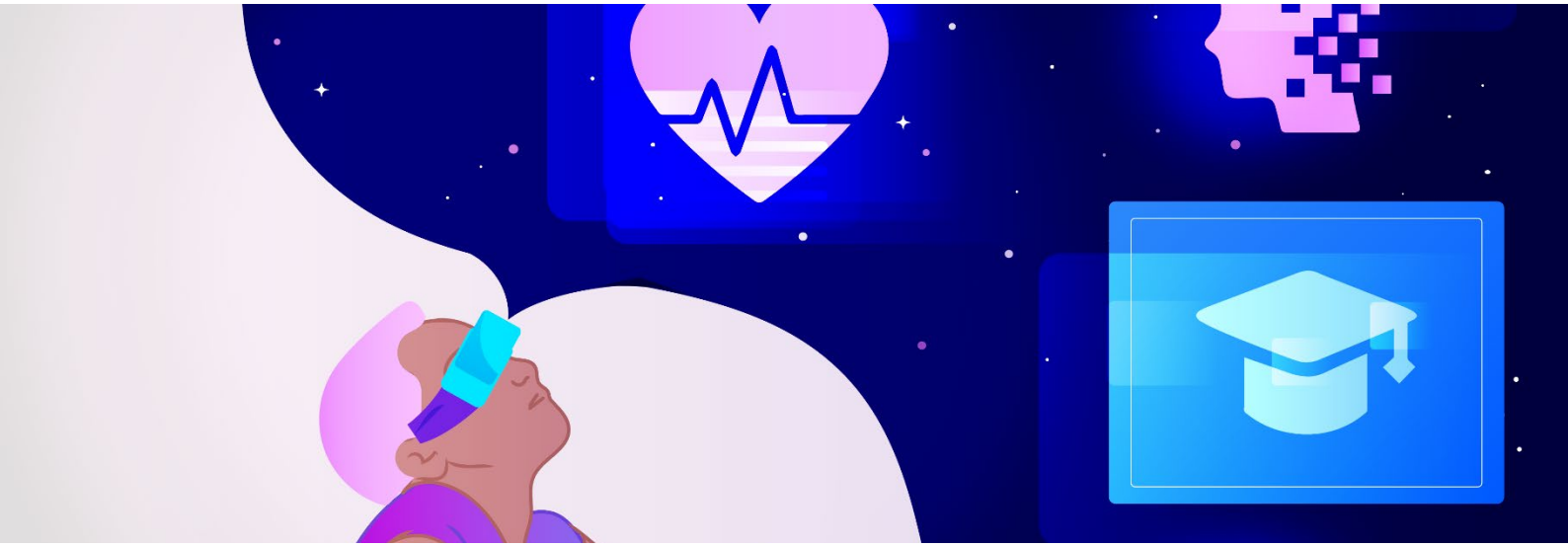
Rathenau Instituut

Immersive technologies



Rathenau Scan

Introduction
In this scan, the Rathenau Instituut describes a technology that is still in development in order to make timely adjustments from a public values perspective. It focuses on immersive technologies and shows in which societal sectors these technologies are already being applied (experimentally), and analyses the risks through the lens of public values. The scan also includes an analysis of relevant policies and an overview of options for action to mitigate the risks identified.

The scan is the result of a short-term study based on the Rathenau Instituut's knowledge base, supplemented by a literature review, working sessions, and interviews with researchers and experts. It aims to inform policymakers and politicians about immersive technologies. The scan was developed at the request of the Ministry of the Interior and Kingdom Relations.

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Summary

Immersion literally means: submersion. Under immersive technologies we include a collection of technologies that immerse users in fully virtual worlds or in a hybrid mix between physical and digital worlds. The two main technologies that make this possible are augmented reality (AR) and virtual reality (VR). In AR, a user sees a virtual layer over the physical world; in VR, the user enters a fully virtual environment. Immersive technologies are referred to as extended reality (XR) because the existing physical environment is extended by merging with or giving way to a virtual environment.

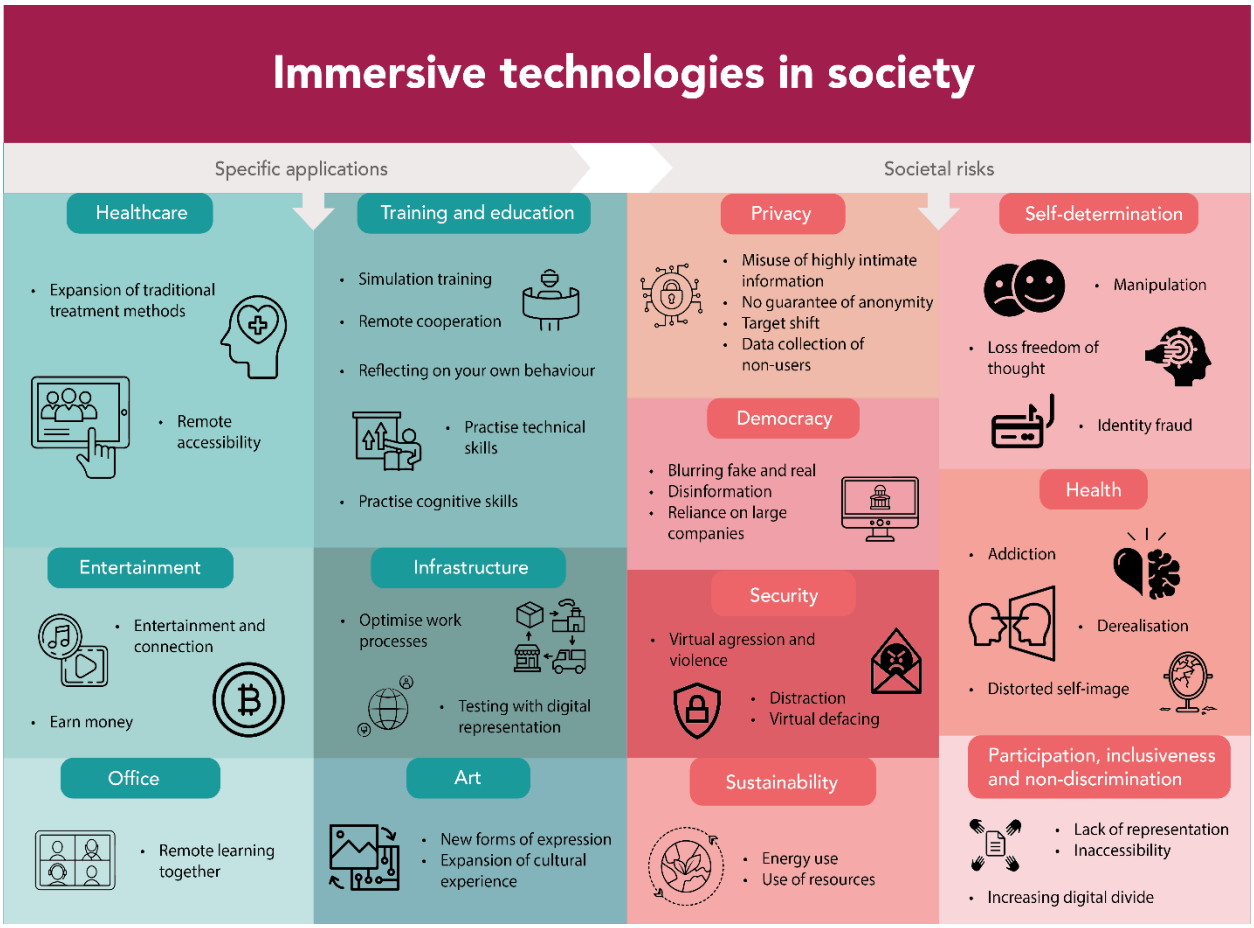
With immersive technologies, it becomes possible to experience a new kind of ‘realness’ that can also be considered reality, even if the experience is fully or partially virtual. The technology is literally more in touch with the skin and the senses than smartphones or computers.

The impact of immersive technologies on society is strongly related to a large-scale consumer breakthrough. We do not know if or when that breakthrough will come.

We do already see actual uses of immersive technologies in certain sectors, and promises and investments aimed at developing further implementation. The sectors in which we see the most experiments and applications are healthcare, training and education, entertainment, infrastructure, industry, office and art (see Figure 1).

In this scan, the Rathenau Instituut discusses the risks involved in the further development and possibly widespread adoption of immersive technologies. When coupled with the large-scale collection of physical and behavioural data by companies, immersive technologies can have a major impact on privacy, self-determination, democracy, and security. Far-reaching digitisation, which includes immersive technologies, also carries more generic risks that have an impact on, participation, inclusiveness and non-discrimination, and possibly sustainability (see Figure 1).

