbal behaviour. Some of these trainees were on the job during the 2019 mass shooting at a Walmart store in El Paso, Texas. According to Walmart CEO Doug McMillon, "lives were saved and seconds were gained" because of the training (Jenkins, 2019[61]). Those associates were not daily VR users, but the intense experience of training in VR had stayed with them.

VR digital twins

Some companies are focusing on VR digital twins to save time and resources. They use digital twins to model complex systems, often in urban planning, architectural design, manufacturing and training (Botín-Sanabria et al., 2022[62]). In a factory that never closes and where employees work continuous, alternating shifts, any real-world training of new workers would require shutting down operations. Digital twins allow for training without disrupting workflow.

There are two types of building techniques – modelling and capture. Modelling involves building a VR world, one asset at a time. For example, construction of a specific factory would require 3D modelling software or photogrammetry to build machinery, parts, workers and the accompanying sounds. These elements would then be assembled as if building a diorama.

Capture involves using special cameras to produce spherical video. Volumetric capture – which uses passive and active cameras to produce point clouds of scenes – allows for movement within a scene and renders realistic models. However, this is expensive, requiring dedicated rooms, stereoscopic video and other forms of video that can capture a scene "as is". For example, a spherical video creates a seamless 360-degree vista that can be seen by turning one's head around. While it has high resolution, and is easy to record with a single camera, it only allows for a single viewpoint. For example, if a 360-degree video were shot from a factory assembly line, the viewer would never be able to look underneath a nearby table. Photogrammetry, which infers 3D structure by instantiating many different still images of the same object from alternate angles, is a robust technique. However, it does not work well in scenes with movement, such as a conveyer belt that has many people working around it.

Elizabeth Baron's work at Ford Motor company (Baron, 2009[63]) offers one of the best examples of digital twins. Baron's lab used VR to test how drivers of various ages responded to digital twin car prototypes. Their test results guided car designs to make entry and exit easier for older drivers. Additionally, Ford wanted to understand how the shape of windshields affects driving distractions. For example, how does the shape of the windshield affect how drivers react to attention-grabbing views? Using VR, Baron's team designed windshields that minimised distraction and improved driving performance. Because VR testing does not produce actual physical damage, it allowed Ford to run experiments that would be impossible otherwise. For example, it tested a life-saving system that detects when one's car is drifting into another lane. Such a test in the real world obviously presents safety risks. However, using a digital twin, scientists captured "naturalistic" driving behaviours without risk.

The downsides and risks of VR

A virtual experience powerful enough to alter psychological well-being and empathetic views towards other people and cultures must also have downsides and risks. This section reviews five unique concerns associated with VR that go beyond those involving 2D digital environments: privacy, particularly around the tracking of body movements; cognitive development of children; simulator sickness; distracted driving; and overuse and addiction. They were chosen for two reasons. First, they all have academic research behind them to help guide policy makers. Second, they are unique to the technological features of VR discussed above.

Privacy risks

VR magnifies privacy risks associated with Internet-connected devices, including the Internet of Things (IoT), and extends them in new ways. VR technologies and their applications are developing at a fast pace. The unprecedented collection of data directly related both to users' environment and their bodies creates even higher risks for the fundamental rights and freedoms of individuals. This is exacerbated by the need for sensors such as cameras (see above) in VR. In other words, blocking cameras – as one might do on a laptop – is impossible in VR.

As a key negative impact, privacy and data protection regulators foresee the constant surveillance of users' interactions, where privacy invasion becomes the norm, including for both direct users and bystanders (European Data Protection Supervisor, 2022[64]). Another impact is the risk of ever deeper profiling that enables the targeting of individuals at a granular level. This is coupled with the unprecedented monitoring of real-time sensitive data like physiological responses, emotions and biometric data (Kim, 2022[65]).

VR technologies routinely record personal data regarding people's location, social ties, search queries and product preferences which, combined, can identify people in detail. Such combined data can already be considered sensitive because of inferences that can be drawn about people (e.g. their health, sexual preferences or religious beliefs).

In VR, the collection of data generated by the person's environment or bodily behaviour amplifies the risks associated with creating detailed profiles of people. Such data relate to the functioning of the body, including verbal communication. However, they also relate to emotions (e.g. inferred from facial expressions and vocal inflections).