Figure 1 Immersive technologies in society



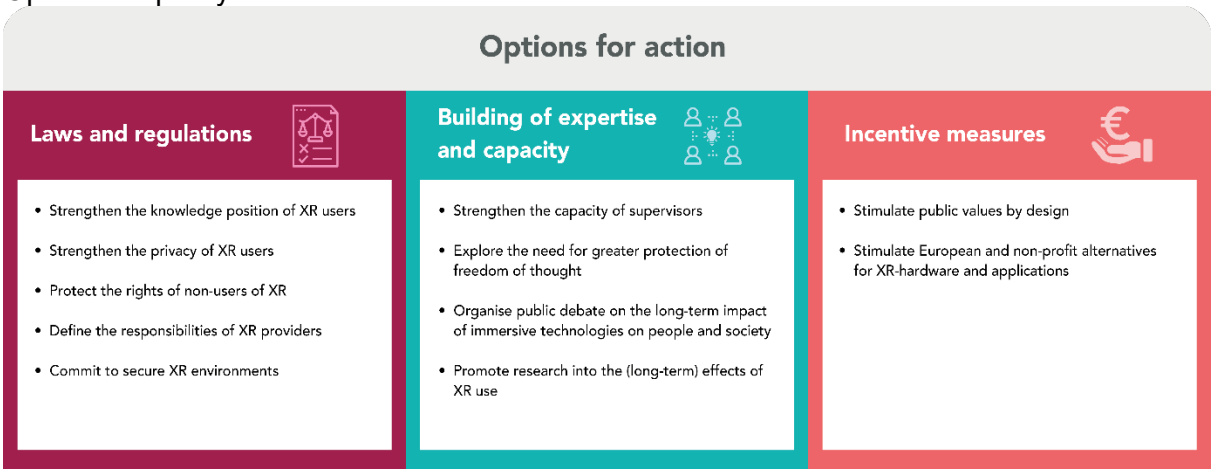
The policies surrounding immersive technologies are in a state of flux. We will discuss a selection of European laws aimed at managing risks associated with immersive technologies. These include the General Data Protection Regulation, the Artificial Intelligence Regulation, and the Digital Services Act. Combined, these laws can limit the opportunities for influence and manipulation based on physical and behavioural data collected in XR. However, there are also several policy gaps and ambiguities. For example, while all kinds of physical and behavioural data may be collected by XR providers if users consent, very sensitive information could potentially be derived from it. This does not cover the risk of function creep: information collected in one location can be used in another, against the interests of the users. There is also uncertainty about the protection of neurodata.

There are also incentives in place to create opportunities for Dutch and European businesses in the XR market. We discuss the investment from the growth fund for the Creative Industries Immersive Impact Coalition (CIIIC), the *European Initiative on Virtual Worlds*, and the Digital Markets Act. With investments in immersive technologies and

wider adoption of these technologies in society, the associated risks also become more plausible.

We have formulated numerous options for action for politicians and policymakers to limit the risks of immersive technologies. However, these technologies carry various inherent risks that will continue to exist once widely adopted, caused by the current and future collection of intimate data. Once this data is available, it can be used for other purposes against the public interest.

Options for policy action



Politicians will have to decide on some fundamental issues: where can immersive technologies help perpetuate and achieve public values (e.g. in therapeutic applications that have demonstrable health benefits), and where should these technologies not be applied at all because of their excessive damage to public values (e.g. large-scale adoption of data-collecting XR devices in schools)? And are there certain types of data, such as neurodata and pupillary reflexes, that should not be collected at all because they reveal too much personal information and abuse of this is a realistic scenario? And to what extent is further hyper-personalisation desirable in public spaces, or should certain spheres remain XR-free?

Because immersive technologies have not yet been implemented on a wide scale, policymakers and politicians have the opportunity to steer their development and adaptation. Consequently, the challenge for policymakers and politicians is to determine how the government might adjust the innovation dynamics that surround immersive technologies, based on its duty to protect citizens' rights and public values.

1 Technology and the market

1.1 Introduction

In this first chapter, we describe what we mean by immersive technologies and their specific characteristics. We also look into their relationship with other technologies, such as artificial intelligence and brain-computer interfaces. Examining such relationships may help to identify the opportunities and risks involved. We will also discuss the far-reaching data collection involved in immersive technologies and expectations about the development of the market.

1.2 The technology

Immersion has the same meaning as submersion. Under immersive technologies we include a collection of technologies that immerse users in fully virtual worlds, or are a hybrid mix between physical and digital worlds. Virtual reality (VR) and augmented reality (AR) are the two main technologies that make this possible. For example, in the St. Bavo Cathedral in Ghent, AR is used as an interactive tool to bring the famous painting 'The Mystic Lamb' to life.[1] In secondary education, students can use accessible development applications such as NeosVR or CoSpaces to build virtual learning environments.[2]

The promise of immersive technologies is to offer new experiences that engage multiple senses and feel lifelike. Through intuitive controls, users experience the feeling of being present in a fully virtual world, or the presence of virtual elements in the physical world. This blurs the distinction between the 'real' physical world and the 'fake' virtual world. Therefore, according to many scientists, the word 'virtual' in virtual reality does not mean that a world is not real, but merely that it is not physical.[3] Immersive experiences extend well beyond just entering virtual worlds via a computer or smartphone. Scientific experiments show that users experience a stronger sense of immersion and more emotional responses when playing a computer game through a VR headset, rather than through a computer with a mouse and keyboard.[4]

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[1] St. Bavo Cathedral in Gent, 'Admire the lamb of God'.
[2] Rathenau Instituut, 'Welke rol krijgt virtual reality in het onderwijs?', March 2023; Rathenau Instituut, 'Eerste aflevering podcast over immersieve technologie', March 2023.
[3] Shields, *The virtual*, 2003.
[4] Lum e.a., 'How Immersion, Presence, Emotion, & Workload Differ in Virtual Reality and Traditional Game Mediums', september 2018; Pallavicini en Pepe, 'Comparing Player Experience in Video Games Played in Virtual Reality or on Desktop Displays', 17 October 2019.

The Rathenau Instituut previously published three comprehensive reports on immersive technologies. In 2019, we described in our report *Responsible VR* how VR as an intimate technology is getting increasingly in touch with our senses.[5] Concerning AR, in our report *Fake for real* (2020), we signalled that the virtual domain is increasingly seeping into the physical domain.[6] And in *Look who's talking* (2020) we described how people are using speech technology, among other things, to interact with computers in an increasingly intuitive way.[7] The virtual and physical worlds are becoming more and more intertwined. Not only because of developments in VR and AR technology, but also because of haptic technology (which responds to the tactile senses, for example through movement or vibration), artificial intelligence (AI), speech technology and biotechnologies.

Box 1 What is the difference between VR and AR?

Virtual reality (VR) is a three-dimensional, computer-generated environment in which users can immerse themselves. Using VR glasses and associated accessories, users can move freely through this environment and interact with each other and objects around them. VR presents a new virtual world via powerful computer simulations and through VR headsets and controllers. Here, the goal is to create a sense of presence in the virtual environment.[8]

Augmented reality (AR) is a new type of environment that is substantially different from the purely physical or purely virtual environment. The distinctive feature of AR is that the virtual environment blends into the physical environment, creating a hybrid physical-virtual environment. Users can experience this kind of environment using various AR systems, such as a phone camera or a headset. The consequence of AR is that it alters our perception of our surroundings.[9]

Immersive technologies are referred to as extended reality (XR) because the existing physical environment is extended by merging with or giving way to a virtual environment. XR forms a continuum with the physical environment at one end of the spectrum and the virtual environment at the other end.[10] Everything in between is a

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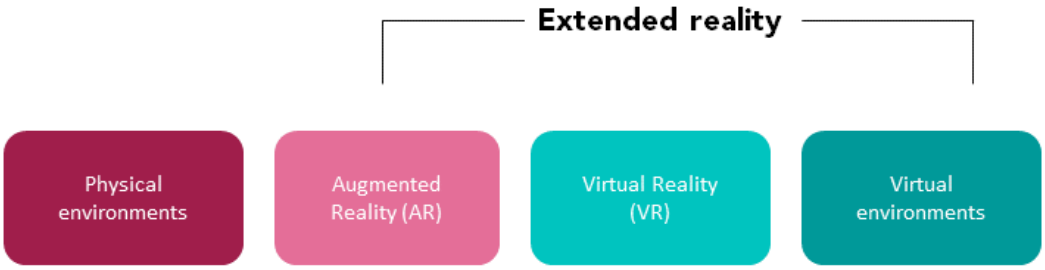
[5] Rathenau Instituut, 'Responsible VR. Protect consumers in virtual reality', 2019.
[6] Rathenau Instituut, 'Fake for real. Ethical and societal implications of augmented reality', 2020.
[7] Rathenau Instituut, 'Look who's talking.Tools for the responsible use of speech technology', 2020.
[8] Rathenau Instituut, 'Responsible VR. Protect consumers in virtual reality', 2019.
[9] Rathenau Instituut, 'Fake for real. Ethical and societal implications of augmented reality', 2020.
[10] In 1994, Professor of Industrial Engineering Paul Milgram and Professor of Communication Fumio Kishino introduced the *reality-virtuality continuum* in: Milgram en Kishino, 'A Taxonomy of Mixed Reality Visual Displays', 1994.