Data are collected about nonverbal behaviour, such as a user's posture, eye gaze, gestures, facial expressions and interpersonal distance. Some of the most popular VR systems in use track body movements 90 times per second to display a scene appropriately. High-end VR systems record 18 types of movements across the head and hands. Consequently, spending 20 minutes in a VR system generates just under 2 million unique recordings of body language.

Nonverbal behaviour is largely automatic, and can be used to infer medical conditions, emotions and a person's identity (Miller et al., 2020[66]). Although people can regulate images and text posted on social media, few can consistently regulate their body size, as well as subtle micromovements and gestures such as sidelong glances or genuine smiles. In this sense, nonverbal data are uniquely telling about an individual (Ekman and Friesen, 1969[67]). A VR service provider arguably knows users more intimately than they know themselves.

Box 4.1. Tracking data: Actions speak louder than words

As VR has evolved, tracking data have grown exponentially. The computer vision sensors of leading standalone headsets rely on cameras on the outside of the headset, which film the physical room users are in and the people they are with. Many privacy policies (Meta, 2023[68]) associated with these headsets clearly state that headset manufacturers may use the imagery from the cameras, in part because tracking data are an essential part of VR.

Scholars have used VR tracking data for research for more than a decade. Early on, Rizzo and colleagues built a virtual classroom with students, a teacher delivering a lesson and distractions throughout the room (Rizzo et al., 2004[69]). There were more head movements tracked in children with attention-deficit/hyperactivity disorder (ADHD) than those who did not have ADHD.

Using a similar assessment paradigm, Jarrold and colleagues demonstrated that students with high-functioning autism spectrum disorder looked less frequently at other people in a VR experience than other students (Jarrold et al., 2013[70]). Won and colleagues used VR tracking data from students during a lesson to accurately predict test scores (Won, Bailenson and Janssen, 2014[71]). The body language of teachers and students during a lesson in VR accurately determined the subsequent test score of the student.

While aggregating and anonymising data generally help protect privacy, they work less well in the case of tracking data. Miller and colleagues tested the identifiability of users under typical VR viewing circumstances, with no specially designed identifying task (Miller et al., 2020[66]). In other words, they examined the tracking data of people doing standard VR activities such as watching 360-degree videos. They then removed the tracking files and used machine-learning algorithms to identify individuals from the set. Out of 511 participants, the system identified 95% of users correctly when trained on less than five minutes of tracking data per person. More recent work shows that length of time in a VR experience, and the frequency of VR experiences, are key elements to help identify users (Miller et al., 2023[72]).

Research on more than 55 000 users of the "Beat Saber" game showed that VR tracking data allowed individual identification of just over 94% of users (Nair et al., 2023[73]). This work also compared the identification accuracy of various biometric technologies (iris scans, motion data from VR and AR systems, fingerprints, face scans and speech). While iris scans were the most accurate at individual identification, motion data from VR and AR systems were rated in second place.

VR also raises issues around protection of biometric health data and other health-related data that are not managed through traditional patient-care channels such as hospitals and health care providers. New questions are emerging about whether and how entities offering immersive experiences should be prohibited from creating behavioural or emotional profiles of users and/or sharing them with others. Do such entities require limits on targeted advertising to minors or to recipients who may be vulnerable because of their gender, race or ethnic origin, or disability?

Simulator sickness

In the real world, the brain constantly assimilates perceptual cues. These include sights, sounds, vestibular cues (i.e. when people walk or move their head, the inner ear vibrates in particular ways) and somatosensory cues (i.e. the muscles in people's feet feel the floor as they walk forward). Humans have evolved by relying on these precise and unwavering perceptual patterns for hundreds of thousands of years. These cues work together in a specific way, and it is only in the last few decades that immersive technologies have presented the brain with a new perceptual challenge.

Simulator sickness occurs when the brain receives these cues in ways that are unnatural, often described as "sensory rearrangement" or "perceptual cue conflict". This phenomenon has been studied since the 1950s, beginning with early flight simulators (NATO, 2021[74]). Given the recent rise of immersive technologies that can trigger simulator sickness (e.g. VR, IMAX or four-dimensional rides), scientific work proliferated in the area. Simulator sickness is a subset of what most people understand as motion sickness. For example, seasickness happens typically because the brain is getting vestibular cues, but the eyes are not receiving changes in optic flow, especially when one is sitting inside of a boat. In VR, the eyes are often receiving optic flow, but there are no corresponding vestibular cues since viewers are stationary in their seats.

Symptoms of simulator sickness are typically measured by about 20 different physiological and psychological markers, including difficulty focusing, nausea, blurred vision, fullness of head, dizziness, vertigo, general discomfort, eye strain, sweating and burping. About one-third of all VR users experience some symptoms, and about 5% experience severe symptoms (NATO, 2021[74]). Individual differences such as age, gender and medical history can influence whether people will have simulator sickness. These symptoms are fleeting, but they are unpleasant. Removing the VR headset every half hour, good hardware (i.e. low latency and high update rate) and content that avoids the perceptual cue conflict described above can be an effective approach to minimise simulator sickness. At the same time, even in short durations, some people – like those who get nauseous in the passenger seat of a car – simply cannot handle VR at all.

Cognitive development and behaviour of children

The effects of long-term exposure of VR and other immersive technologies on the cognitive development of children is an important concern (Allcoat and von Mühlenen, 2018[75]). Others include whether VR differs from other media in how and whether it changes the perspectives and behaviour of children.

While academic research in this area is limited, the literature generally shows that VR experiences are stronger for young children than for adults (Bailey and Bailenson, 2017[76]). In addition, the effects of VR tend to be magnified compared to traditional media such as television. Young children are, for instance, notoriously susceptible to acquiring false memories when exposed to everything from verbal narratives to mental images to altered photographs. In a 2008 study, scholars tested how well children in preschool and early primary school could differentiate virtual experiences from real ones, both directly after exposure and one week after exposure to a VR experience (Segovia and Bailenson, 2008[77]). For instance, after giving children in elementary school a VR experience of swimming with whales, many formed "false memories". They believed they had physically been to SeaWorld to see an Orca as opposed to just seeing it in VR.

Another study examined the potential effects of VR on children's behavioural and cognitive responses (Bailey et al., 2019[78]). The researchers compared the effects of interaction with a virtual character on either a television screen or in VR. In a programmed simulation, 55 children ranging from four to six years of age could interact with a virtual character – in this case the loveable, furry blue monster Grover from *Sesame Street*. When compared to the non-immersive experience (i.e. watching Grover on a television screen), children in the VR experience showed significantly less inhibitory control. This was measured by their success in playing a game of "Simon Says" with Grover. At the same time, children who experienced VR were more likely to interact with, and give away real stickers to, the character in VR. This study suggests that VR elicits different behavioural responses from children than experiences with similar content on 2D screens, and that children may process VR content differently.

Given that more research on the effects of VR on children is needed, moderation in children's use of VR should prevail. Instead of hours of use, which might apply to other digital devices, usage could be measured in minutes. As far as content goes, a good rule: if parents do not want children to live with the memory of the event in the real world, they should not allow it in VR. Travelling to the moon is fine, but scary experiences will stay with them. Physical safety is another important factor for everyone but especially children. By definition, VR blocks out the real world. Therefore, children should be watched around sharp edges, pets, stairs, etc. Studies show that most children are delighted to play with VR and do not report sickness or injury. However, in these studies, children were meeting Grover from *Sesame Street* and were supervised in VR sessions that lasted only about five minutes.

Distracted driving

The notion that someone would drive an automobile while wearing a VR headset may sound extraordinary, but a number of companies are pushing towards this direction. The motivations range from entertaining passengers, who often read books or use other media for entertainment, to creating an "add-on" to a self-driving car similar to a car radio. Sometimes companies also promote the use of VR headsets for drivers.

In a recent collaboration, the car company BMW and Varjo, a VR headset producer, touted the ability of drivers to use VR headsets in automobiles in the same way that fighter pilots use virtual cockpits. In this way, drivers would see a computer rendering of their surroundings as opposed to light through a glass windshield. Consequently, information about traffic, temperature and speed could be projected onto the driver's FOV (XR Today, 2022[79]).