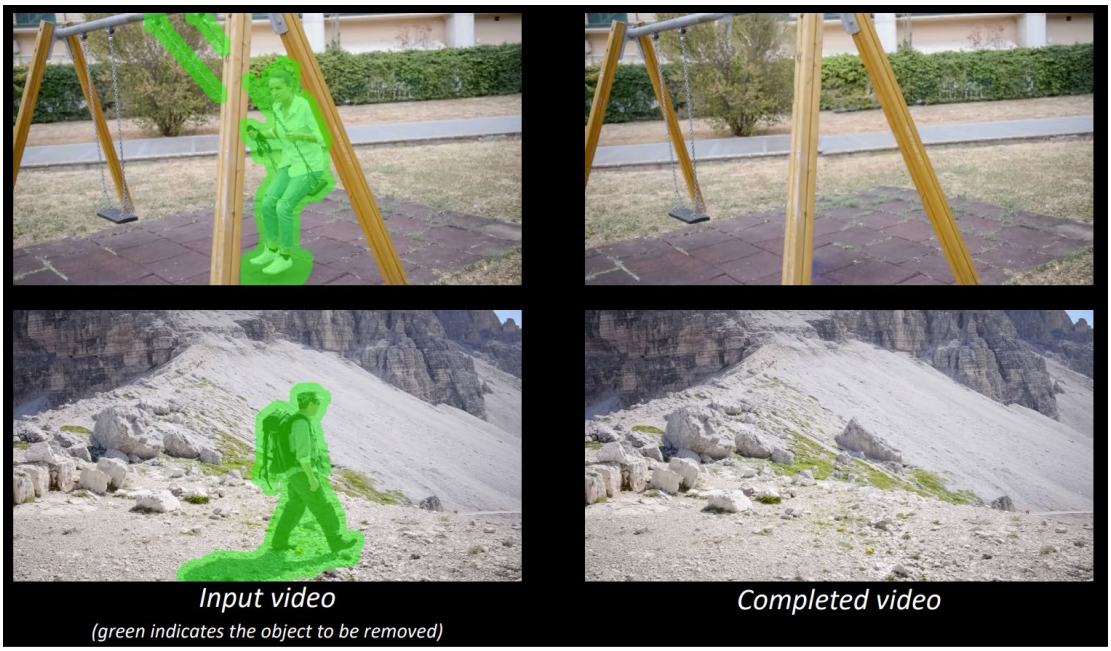
blend of the physical and virtual worlds. *Virtual reality* and *augmented reality* fall within this spectrum.

Figure 2 Extended Reality Continuum



Another form of XR is *diminished reality*, where technology is used to hide certain elements of the physical world from view. A well-known example of this is *inpaint* or *generative fill*, techniques available in photo editing software.[11] Here, the software reconstructs the image after removing certain objects, illustrated in figure 1. A person on a swing and a hiker have been removed from a video. A future application of this could be the modification of a live video. For example in interior design, by removing furniture in a room during a live stream and replacing it with other furniture.

Image 1 Example of diminished reality from research by Virginia Tech and Facebook.[12]



[11] Adobe, 'Remove Objects in Photoshop'.
[12] Gao e.a., 'Flow-edge guided video completion', 3 September 2020.

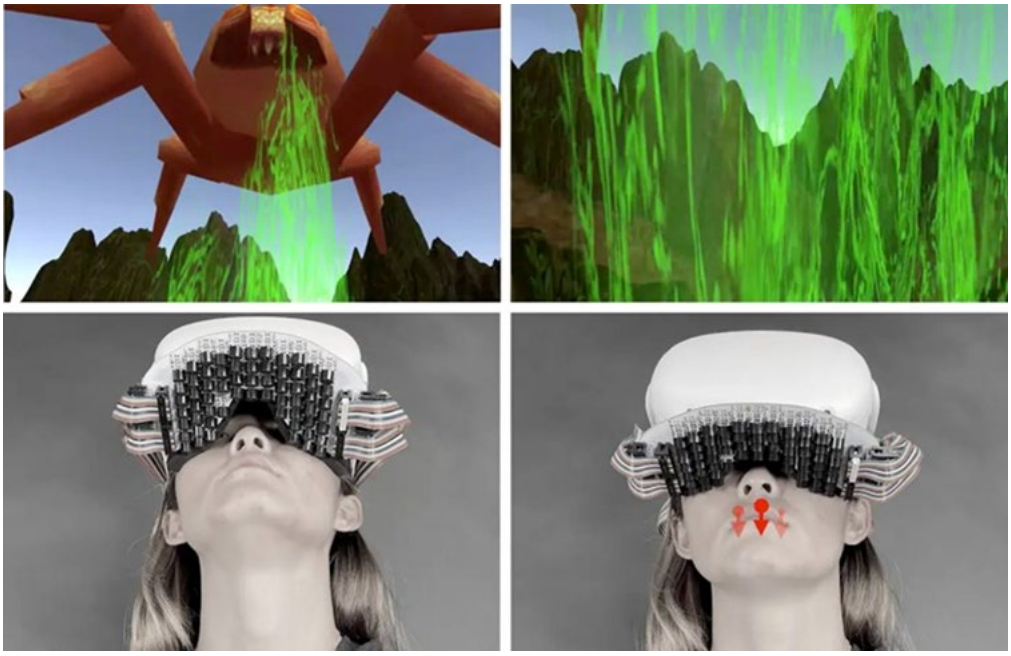
Newly launched XR devices increasingly consist of a combination of AR and VR (mixed reality) technologies. Users can fully immerse themselves in VR, as well as add elements to physical reality through AR. These include, for example, the Meta Quest Pro or the Apple Vision Pro, which were announced in June 2023.

In this report, we use the term XR when discussing the combination of the virtual adaptations to the physical environment mentioned above. We use the terms VR and AR when referring to one of these forms specifically.

1.3 Relationship to other technologies

Technology companies are focusing on new ways for people to interact more intuitively with technology. They are doing so by employing a variety of technologies. In 2020, the Rathenau Instituut reported on the growing normalisation of voice control for machines.[13] By using artificial intelligence, XR devices are also improving at recognising objects and, for example, generating virtual representations of people.[14] Haptic technology, which is still under development, also allows users to feel pressure, heat and cold in XR. Figure 2 shows a prototype for glasses where haptic technology allows users to experience a simulated feeling of rain, spider webs and swarming insects on their mouths.

Image 2 Prototype with haptic technology[15]



[13] Rathenau Instituut, 'Look who's talking.Tools for the responsible use of speech technology', 2020.
[14] European Parliament, Directorate General for Parliamentary Research Services, *Tackling Deepfakes in European Policy*, 2021.
[15] Shen, Shultz, en Harrison, 'Mouth Haptics in VR Using a Headset Ultrasound Phased Array', 29 April 2022.

A key technology that is being focused on by certain XR developers is brain computer interfacing (BCI). BCIs were originally developed as biomedical devices to measure brain activity and translate it into signals that can be used to control other technological systems.[16] BCIs can collect data about brain activity as well as the nervous system. This data is called: *neurodata*.[17] With the collection, analysis and processing of neurodata, an XR experience can be further personalised or made more immersive. Reality Labs, the XR research division of technology company Meta, is working on a prototype for a bracelet that can convert the electrical signals travelling from the brain to the arm muscles into finger movements within an XR environment.[18] The developer expects this to eliminate the need for a keyboard or mouse by allowing users to type in the air. XR developer Varjo and neurotechnology company OpenBCI are engaged in integrating XR and neurotechnology: they are developing XR glasses called Galea that analyse neurodata and muscle activity. According to the developers, this could gauge emotions, stress levels and arousal. As an example, they mention changing the colour of a virtual environment to alert users of their state of mind, such as with stress or fatigue.[19]

1.4 Interaction between user and technology

The interaction between sensors on XR devices, software and users can be described as a cybernetic feedback loop.[20] This feedback model centres on three steps: data collection, data analysis, and application. In Figure 3, we explain the cybernetic feedback loop using an example. Sensors on an XR device track a user's eye movement (collection). With this data, the software connected to the glasses knows what a person is looking at (analysis), in order to adjust the 3D world based on this information (application).

[16] Rathenau Instituut, 'From Bio to NBIC. From Medical Practice to Daily Life', 18, 2014.
[17] Agencia Española Protección Datos, 'Neurodata', 18 januari 2023.
[18] Tech at Meta, 'Inside Facebook Reality Labs', 18 maart 2021.
[19] Artuso, 'Neurotechnology and VR Combined – Meet Galea', 15 november 2022.
[20] Rathenau Instituut, 'Urgent upgrade. Protect public values in our digitized society', 2017.

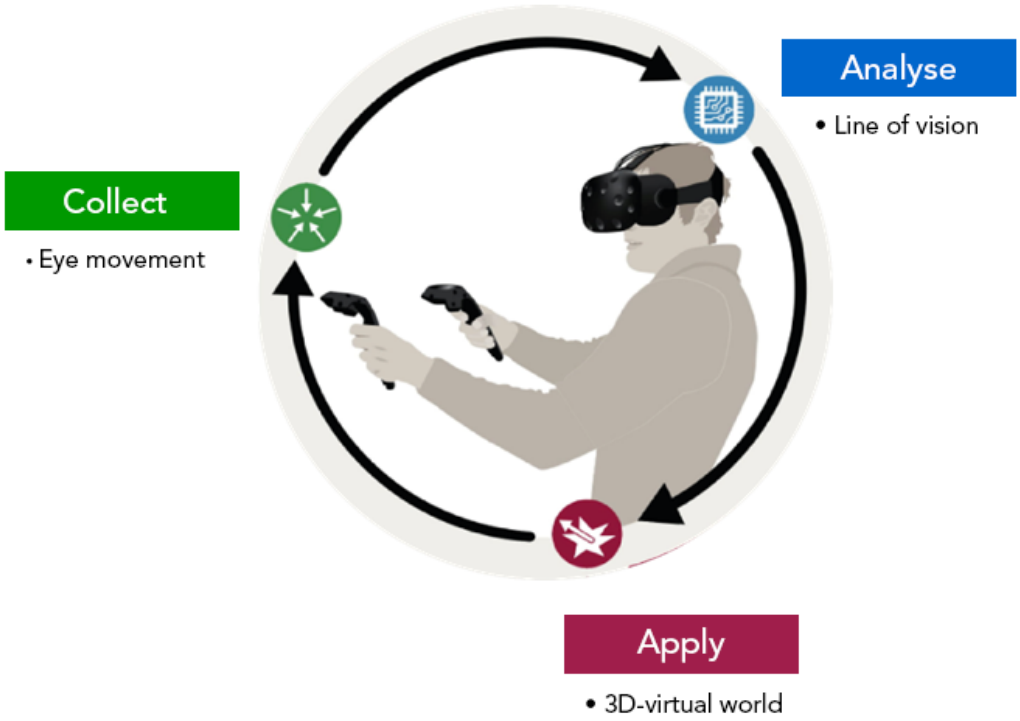


Figure 3 Cybernetic feedback loop

There are many more possibilities of analyses and applications after collecting data from the user. Information on pupil size, for example, can be used to measure an emotional response and deduce someone's preferences.[21] This analysis could then be used to generate personalised ads. These possibilities expand as more data is collected.