Faccio and McConnell (2018[80]) studied the impact of the AR video game Pokémon GO, where players navigate the real world by looking at a real-time camera feed that layers virtual objects onto the scene. While this is not technically a VR or AR headset, it is an important precursor to how people may use VR in cars. The authors show that Pokémon GO was downloaded 100 million times in the 148 days after the game was introduced. They then analysed just under 12 000 police reports of accidents in a single city to identify those caused by playing Pokémon GO, and projected the impact nationally. The authors concluded that playing Pokémon GO was associated with just under 150 000 car crashes during the study period, including just over 250 fatalities (Faccio and McConnell, 2018[80]). Since completion of the study, the popularity of this AR location-based game has remained steady. More than a third of all people who regularly play video games in the United States play Pokémon GO (Statistica, 2023[81]).

Overuse and addiction

VR is special because it is immersive, responds to natural body movements and blocks out the physical world to make the illusion that much more compelling. Yet these same qualities also make virtual temptations hard to resist. In the novel *Ready: Player One*, by Ernest Cline, the only refuge from a dystopian world is a massive virtual universe into which people retreat whenever they have a chance. VR is depicted in these and other stories as a place of ultimate escape, with disturbing consequences for the physical world. Based on contemporary media use patterns, retreat into a self-curated fantasy world no longer seems like science fiction (Steinicke and Bruder, 2014[82]). Imagine a world in which social media resembles the best party ever, and online gambling puts the player into the most exclusive room in Monaco. The constant availability of perfection in the virtual world could change how people engage with the real world.

There is a lack of research on the health consequences of prolonged VR use. In one study, a scholar spent 24 hours in a VR headset under carefully monitored conditions (Steinicke and Bruder, 2014[82]). In their paper, the authors indicate that, "Several times during the experiment the participant was confused about being in the virtual environment or in the real world, and mixed certain artefacts and events between both worlds." Of all the pressing needs within the research community, studying how prolonged VR use over months affects people physiologically and psychologically is paramount (Han et al., 2023[83]).

Experimental research has sought to quantify the effects of exchanging a desktop-based work environment with a VR-based environment (Biener et al., 2022[84]). In this study, participants worked either in a traditional office environment or in a VR environment for eight hours per day for five days straight. The results showed that people in the VR environment had lower ratings of usability in addition to non-trivial amounts of simulator sickness compared to the traditional office environment. Moreover, two participants in the study had to quit the experiment on the first day because of physical discomfort, including nausea and migraine headaches. However, those who continued in the VR condition showed a slight increase in their usability ratings over the week.

Governing VR

Fast-paced technological developments often race ahead of regulatory frameworks. Digital transformation is multi-faceted and complex, and a comprehensive and co-ordinated digital policy framework, such as the Going Digital Integrated Policy Framework (OECD, 2020[85]), is essential. Such a framework helps ensure that digital technologies are on balance a positive force for people and society. As VR becomes more widespread, policy makers need to consider if VR has unique characteristics. Does it require specific policy action or are existing rules governing digital transformation (e.g. privacy, digital security or competition) sufficient?

VR and other immersive technologies are at a tipping point. They are developed enough to clarify opportunities and risks, but policy can still shape their future development. Many countries increasingly recognise the need for a unified policy for VR and other immersive technologies, including the metaverse. G7 leaders have underscored that governance of digital transformation should reflect shared democratic values (G7, 2023[86]). While a technology-neutral approach to digital policy is important, this section considers how policy frameworks may need to be adapted – or complemented – to support a positive immersive future.

Policy action on VR and immersive technologies is focused on promoting the domestic VR industry

Policy initiatives on VR and immersive technologies more broadly are limited. Data from the *DEO 2024* Questionnaire suggest that any policy action is primarily focused on supporting development of immersive technologies domestically. For example, the “Digital Luxembourg” strategy includes a VR financing initiative.[4] Spain provides grants to promote projects using immersive technologies,[5] Germany funds immersive technologies programmes[6] and Korea has a “Metaverse Industry Promotion Strategy”.[7] Meanwhile, Singapore’s PIXEL Innovation Hub[8] includes a focus on VR and immersive technologies, and Finland promotes these technologies with its “National Metaverse Strategy”.[9] The US CHIPS and Science Act, signed into law in 2022, directs the federal government to carry out a programme of measurement research in communications technologies, including VR and other “immersive technologies” (US Government, 2022[87]).