We investigated which sensors XR devices currently on the market are equipped with. In Annex 2, we list the sensors of a selection of popular glasses available on the market. In section 1.3, we described some prototypes currently being developed, including the Galea, that are equipped with sensors that collect new types of data, such as neurodata and muscle data.[22]

But it is far from clear exactly what kind of data is collected by XR devices. Consumer information for some glasses does not clearly state that data is collected on pupil size change, even though it is. For example, documentation for developers revealed that

[21] Bradley e.a., 'The Pupil as a Measure of Emotional Arousal and Autonomic Activation', 2008.

[22] Artuso, 'Neurotechnology and VR Combined – Meet Galea', 15 November 2022.

with some Pico, Varjo and HTC Vive glasses, developers not only get access to data on what users are looking at, but also data on pupil size change.[23]

Table 1 Possible analysis and application of collected physical and behavioural data through XR devices

Collect	Analyse	Apply
• Eye movements • Images of the user's environment • Location data • Neuro data • Body scan • Facial movements (facial expressions and emotions) • Pupil size • Hand movements • Head movements • Body movements • Brain activity • Voice and speech data • Heartbeat • Scans of the iris • Muscle reaction • Transparency • Body scan	• Viewing direction • Body posture • User position in relation to surroundings • Geographical location • Gender • Age category • User identity • Objects in the environment • Emotional response • Emotional state of mind • Cognitive state • Stress • Anxiety • Attention • Focus • Facial expression • Ethnicity • Sexual preference • Medical conditions (such as ADHD and autism) • Gait profile	• Generation of 3D (interactive) virtual environments, people or objects (incl. filters) • Stimulation of senses • Erasing elements from the physical world • Personalised advertising • Targeted content recommendation • Predicting thoughts and behaviour

Table 1 provides an overview of possible collection, analysis and application of physical and behavioural data by XR devices. It covers features relevant to XR devices already on the market or soon to be launched, issues that are being researched or plausible based on existing data processing practices on smartphones, smartwatches, etc. The fact that these are possibilities does not mean that all the examples listed above are a feature of all the glasses currently on the market.

In this scan, we use the term *physical* and *behavioural data* to refer to all data that can be collected via XR devices (listed in the first column of Table 1).

Processing of collected data is done roughly in two different ways. It happens via *on device processing,* or the data is sent to servers of the provider. If no data leaves the device, other parties cannot use the data for profiling, for instance, and it is also harder to misuse the data (see chapter 3 for these and other societal risks).

[23] They are the Pico 4 Enterprise, the Varjo XR-3, VR-3 and Aero, and the VIVE Pro Eye, Focus 3 Eye Tracker. For more information, see https://developer-global.pico-interactive.com/document/unreal/eye-tracking/, https://varjo.com/vr-lab/eye-tracking-your-questions-answered/ en https://developer.vive.com/resources/hardware-guides/vive-pro-eye-specs-user-guide/

1.5 Market developments

Facebook's name change to Meta in October 2021 has created tremendous hype around the term *metaverse*, which was originally introduced by science fiction writer Neal Stephenson.[24]

The term metaverse has many different interpretations, depending on one's perspective. Some emphasise decentralisation, with users having more control over social platforms and paying with virtual money. Others see the metaverse more as a collection of integrated virtual and hybrid worlds, with easy movement between the two. Companies like Meta and Epic Games, the makers of computer game Fortnite, see the metaverse primarily as an (immersive) 3D environment on the internet where people can engage in social interactions.[25]

Companies and governments announced their investments in the metaverse, spoke of unprecedented opportunities and a surge in start-ups. Despite numerous companies claiming to be contributing to the metaverse, what they are exactly referring to often remains unclear. Despite the hype, growing scepticism can also be seen in the public debate and among investors about what the added value of the metaverse might be.[26] In a report written by the *Norwegian Board of Technology* together with the Norwegian Human Rights Authority, they noted that the metaverse still poses many technical challenges. Transferring data between different virtual worlds, for example, is very complex as systems are not compatible, and standardisation is non-existent. Also, large numbers of users being in a virtual world at the same time, requires much more internet speed and computing power than currently available.[27]

There is a big gap between the optimistic predictions about the size of the XR market and the reality in 2023. International consulting firm McKinsey estimated in 2017 that the XR market would make $60 billion in profits by 2022. In 2015 XR analytics firm Digi-Capital even predicted a profit size of 150 billion in 2022.[28] Digi-Capital's forecast was mentioned on the websites TechCrunch, Vox, and Fortune, contributing to an optimistic outlook. Both estimates turned out to be too high: according to statistical research firm Statista, the entire XR market comprised $30 billion by 2022.[29]

Estimates on the XR market are still high in 2023. In July 2023, the European Commission relied on market research by the company Verified Market Research in

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[24] Meta, 'The Facebook Company Is Now Meta', 28 October 2021; Stephenson, *Snow Crash*, 1992.
[25] Peters, 'Tim Sweeney Wants Epic to Help Build a Metaverse That's Actually Positive', 15 December 2022.
[26] Farokhmanesh, 'Will the metaverse live up to the hype? Game developers aren't impressed', 19 januari 2023; Quiroz-Gutierrez, 'Disney Joins Microsoft and Snapchat as Latest Big-Name Company to Slink Away from Metaverse Ambitions', 28 maart 2023; Deckmyn, 'Microsoft trekt stekker uit virtuele wereld AltspaceVR', 23 januari 2023; Zitron, 'RIP Metaverse, We Hardly Knew Ye', May 2023.
[27] Norwegian Board of Technology en Norwegian National Human Rights Institution, 'The Metaverse and Human Rights', 24 April 2023.
[28] Mckinsey, 'Augmented and virtual reality: The promise and peril of immersive technologies McKinsey', 2017; Merel, 'Augmented and Virtual Reality to Hit $150 Billion, Disrupting Mobile by 2020', 6 April 2015.
[29] Alsop, 'Extended Reality (XR) Market Size Worldwide from 2021 to 2026', March 2023.

their estimates that the global metaverse market would grow from $30 billion in 2022 to more than $800 billion by 2030 (see figure 4).[30] We have been unable to verify the substantiation of this claim with publicly available sources.

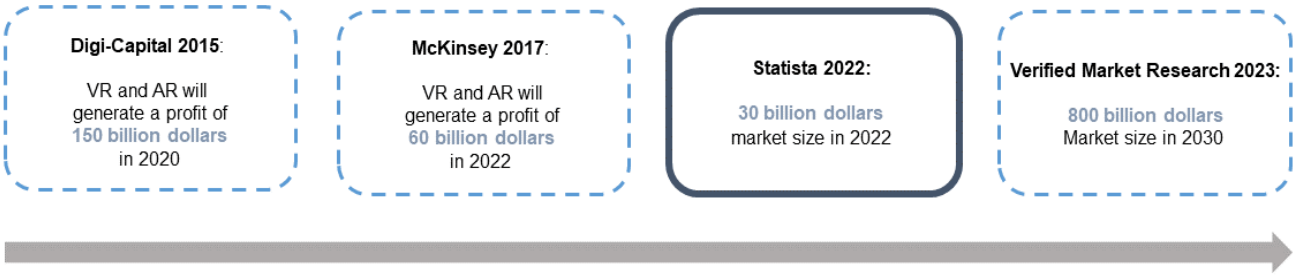


Figure 4 Expected earnings and realised market size of VR and AR[31]

The number of AR/VR headsets sold in 2022 was 9.1 million worldwide.[32] Meta, with its various Quest headsets, is the clear market leader in this field. In the last three months of 2022, its global market share was 81%, followed at a good distance by DPVR (a Chinese XR company) and Pico with around 7%.[33] By comparison, 1.4 billion smartphones were sold worldwide in 2022.[34]

In June 2023, Apple announced the Apple Vision Pro, a $3,499 pair of XR glasses aimed at home or office use. Tim Cook, Apple's CEO, sees AR as an important next step in more intuitive interaction with computers: “I think it's one of those technologies that, in retrospect, we'll ask how we ever managed without it,” he stated in an interview with YouTuber iJustine last year.[35] So, despite the fact that a major consumer breakthrough of XR devices does not yet seem imminent, major tech companies continue to invest in what they see as an important new step in the development of digital technology.

1.6 Conclusion

With immersive technologies, it becomes possible to experience a new kind of ‘realness’ that is also considered reality, even if the experience is completely or partly virtual. Technology is literally more in touch with the skin and the senses than smartphones or computers. As XR technology and neurotechnology become more and

[30] Verified Market Research, ‘Metaverse Market Size and Forecast’, March 2023; European Commission, An EU initiative on Web 4.0 and virtual worlds. A head start in the next technological transition, 11 July 2023.
[31] Digi-Capital, ‘Augmented/Virtual Reality to hit $150 billion disrupting mobile by 2020’, April 2015; Mckinsey, ‘Augmented and virtual reality: The promise and peril of immersive technologies McKinsey’, 2017; Alsop, ‘Extended Reality (XR) Market Size Worldwide from 2021 to 2026’, March 2023.
[32] Alsop, ‘Augmented Reality (AR) and Virtual Reality (VR) Headset Shipments Worldwide from 2020 to 2023’, 3 July 2023.
[33] Alsop, ‘Extended Reality (XR) Market Size Worldwide from 2021 to 2026’, maart 2023.
[34] Laricchia, ‘Number of smartphones sold to end users worldwide from 2007 to 2022’, 21 juli 2023.
[35] *Tim Cook Interview with iJustine! iPhone 13, Apple Watch Series 7 and new iPad Mini!*, 15 September 2021.

more integrated, the experience may become increasingly immersive and the data collected all the more intimate.

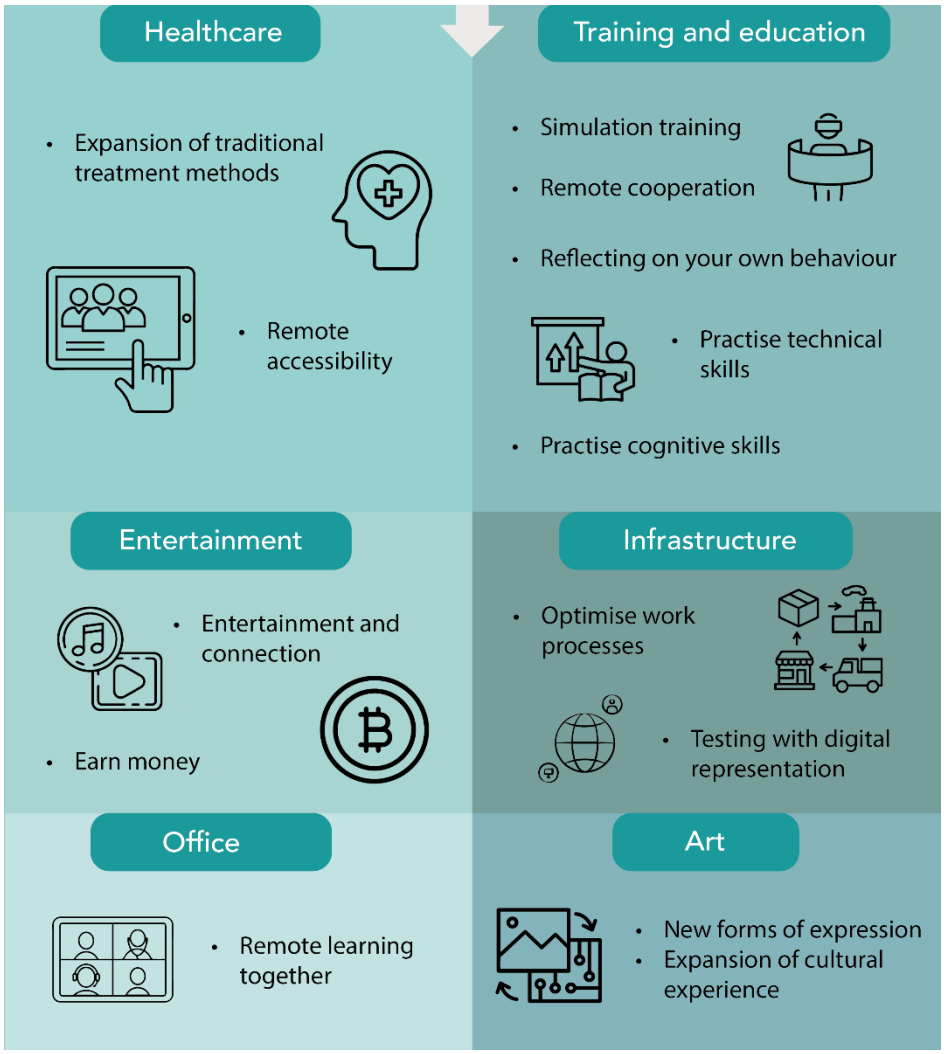
The impact of immersive technologies on society is strongly linked to a large-scale consumer breakthrough. While expectations of market size have been high for years, realisation lags behind. Whether and when the consumer breakthrough will come is unknown.

2 Specific applications in sectors

2.1 Introduction

In our investigation into how immersive technologies are currently applied, and where there are opportunities for further application, we spoke to experts and consulted literature. Several societal sectors are already working (experimentally) with immersive technologies. The sectors we encountered the most are healthcare, training and education, entertainment, infrastructure, industry, in offices, and art. These applications and experiments paint a picture of the current status of immersive technology and provide a glimpse of what may be in store.

Figure 5 Immersive technologies: specific applications



2.2 Healthcare

Immersive technologies are used experimentally by psychologists to treat people for a wide range of complaints and conditions. Meta-studies[36] describe, among other things, practicing certain situations with children with autism, treating anxiety, fatigue and pain in patients during chemotherapy, as well as treating phobias and post-traumatic stress.

The studies we analysed looked at the effect of XR compared to traditional treatments. In the case of patients undergoing chemotherapy, the hope is that successful VR treatment can replace drugs to control pain. The literature we consulted suggests that there is potential for expanding traditional treatments to include those using immersive technologies.[37]

Other benefits of immersive technology in healthcare mentioned in the literature are improved accessibility through remote treatment, and higher efficiency because parts of the therapy can be completed without the presence of a practitioner. Lower costs are also mentioned as a potential benefit. In addition, it is expected that treatments can be fine-tuned using data collected on the patient. For example, exposure during phobia treatment can be systematically adjusted, potentially improving treatment. How often and to what extent a person is exposed to their phobia can be monitored with XR.[38]

We note that in the field of healthcare, several professions are experimenting with immersive technologies. Studies comparing treatments using immersive technologies with classical forms of treatment indicate potential benefits of XR treatment methods. However, there is too little evidence to state this conclusively, as the number of patients treated is (still) too small.

2.3 Training and education

Our research shows that immersive technologies are already being used experimentally to train surgeons, pilots, military personnel, and police officers. Immersive technologies seem particularly suitable for training used for simulations and learning to work together. A growing number of scientific studies are looking into the effect of teaching using immersive technologies in comparison to classical teaching tools. Looking at these studies, a positive picture emerges about the effect of teaching with XR.[39]

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[36] Meta-studies are review articles comparing results from previous studies to arrive at a picture of the state of knowledge.

[37] Corrigan, Păsărelu, and Voinescu, “Immersive Virtual Reality for Improving Cognitive Deficits in Children with ADHD”; Burrai et al., “Effectiveness of Immersive Virtual Reality on Anxiety, Fatigue and Pain in Patients with Cancer Undergoing Chemotherapy”; Maples-Keller et al., “Virtual Reality-Enhanced Extinction of Phobias and Post-Traumatic Stress.”

[38] Maples-Keller e.a., ‘Virtual Reality-Enhanced Extinction of Phobias and Post-Traumatic Stress’, 1 July 2017.

[39] Tang e.a., ‘A Systematic Review of Immersive Technology Applications for Medical Practice and Education. Trends, Application Areas, Recipients, Teaching Contents, Evaluation Methods, and Performance’, 1 February 2022.

One example comes from education researcher Van Der Meer. He writes in a literature review that teaching in virtual reality was generally found to be effective for teaching collaboration.[40] This offers many opportunities for people who need to train teams whose members are in separate locations.

Behavioural scientist Kleygrewe describes how the Dutch police train with scenarios using actors and as well as a virtual experience. Kleygrewe concludes that training in VR can induce the same level of stress, mental effort and heart rate increase in officers as training without VR.[41] Behaviourist Cornet describes opportunities with XR for offenders, victims and professionals.[42] For offenders, the development of VR applications for treatment purposes, prevention and diagnostics can be considered. For victims, treatment for post-traumatic stress disorder and resilience training and education can be considered.

One example is treatment through the VR simulation Vergeet Mij Niet (Don't Forget Me). In 2017, Reclassering Nederland (the Dutch Probation Service) tested 13 perpetrators of (former) partner violence on how they reacted while, via a VR simulation, adopting the perspective of a 7-year-old boy who witnesses his parents having a serious argument. After the experience, participants reported being better able to reflect on their own behaviour.[43]

In healthcare, immersive technologies can assist students in practising scenarios where they have to interact with patients. With VR, this can be done without patients being involved and, therefore, puts less pressure on this vulnerable group.[44]

On its website, the Ministry of Defence writes that military personnel can practise technical skills, such as assembling a satellite dish, in a virtual environment.[45] Immersive technologies can offer a virtual version of a vehicle of which there are few available during training practice. This saves time and avoids logistical challenges in transporting training equipment.

Rijkswaterstaat, responsible for the execution of the primary infrastructure facilities in the Netherlands, is currently testing the use of VR when training personnel to operate bridges. Employees can virtually practise how to operate the Wantijbrug in Dordrecht using various scenarios. For example, in weather conditions that obstruct the bridge operator's view, or with a car driving through the barriers.[46]

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[40] Van Der Meer e.a., 'Virtual Reality and Collaborative Learning', 19 May 2023.
[41] Kleygrewe e.a., 'Virtual reality training for police officers', 9 February 2023.
[42] Cornet, van Gelder, en den Besten, 'Virtual reality en augmented reality in justitiële context', 2019.
[43] In the exploratory study 'Virtual Reality and Augmented Reality in judicial context', psychologist Liza Cornet provides thirty-two examples of applications in the Netherlands and abroad. Although not exhaustive, the overview indicates the scope of the various applications that have already been developed and tested. Henskens e.a., '"Vergeet Mij Niet". Hoe ruziënde ouders in een virtuele omgeving de emoties van plegers van partnergeweld beïnvloeden', 2018.
[44] Aiello, Cochrane, en Sevigny, 'The Affordances of Clinical Simulation Immersive Technology within Healthcare Education', 14 January 2023.
[45] Perreijn, 'Virtuele wereld vol mogelijkheden', 6 April 2021.
[46] Rijkswaterstaat Innoveert, 'Virtual Reality voor 3B-bouwblokken'.