Belgium stands out as a country that has taken policy action in a particular sector – the education sector. Its “Action Plan Extended Reality” aims to integrate XR into technical and vocational secondary education. To that end, it promotes training on the use of XR and further development of XR in education. The plan involves co-operation with Belgian universities of applied science, which will help analyse the nature and effectiveness of the plan.[10] Pilot projects in certain Spanish provinces under “InnoVET XR” will encourage creation of new software and apps for technical and vocational education.[11] In the United States, a similar trend is emerging. In December 2022, US House Representative Lisa Blunt introduced the draft “Immersive Technology for the American Workforce Act”. The proposed legislation aimed to fund use of immersive technology to train workers at community colleges and other educational centres, but it did not pass Congress (Davalos, 2023[88]).

Data from the *DEO 2024* Questionnaire also indicate that some countries are adopting VR and other immersive technologies to enhance public services. Austria is testing an application that uses AR to streamline customs inspections by overlaying digital information over a vehicle. Türkiye is leveraging immersive technologies within the cultural sector to promote interactive virtual tours of cultural sites and boost tourism. The United States has taken steps towards integrating AR to help screen passengers at airports, enhancing security while ensuring a smoother screening (Deloitte, 2021[89]). Furthermore, the regional government of Korea introduced the “Metaverse Seoul”. The platform allows citizens to access various public services, such as filing complaints and talking to officials through avatars.[12] Finally, Luxembourg launched a “Luxembourg Megaverse” and the European Commission funds the development of “Citiverses”, immersive environments that provide engaging experiences of policy processes (Hupont Torres et al., 2023[90]).

Spain actively promotes the integration of underprivileged groups, particularly women, in financing initiatives involving immersive technologies.[13] This is important considering studies that indicate women are more likely than men to experience discomfort while wearing VR (Stanney et al., 2003[92]; Munafo, Diedrick and Stoffregen, 2017[91]) and are less inclined to purchase VR headsets (Kommando Tech, 2022[93]). Australia also recognises the importance of designing immersive hardware with inclusive access in mind (Australian eSafety Commissioner, 2020[94]). Other policy makers are also indicating an interest in specific legislation on immersive technologies. For example, the European Commission has announced it will propose legislation “on virtual worlds, including the metaverse” (European Commission, 2022[95]).

Towards the development of "rights" or "principles" for VR and immersive technologies

Given the limitations of regulatory approaches to address issues arising in VR experiences (Dick, 2021[96]), scholars and policy makers have turned their attention to developing "rights" or "principles" for VR and immersive environments. In a July 2023 report, Japan advocates for fostering international common recognition of the metaverse and encourages the trustworthy use of metaverse technologies based on democratic values (MIC, 2022[3]). Researchers also argue that safeguarding equitable access and authenticity is crucial for VR and immersive experiences.

If VR and immersive environments will become the place where people will work, learn and interact, they should be accessible to all. The adaptability of VR hardware to diverse people and body types should be prioritised. As noted, many VR displays in the market do not provide a comfortable fit for women, leading to discomfort and nausea (Stanney, Fidopiastis and Foster, 2020[98]). This may partially explain why most intended VR headset purchasers are men (Kommando Tech, 2022[93]). Failing to make VR more accessible may widen digital divides. As a result, it is important to ensure equal and effective access to immersive environments, including women, people with disabilities and cultural minorities (Dick, 2021[100]; Heller, 2022[99]).

Some also argue that users should have "rights" in immersive environments that are protected (i.e. the right to "authentic" experiences). Most adults can recognise advertisements in the physical and digital realms as paid messages. However, in VR and other immersive environments, advertisers can undermine context by seamlessly blurring the lines between authentic experiences and those engineered for marketing (Rosenberg, 2022[101]). The "self-endorsement" possible in VR represents a new and powerful advertising strategy (Ahn and Bailenson, 2011[102]). As one approach, engineered marketing artefacts and people could be required to be visually and audibly different in immersive environments. This would enable users to perceive promotionally altered experiences as different from authentic ones.

Korea is at the forefront of developing principles for VR, announcing a set of non-binding ethical guidelines for the use and development of metaverse services in 2022.[14] The "Metaverse Ethical Principles" aim to provide guidance for developers and consumers based on three core values: self-identity, safe experiences and sustainable prosperity. These values advocate for individuals to have the autonomy to authentically embody their chosen identities (self-identity) and to enjoy immersive environments in a safe manner (safe experiences). Furthermore, the principles state every individual should have the right to benefit from immersive environments without being intentionally excluded, with these rights extended to future generations (sustainable prosperity).

To implement these core values, Korea proposes eight practical principles: authenticity, autonomy, reciprocity, respect for privacy, fairness, protection of personal information, inclusiveness and responsibility for the future. The authenticity principle, for example, encourages users to sincerely define their virtual identities and act truthfully towards them, recognising the impact of the virtual self on the real self. Similarly, developers are urged to enable users to present themselves as closely as possible to their real selves.

Data from VR applications bring new challenges to existing privacy frameworks

VR and immersive environments magnify privacy issues and extend them in new ways. Policy makers and relevant stakeholders, including privacy enforcement authorities, thus look to clarify the application of relevant privacy regulations to these new realities. To that end, they want to identify suitable mitigation measures, including technological solutions integrated into VR applications.

How do data sources, contexts and activities help identify and support the building of algorithms, privacy enhancing technologies (PETs) (OECD, 2023[103]) and policies that can protect privacy? By understanding what influences the accuracy of de-anonymisation techniques, researchers can develop more effective ways to limit risks to end-users. This can further enable development of privacy-by-design VR products, including PETs such as federated analytics and trusted execution environments (TEE)[15] (OECD, 2023[103]). TEE ensure data remain shielded from third-party applications by processing them within a secure environment on the device.

No policies target the unique data collected from VR applications and how they are used or shared. However, a growing number of privacy legal frameworks such as the EU General Data Protection Regulation (European Union, 2016[104]) already address biometric data and thereby apply to VR directly. Processing of biometric data in VR is commonly subject to reinforced obligations (e.g. user explicit consent or legal authorisation) depending on their purpose.

How can such definitions remain relevant over time? Certain provisions may prove to be too specific as technological developments overtake the law. For example, the Illinois Biometric Information Privacy Act in the United States applies to information based on "scans" of hand or face geometry, retinas or irises, and voiceprints. This definition of "biometric identifiers" does not explicitly cover the collection of behavioural characteristics or eye tracking, making its application to VR data uncertain (Berrick and Spivack, 17 November 2022[105]).

VR further creates a new dynamic for legislation that revolves primarily around consent. For example, a user cannot have a VR experience without consenting to the terms and conditions of the VR system. This, in turn, requires processing such data to ensure a realistic immersive experience. Given there is no way to "opt out" or "go incognito" in VR, new approaches will be needed to adequately protect the privacy of VR users.

Moreover, users may not fully understand how their highly personal data may be monetised. They may also not know about subliminal techniques or automated decisions that may cause harm (Barros Vale and Berrick, 2023[106]). This leads to questions about the relevance of consent-centric legislation that places an unfair burden of choice on individuals.

As another challenge, consent requirements commonly add to additional baseline requirements that include transparency, fairness, purpose limitation, data minimisation or storage limitation. Some of these principles may significantly constrain development of VR and other immersive technologies. In particular, the "data minimisation" principle (i.e. only strictly necessary data should be collected for the purpose to be achieved) embeds consent into the design of VR and other immersive technologies.

VR developers must also pass the test of "purpose compatibility". Biometric and tracking data, for example, can be used effectively for authentication (e.g. facial recognition data can make accessing password-protected websites easier). This can help protect young children by automatically detecting if they are using their parents' VR headsets. It can also improve medical care and rehabilitation (see above). At the same time, biometric and tracking data can identify people in a way that is not transparent (e.g. creation of a user profile for targeted advertisements) (Miller et al., 2020[66]).

User behaviour captured by tracking data has also been associated with medical problems (e.g. dementia or ADHD) (Cherniack, 2011[107]), raising questions about discrimination (e.g. by prospective employers and insurance companies). As VR moves from tracking via headsets to full body tracking, motion data will become even more predictive of a user's identity. Such risks of "function creep" raise new questions about whether and how entities offering immersive experiences should be prohibited from creating behavioural or emotional profiles of users and/or sharing them with others.

Another privacy issue emerging with VR is how to treat the "personal" data from avatars – a new type of actor in VR. In some VR applications, a user can create multiple avatars or personalities (so-called alts) with different identities. To whom do such "personal data" belong? How will identity theft of avatars be addressed (Madiega, Car and Niestadt, 2022[108])? At first blush, avatars might appear to engage in VR experiences anonymously. However, once a VR system correctly maps a user's name with tracking data, it becomes extremely difficult to re-anonymise a user (Bailenson, 2018[109]).