Developmental psychologists have concluded that children who play a particular problem-solving game do so more easily in a VR environment than with a tablet or a board game. The children who participated in the test also found it more fun to play with VR glasses than the tablet or board game. A similar conclusion is drawn in a study on the learning progress of students being taught about anatomy and embryology. Students who learned about anatomy in VR knew the material better than students who learned the material from a textbook.[47]

Immersive technologies could also support teachers in their work.[48] Innovation scientist Dwivedi writes that when immersive technologies are used to track students' eye movements, one can gather which students do not understand the study material. Thus enabling the teacher to pay more attention to this group.[49]

The studies we reviewed conclude that more comparable research needs to be done to reach a consensus on the effect of XR on teaching. They often point to the small number of participants and the specific context in which a study took place.[50] Therefore, caution should be exercised in interpreting the results. Kaimara additionally argues that it is difficult to conduct studies on the effect of XR on children.[51] Results from the studies with adults cannot simply be generalised and applied to children.

2.4 Entertainment

Perhaps the greatest opportunities and promises of immersive technologies are seen in the entertainment field: in 2018, the largest market for XR applications came from video games and the porn industry.[52] This offers consumers new opportunities for entertainment, connecting with others, and having impactful experiences. For hardware, software and content providers, there are big money-making opportunities in the entertainment field because of the potential market size.

Investments by large companies such as Meta, Apple, and ByteDance are all in the entertainment field. The economic opportunities of hardware for home use by consumers are the most prominent. Content creators such as Disney have also called immersive technologies "a major revolution for Disney and the entertainment industry".[53]

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[47] Ryan e.a., ‘Learning Outcomes of Immersive Technologies in Health Care Student Education’, 1 February 2022.
[48] Barry e.a., ‘Evaluation for students’ learning manner using eye blinking system in metaverse’, 1 January 2015.
[49] Dwivedi e.a., ‘Metaverse beyond the Hype’, October 2022.
[50] Saghiri, Vakhnovetsky, en Nadershahi, ‘Scoping Review of Artificial Intelligence and Immersive Digital Tools in Dental Education’, 2022.
[51] Kaimara, Oikonomou, en Deliyannis, ‘Could Virtual Reality Applications Pose Real Risks to Children and Adolescents?’, 1 June 2022.
[52] Hall en Takahashi, ‘Augmented and virtual reality. The promise and peril of immersive technologies’, October 2017.
[53] In March 2023, the Wall Street Journal reported that Disney had laid off the team that would develop these new technologies. According to the newspaper, this fell within a larger reorganisation of the company that involved cutting back on non-essential parts of the business. Huut, 'Why Disney's plans for the metaverse are more than just hype', 26

AR applications have already managed to reach a large audience via mobile phones. Filters on Snapchat are the best known. Successful AR games have also been developed. In July 2016, Pokémon GO, a game by US company Niantic, became a huge worldwide success. In recent years, various VR games have been developed that caught on with a relatively wide audience. The game Beat Saber was released in 2018 and had sold more than four million copies by February 2021.[54]

Sociologist-economist Orel concludes that VR pornography is booming.[55] After conducting an online questionnaire among Americans in February 2022, social development psychologist Amanda Gesselmanen concluded that sextech has a growing number of users in the United States. In addition to video and webcams, users reported using teledildonic technology and VR pornography. Teledildonic technology comprises of sex toys that are remotely controlled and can be synchronised with VR videos, allowing physical stimulation to take place during the video.[56] There are also those in the entertainment industry who oppose VR porn; hardware companies such as Sony, Samsung and Meta do not allow the commercial use of XR porn on their platforms.[57]

2.5 Infrastructure

Immersive technologies are already being employed to shape and design public spaces. A term commonly used in this regard is Digital Twin. The term refers to virtual and physical 'twins' connected by the exchange of data and information. This can work both ways; data about the physical world feeds the virtual twin and insights from the virtual twin can be used to intervene in the physical world.[58]

According to the European Commission, a Digital Twin allows simulations to test the effect of an intervention in a virtual representation of reality, before being tested in the physical world.[59] For example, consider simulating a bridge closure to calculate its effect on traffic and air quality.

Immersive technologies to improve road safety have also been developed and deployed. According to engineer Li, immersive technologies can bring significant benefits to the transport industry and could change the interaction between people and their physical environment.[60] Li mentions two different applications for improving safety.

July 2022; Whelan and Flint, 'Disney Eliminates Its Metaverse Division as Part of Company's Layoffs Plan', 28 March 2023.

[54] Verhage, ‘Beat Saber komt naar PlayStation VR2’, 5 januari 2023; Verdu, ‘From Bear to Bull. How Oculus Quest 2 Is Changing the Game for VR’, 2 Februaryi 2021.
[55] Orel, ‘Escaping reality and touring for pleasure’, 1 October 2020.
[56] Gesselman e.a., ‘Engagement with emerging forms of sextech’, 2023.
[57] Rathenau Instituut, ‘Responsible VR. Protect consumers in virtual reality’, 2019.
[58] (zie bv. Kloppenbrug et al. 2022).
[59] Europese Commissie, An EU initiative on Web 4.0 and virtual worlds, 3 Mayi 2023.
[60] Li e.a., ‘Immersive Technology-Enabled Digital Transformation in Transportation Fields’, 15 September 2022.

The first is providing safety training in a virtual environment to encourage safer behaviour in the physical environment (e.g. wheelchair use or steering a ship). A second application Li mentions is tracking people to better understand behaviour in dangerous situations (e.g. pedestrians and motorists).

In construction, XR could potentially be used as a tool for creating complex structures. When building the Boekelose Bridge, for example, a headset made it possible to see a hologram of the bridge projected across the river. This improved collaboration between the bridge's designers and builders.[61]

AR is also being experimented with in distribution centres. Several companies in the Benelux are currently using smart glasses, which could be an improvement compared to using hand scanners or receiving instructions via headphones. Employees in warehouses are shown instructions via AR glasses, which shows them which shelving unit to go to, which products to pick up there and where to take them. The intended purpose of implementing smart glasses is to use time as efficiently as possible. Moreover, your hands remain free while wearing glasses.

2.6 Office

Technology companies such as Meta and Microsoft expect to sell immersive technologies to use in offices.

With the launch of Horizon Workrooms, Meta offers the ability to extend a workplace in XR. You enter the virtual environment with Quest-2 VR glasses, but you can also join via a browser or video call. According to Meta, the added value of working in Workrooms is that colleagues experience collaboration as if they were sitting next to each other in a room. One thing that differentiates Workrooms from existing virtual environments is its integration of the physical environment and the virtual workspace. For example, by having VR glasses recreate a full-size workspace, table and keyboard. This, according to Meta, creates a familiar feeling, as the space feels like the physical space the user is in. [62] In 2022, Microsoft and Meta announced their collaboration to integrate digital working environments with Meta's headsets.[63]

[61] Rathenau Instituut, ‘Fake for real. Ethical and societal implications of augmented reality’, 2020.
[62] Meta, ‘Introducing Horizon Workrooms. Remote Collaboration Reimagined’, 19 August 2021.
[63] Teper, ‘Microsoft and Meta Partner to Deliver Immersive Experiences for the Future of Work and Play’, October 2022.

2.7 Art

The art industry uses immersive technologies in various ways. Museums use immersive technologies to allow visitors to experience art differently, and artists use these technologies to create new artwork. [64]

The use of immersive technologies in museums ranges from physically interacting with virtual art, to being able to try on digital futuristic fashion through face filters and AR.[65] Film director Celine Daemen used immersive technologies to create an opera in VR. The performance was shown at the Venice Biennale in 2022.[66] Visitors of Impakt, centre for media and culture in Utrecht, can walk around four virtual spaces in the XR installation entitled *Enter New Babylon* and view work by artist Constant Nieuwenhuis.[67]

2.8 Conclusion

There are two main benefits of XR reflected in the different societal sectors: the experience of being together despite physical distance, and the life-like experiences that can be achieved through virtual scenarios. These benefits are linked to the two main characteristics of immersive technologies: the feeling of being present in XR and having a strong emotional experience. A third and often mentioned advantage is the efficiency benefits of working with XR. Across all industries, logistics in particular could benefit from immersive technologies, leading to a significant cost reduction.

However, the opportunities of XR that current research and practice show should be considered with caution. The fact that VR offers training advantages for police officers and surgeons, for example, does not mean that a complete move to VR for all training purposes is justified. The studies we discussed focus on the XR implementations that work, and do not look at the potential risks of the technology on a larger scale, such as the risk of a loss of human contact.