Defining who is a data controller and a data processor may also be difficult in VR and immersive environments (Madiega, Car and Niestadt, 2022[108]). A governance challenge shared with the IoT thus consists in clarifying the chain of responsibilities in VR among stakeholders ranging from device manufacturers and VR service providers to app developers, owners of the underlying algorithms and network providers. When will data be produced, collected and shared based on choices by such stakeholders and at what moments in the operation of the VR system? It can be challenging to demonstrate accountability, and the legal and ethical responsibilities in the case of errors, hackings or accidents may be far from clear. This chain of responsibilities can also be blurred by the applicability of other statutes, including consumer protection, non-discrimination, privacy, data protection and effective judicial remedies.

VR mental and physical safety must be carefully considered

While this chapter documents the positive effects of VR on mental health, negative behaviours in digital environments are associated with mental health risks (e.g. cyberbullying, harassment, overuse and addiction). Such risks may become even more dangerous in immersive environments (Danaher, 2018[43]) (see also the Spotlight "Mental health in digital environments"). Phenomena such as presence, emotion and immersion mean that emotionally charged content, including violent threats, can make users feel effects more deeply since such content is less abstract and more visceral. VR applications should include safety by design features that allow users to protect themselves from bad actors. For example, Meta's Personal Boundary prevents avatars in Horizon Worlds and Horizon Venues from getting within about four feet of each other (Tabahriti, 2022[110]).

In addition to possible mental health risks, careful consideration of physical harms from VR and immersive environments is also important. Policy makers may want to prioritise use of VR in cars and other moving vehicles. The safety challenges of moving vehicles have already become clear with the Pokémon GO game (see above), as well as the significant number of deaths due to smartphone use in moving vehicles. In 2021, distracted driving resulted in 3 522 deaths in the United States, and many individual states in the country have laws against texting and using a mobile phone while driving (US DOT, 2022[111]). With respect to drivers wearing VR or AR headsets that block out or otherwise impede drivers' ability to see the "real world", it is unclear whether advantages outweigh the risks.

Safety by design principles are likewise important in VR and other immersive experiences, including parental controls, age verification and content moderation (OECD, forthcoming[112]). Some immersive applications incorporate human and automated image review, automated chat filtering and rules, special chat restrictions, community reporting, and user and parental controls.[16]

More research on the effects of VR on children is needed, but in the meantime moderation should prevail. Frightening experiences in VR could scar children. Instead of hours of use, which might apply to other digital devices, usage for children should be measured in minutes. Physical safety is another factor especially important for children. As VR blocks out the real world, children should be supervised when using VR.

VR businesses have been self-regulating

In the vacuum of comprehensive policy by governments, VR businesses have developed their own guidelines. Valve, one of the largest marketplaces for VR games and experiences, has a minimalist approach to self-contained content moderation. It allows anyone to upload content to its Steam Store except for things that are identified as "illegal" or "trolling" (Steam, 2018[113]). As of April 2023, more than 4 500 VR applications were available for download on the Steam Store.

Meta is an especially salient example given its large market share – 80% in 2022 – of VR headsets. Its code of conduct (Meta, 2022[114]) condemns sexualising minors, cyberbullying, harassing, stalking, hateful behaviour, advocating violence, human trafficking, supporting terrorism, hate-based organisations and/or criminal groups, promoting or co-ordinating acts of suicide, and sharing intimate images of others without consent. Primary responsibility for enforcing these policies rests with VR creators and app developers.

Self-regulation matters depending on whether users are in a self-contained VR experience or a social VR experience. Meta's code of conduct applies to self-contained VR; content regulation in its social VR app Horizon Worlds is more robust. Meta enforces its code of conduct by temporarily or permanently suspending accounts primarily on the basis of human content moderation (Meta, 2022[114]). In some cases, Community Guides, who are humans paid to don headsets, maintain order and remove malicious users. In other cases, community members report unruly behaviour directly to the platform or remove players by vote.

VRChat – a company that began dedicated to VR (as opposed to 2D screens) – is another example of social VR moderation. However, it did not attempt to retrofit social media legacy standards. From its inception, VRChat focused on allowing people in a scene to eject bad actors from the virtual world by community vote. However, this is a cumbersome process that requires both identification of malicious intent and consensus from multiple parties in the environment. In practice, it is difficult to eject a bad actor via community vote (Freeman et al., 2022[115]). Exacerbating this situation, current social VR platforms are rife with underage children who circumvent the minimum age limit of platforms (Nix, 2023[116]).

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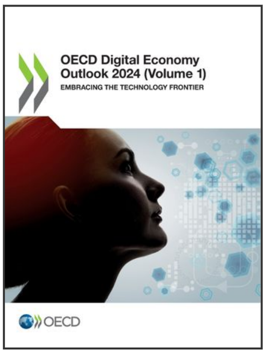
Notes

1. The Steam Store is a popular VR app seller.
2. Haptic devices simulate the experience of touch through vibrations or motion.
3. While some VR video games have achieved broad popularity, VR video games considerably lag 2D video games in terms of revenue. Overall total consumer spending on video games in the United States amounted to USD 56.6 billion in 2022 (ESA, 2023[121]). Conversely, Beat Saber, the best-selling VR video game in 2022, earned USD 255 million as of October 2022 (Bezmalinovic, 2023[122]).
4. For more information, see: *https://digital-skills-jobs.europa.eu/en/actions/national-initiatives/national-strategies/luxembourg-digital-luxembourg-initiative#:~:text=Digital%20Luxembourg%20is%20an%20ongoing,within%20the%20national%20tech%20sphere*.
5. For more information, see: *https://spainaudiovisualhub.mineco.gob.es/en/actualidad/publicada-convocatoria-metaverso-web3*, *www.red.es/es/actualidad/noticias/la-incubadora-de-empresas-del-sector-tecnologico-sobre-realidad-virtual-y* and *www.boe.es/boe/dias/2021/12/22/pdfs/BOE-A-2021-21192.pdf*.
6. For more information, see: *https://bmdv.bund.de/SharedDocs/EN/Articles/DG/mFund-overview.html*.
7. For more information, see: *www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=238&pageIndex=2&bbsSeqNo=94&nttSeqNo=3181303&searchOpt=ALL&searchTxt=%EB%A9%94%ED%83%80%EB%B2%84%EC%8A%A4*.
8. For more information, see: *https://pixel.imda.gov.sg*.
9. For more information, see: *www.businessfinland.fi/en/whats-new/blogs/2022/what-is-the-metaverse--humanitys-digital-future*.
10. For more information, see: *www.vlaanderen.be/kenniscentrum-digisprong/nieuws/ga-jij-binnenkort-aan-de-slag-met-xr-in-je-school*.
11. For more information, see: *https://onderwijs.vlaanderen.be/nl/onderwijspersoneel/van-basis-tot-volwassenenonderwijs/lespraktijk/extended-reality-in-de-klas*.
12. For more information, see: *www.seoul.go.kr/news/news_report.do#view/378498*.
13. For more information, see: *https://spainaudiovisualhub.mineco.gob.es/en/actualidad/publicada-convocatoria-metaverso-web3*.
14. The set of principles is the result of a research group to identify public awareness, experiences and concerns about the metaverse through a survey of 2 626 people aged 20-69 nationwide. Among the issues raised by the survey are unethical and anti-social behaviour, the digital divide, invasion of privacy and personal information, and potential restrictions on creative activities. More information about Korea's Metaverse Ethical Principles is available in *www.msit.go.kr/bbs/view.do?sCode=user&mId=113&mPid=238&pageIndex=1&bbsSeqNo=94&nttSeqNo=3182405&searchOpt=ALL&searchTxt=%EB%A9%94%ED%83%80%EB%B2%84%EC%8A%A4*.
15. An example is Apple's Vision Pro, where Apple affirms that federated Optic ID data remains encrypted, never leaving the user's device while being solely accessible to the device's TEE (the Secure Enclave processor). Furthermore, the system-level processing of data from cameras and sensors would eliminate the need for individual apps to access the users' surroundings, while still enabling spatial experiences.
16. An example is Roblox platform's safety features. For more information, see: *https://en.help.roblox.com/hc/en-us/articles/203313120-Safety-Features-Chat-Privacy-Filtering*.



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