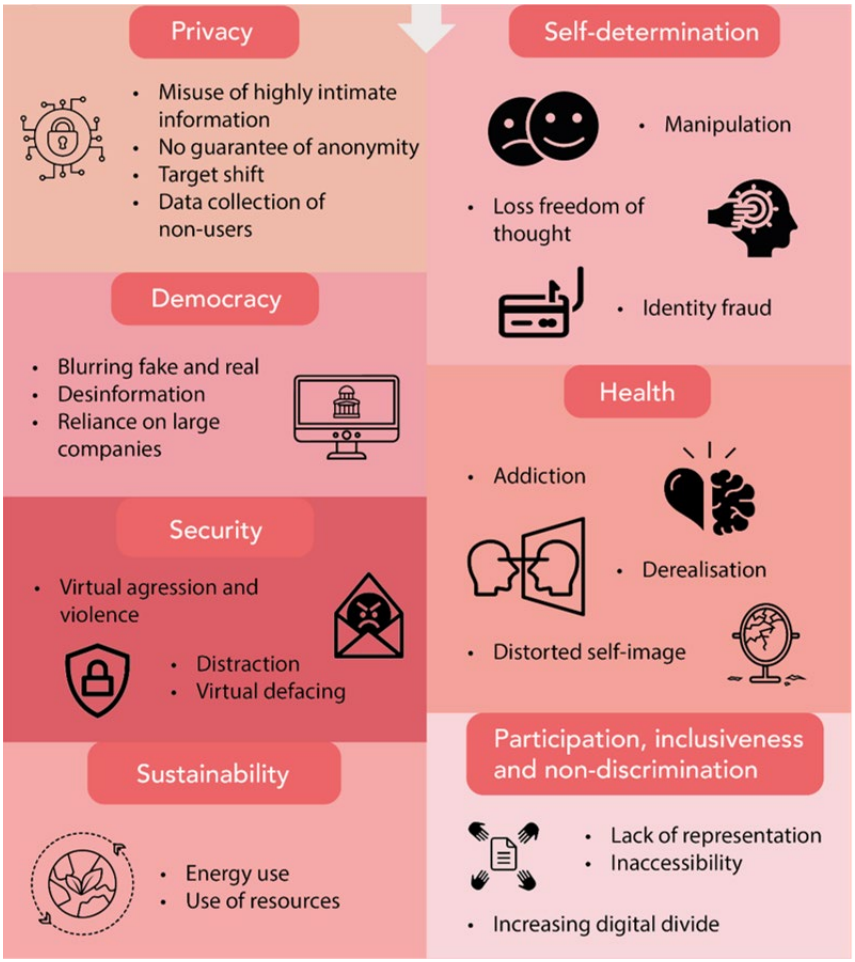
[64] Voor een artikel met veel verschillende voorbeelden, zie Richardson, 'How Are Museums Harnessing Immersive Technology to Provide Experiences?', 28 januari 2021.
[65] Nxt Museum, 'WHOLELAND', 2022.
[66] La Biennale di Venezia, 'Biennale Cinema 2022. Eurydice, Een Afdaling in Oneindigheid', 6 July 2022.
[67] IMPAKT, 'Enter New Babylon. A Theatrical Virtual and Mixed Reality Installation'.

3 Societal risks in relation to public values

3.1 Introduction

In Chapter 2 we saw that various industries are experimenting with applications of immersive technologies. However, these technologies also come with associated risks. In this next chapter, we identify which aspects of immersive technologies pose a risk to the public interest, which we narrowed down to eight public values.[68]

Figure 6 Immersive technologies: societal risks



[68] This selection is based on the public values contained in the coalition agreement 2021-2025, supplemented by public values emerging from recent research by the Rathenau Instituut.

3.2 Privacy

Immersive technology puts pressure on the privacy of both users and non-users. This technology enables the collection of physical and behavioural data that derives very intimate information, which can then be misused.

In Chapter 1, we saw that some XR devices track eye movements. In Annex 2, we list the sensors that different XR devices use to collect physical and behavioural data. A lot of very intimate information can potentially be derived from the data collected by the sensors. According to researchers, age, gender, ethnicity, sexual preference, and medical diagnoses such as ADHD and autism have been linked to eye-tracking.[69] [70]

Data thought to be anonymous turns out to be far from anonymous in practice. A 2020 study showed that 95% of XR device users could be identified within five minutes of using an XR device.[71] This risk of deanonymisation should be considered before the collection of data.

Physical and behavioural data can be used to profile people. The data scandal surrounding Cambridge Analytica is a well-known example of this. The company was accused of collecting data from millions of Americans through Facebook, without the users' explicit consent. The company tried to use this data to target American voters with political campaign ads tailored to them, in order to influence the outcome of US presidential elections in 2016.[72]

When very intimate information is collected on a device, there is a high risk of this data being misused. Information collected in one location can be used in another. This creates function creep, which means collected data is used for a different purpose than what it was intended for. The data scandal surrounding the app Muslim Pro is an example of function creep and data trafficking. The app reminded users when it was time for prayer and the direction of Mecca relative to the user's location. Online magazine Vice revealed that this data came into the possession of the US military. The army said it used the information to support special operations abroad.[73]

Risks that apply to users of immersive technologies may also apply to non-users. As described in Chapter 1, sensors of immersive devices also analyse the environment. Potentially, physical and behavioural data can be collected and processed about anyone within the vicinity of a sensor. Although applications could use guidelines to prevent processing without consent,[74] in practice, it is easy to film or photograph people

[69] Pahi en Schroeder, ‘Extended Privacy for Extended Reality’, 28 August 2022.
[70] Rieger e.a., ‘Sexual Arousal’, January 2015.
[71] 6DOF data van zowel headset als controller, zie: Miller e.a., ‘Personal Identifiability of User Tracking Data during Observation of 360-Degree VR Video’, 15 October 2020.
[72] Potenza, ‘Cambridge Analytica’s Facebook Data Abuse Shouldn’t Get Credit for Trump’, 20 maart 2018.
[73] Cox, ‘How the U.S. Military Buys Location Data from Ordinary Apps’, 16 November 2020.
[74] For example, AR glasses *Magic Leap* has included in its Technical Requirements Checklist that it is prohibited from identifying non-users.

without their knowledge or consent. This, therefore, poses risks to privacy when using XR devices in public spaces.

A certain amount of data collection is required for XR devices to function, but there are considerable differences between how much data XR devices collect (see Annex 2). The technology is now mainly being developed by a few large companies. These companies are known for building their revenue models around data collection. This revenue model combined with the wide variety of sensors possible on XR devices means that data collection via XR devices and applications could potentially be even larger in scale than current social media and smartphones.

3.3 Self-determination

Immersive technologies put pressure on users' self-determination because they can be used to manipulate people. Manipulation can be hidden in XR and play on users' emotions or behaviour. Take the popular AR game Pokémon Go. *Financial Times* reported that this game managed to mobilise players in public spaces and draw them to commercial locations in the physical world by placing game elements there.[75]

In 2021, cyber forensics researcher Casey tested VR headsets HTC Vive and the Oculus Rift. The goal was to see how vulnerable these headsets are to possible attacks by malicious actors. By making small adjustments to a game's virtual environment, they managed to cause users to run into physical objects and walls.[76]

According to visual information researcher Bibri and sustainability researcher Allam, the combination of digital technology and biotechnology makes it increasingly possible to predict people's thoughts, preferences, and behaviour, and thus respond to these cues.[77]

Moreover, virtual environments are being increasingly personalised.[78] Immersive technologies can reinforce this because they provide strong sensory illusions.[79] Ethicist O'Brolcháin warns that the combination of VR and AI could lead to users being influenced in their ideas and views via computer-generated avatars.[80] This is a form of intuitive influence that can potentially infringe on our freedom of thought.

Users could also manipulate each other. For example, the advent of immersive technologies brings with it risks of identity theft.[81] Making digital copies of people, such

[75] Bradshaw en Lewis, 'Advertisers set for a piece of "Pokémon Go" action', 13 July 2016.
[76] Casey, Baggili, en Yarramreddy, 'Immersive virtual reality attacks and the human joystick', March 2021.
[77] Bibri en Allam, 'The Metaverse as a Virtual Form of Data-Driven Smart Cities', 28 July 2022.
[78] Rathenau Instituut, 'Fake for real. Ethical and societal implications of augmented reality', 2020.
[79] Rathenau Instituut.
[80] O'Brolcháin e.a., 'The Convergence of Virtual Reality and Social Networks', 2016.
[81] Europol, *Policing in the metaverse. What law enforcement needs to know, an observatory report from the Europol Innovation Lab*, 2022.

as a 3D scan, is becoming more and more simple, partly because of the onset of *generative AI* (an AI system that generates output, including text, image, sound and video in response to a user's request). VR allows cloned avatars to do things that the actual person would never do. Associated literature warns of virtual revenge porn: the distribution of fake sexual videos of people.[82]

In view of the prototypes and XR devices currently in development (see Chapter 1), we expect data collection to become even more intimate in the future, further increasing manipulation risks. BCIs incorporated in XR technology could, in the future, collect our neurodata to read our thoughts and feelings. According to the US think tank NeuroRights Foundation, five types of fundamental rights are specifically at stake when using neurotechnologies such as BCI systems. These rights include mental privacy, physical and mental personal identity, free will, fair access to neurotechnologies, and protection against bias. In the context of the use of neurotechnologies, they call these fundamental rights: neural rights.

3.4 Democracy

The aforementioned risks at the individual level also play out in a societal context: manipulation using immersive technologies can harm democracy. The blurring of boundaries between physical and virtual, combined with an extensively personalised virtual environment (hyperpersonalisation), puts pressure on a shared perception of reality. In this confusing context, distrust may arise about what is real and what is fake, while democratic decision-making is meant to be served by a common fact base.[83]

The blurring of fake and real is already impacting the public debate. Stating that reality has been manipulated can be said with increased certainty, even in the case of images that have not been altered. In the summer of 2021, a video appeared online in which *Viruswaarheid* foreman Willem Engel openly questioned the authenticity of the major flooding in Limburg.[84] Twitter users here quick to react: his statements were considered so absurd, this video had to be a *deepfake*. In the end, the footage turned out to be authentic.[85] Unintentionally, this discussion warned of what lies ahead. The proliferation of manipulated images will cause us to distrust any material, even that which is not manipulated.

As virtual adaptations become more convincing, disinformation in the form of image manipulation may also become increasingly harmful. With the highly intimate data made

[82] Wood, Wood, en Balaam, ‘They’re Just Tixel Pits, Man’, 2 May 2017.
[83] Rathenau Instituut, ‘Digitalisering van het nieuws. Online nieuwsgedrag, desinformatie en personalisatie in Nederland’, 2018.
[84] Van Huijstee en Das, ‘We moeten leren leven met “deepfakes”’, 13 October 2021.
[85] See, among others: https://web.archive.org/web/20210717132722/https://twitter.com/maarjuna/status/1416388763446566916 en https://web.archive.org/web/20210717101720/https://twitter.com/Regiusfrie/status/1416341202765496321

available through immersive technologies, people can be better profiled and targeted. Europol predicts that this intimate knowledge could be used by distributors of disinformation, potentially increasing the effectivity of disinformation campaigns and giving them a wider reach.[86]

The societal risks we discuss in this chapter take place in the context of technology development by private parties. In Chapter 1, we saw that the market for immersive technologies is dominated by just a handful of US and Chinese technology companies. We see a similar concentration of power in other digital technology fields: think of the cloud market, social media and search engines.[87] These digital technologies have become essential in many public domains (such as education, healthcare and journalism), leaving society dependent on a small number of multinational companies.[88] Having control over public domains is a prerequisite for a democratic rule of law, but may become jeopardised by unequal power relations.[89] If this trend continues, society may become even more dependent on the services of a small number of multinational companies with a significant power base. And with power comes the risk of abuse of power.

3.5 Health

The use of immersive technologies can have a negative impact on users' health. This concerns the physical impact of excessive use, and the impact on users' mental state through addiction and a distorted self-image.

Research on the risks and impact of XR reveals several physical health risks, both for users and others. Cybersickness (or being seasick during and/or after using VR glasses) and dizziness are frequently mentioned.[90] [91] A meta-study on the effect of VR on children by psychologist Kaimara, found that many publications particularly point to the physical risks of overuse. Examples include eye damage and sleeping difficulty.[92]

Excessive XR use is also potentially addictive, which comes with various mental risks. Psychologists have long been concerned about disorders caused by being online for extremely long periods of time.[93] XR use may have the same risks. Philosopher Madary points out that XR use can cause derealisation and depersonalisation disorder. The

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[86] Europol, *Policing in the metaverse. What law enforcement needs to know, an observatory report from the Europol Innovation Lab*, 2022.
[87] Van Dijck, 'Seeing the Forest for the Trees', September 2021.
[88] Sharon en Gellert, 'Regulating Big Tech expansionism?', 16 August 2023.
[89] Gerbrandy en Phoa, 'The Power of Big Tech Corporations as Modern Bigness and a Vocabulary for Shaping Competition Law as Counter-Power', 3 november 2022; Passchier, 'Big Tech vs de soevereiniteit van democratische wetgevers: Naar een neofeodalisme 2.0.?', 2022.
[90] Li e.a., 'Considering the Consequences of Cybersickness in Immersive Virtual Reality Rehabilitation', januari 2023.
[91] Kelly e.a., 'Gender differences in cybersickness', March 2023.
[92] Kaimara, Oikonomou, en Deliyannis, 'Could Virtual Reality Applications Pose Real Risks to Children and Adolescents?', 1 June 2022.
[93] Madary en Metzinger, 'Real Virtuality', 2016.

main symptom of depersonalisation is one's feeling of being alienated from their own body, thoughts or psychological processes. Derealisation is experiencing familiar surroundings, people and objects as unreal. Users can lose contact with physical reality and may experience increasing difficulty to become accustomed to it again. Madary argues that users should be warned of these risks prior to and while using XR.

Furthermore, the use of XR and digital filters can cause a distorted self-image. One example is Snapchat, where *filters* can be used to alter users' images and videos, including their appearance. This mismatch between what you see in the mirror and what you see on a smartphone screen can leave users with significant mental problems.[94] A British plastic surgeon, for example, noticed that instead of bringing images of celebrities to a consultation, some clients brought in filtered Snapchat images of themselves. He called this phenomenon *Snapchat dysmorphia*.[95]

3.6 Security

Immersive technologies can jeopardise users' safety and privacy, giving them the impression of intimacy with other users despite there being a physical distance. This carries the risk of harassment and invasion of personal space.[96]

Online harassment of women is already a significant problem: in an international survey of girls and women aged 15 to 25, 55% said they had experienced a form of online harassment.[97] This pattern may start to appear and possibly intensify in XR environments. Instances of this kind of harassment have already started occurring. In December 2021, for example, a woman in a testing environment of Horizon Worlds (the VR environment built by Meta) was sexually harassed by other avatars.[98] The strong immersive nature of the technology ensures that these virtual attacks become intrusive experiences. With haptic feedback, where users physically experience virtual touches, a virtual attack can even feel like a physical attack.

In XR environments, there is also the risk of users virtually vandalising a virtual or public space. On New Year's eve of 2022, slogans were projected on the Erasmus Bridge in Rotterdam.[99] These slogans could be seen by everyone. In an XR environment, a user or developer could potentially project such a layer over the physical world as well.

Another risk related to safety is distraction. XR devices often require a high level of attention, which can lead to dangerous situations in public spaces and traffic. Financial economists Mara Faccio and John McConnel have linked the aforementioned AR game

[94] Rathenau Instituut, 'Fake for real. Ethical and societal implications of augmented reality', 2020.
[95] Hunt, 'Faking It', 23 january 2019.
[96] Rathenau Instituut, 'Responsible VR. Protect consumers in virtual reality', 2019.
[97] 'Online Harassment Is Silencing Girls', 2020
[98] Patel, 'Reality or Fiction?', 21 December 2021.
[99] Meeuwissen, 'Juridische vervolging voor leuzen op Erasmusbrug moeilijk', 2 January 2023.

'Pokémon Go' to an increase in traffic fatalities in Indiana, USA around the time of the game's launch.[100] Distraction in traffic already increased with the arrival of mobile phones. As AR goggles gain popularity, the risk of distraction in traffic increases even further.

Box 2 Dutch criminal law in relation to safety risks

Consultancy firm Considerati was commissioned by the Scientific Research and Documentation Centre (WODC) to investigate whether the legal framework in the Netherlands is sufficiently equipped to deal with risks posed by the widespread adaptation of immersive technologies.[101]

The consultancy firm concluded that criminal law combined with civil law was generally well equipped, but it also identified several flaws. These were mainly the result of the fact that criminal offences such as rape, assault or vandalism often require a physical component. This physical component is missing in purely virtual experiences, while the impact for the victim can be just as significant. The government responds more positively to the Considerati report. As there are possibilities offered by criminal law to prosecute virtual harassment and aggression without a physical component when it is considered psychological violence.

There is also a new law in the making that will criminalise sexual harassment in (online) public spaces. That will cover some gaps, although it is not yet clear to what extent. After all, what if someone is assaulted in a virtual private space? Is that public or not? Does that count as an offensive act under this new law? And, if you apply an offensive AR filter to someone on the street, is that considered public? Or would that be private because you are the only one who can see the results of the filter?

Sources: Schermer & Ham, 2021; and *Kamerstukken II* 2022/2023, 26 643, nr. 1041, appendix II.

3.7 Inclusivity, participation and non-discrimination

There are more general risks associated with digitalisation that could possibly worsen with widespread adaptation of immersive technologies. Inclusivity and participation may become strained by a growing digital divide. As society continues to digitise, the gap between those who can benefit from digital technology and those who cannot is

[100] Faccio en McConnell, 'Death by Pokémon GO', 2020.
[101] Schermer en van Ham, 'Regulering van Immersieve Technologieën', August 2021.

widening. XR devices have (high) purchase costs, and their use could become correlated with the level of income.

In addition, the virtual world currently being developed for XR lacks societal representation. The database that is being populated by the cybernetic feedback loop may exacerbate this problem. This technology then not only remains inaccessible to a group with a lower income level; but the technology is also developed and advanced for and by a small group of users. An example of this is the experience of cybersickness. This appears to be experienced considerably more by women than men. One cause may lie in the development of XR glasses. Generally, they are designed for a male target group, so the distance between the eyes on the device is wider than for many female users.[102]

Currently, there is little research on how discrimination manifests itself in immersive technologies, regardless of it being an important social issue. This is confirmed by an ethnographic study that included interviews with industry experts. This showed that more knowledge and expertise is needs to be developed to make safe, accessible and inclusive immersive environments.[103]

3.8 Sustainability

The amount of energy that immersive technologies consume poses a risk to the development of a sustainable society. Immersive technologies require a large amount of data collection and processing. Large-scale use will mean that many more data centres are needed. There has hardly been any discussion yet about what this means for making society sustainable.[104]

Claims are being made about immersive technologies that could reduce travel movements and in turn CO2. But whether this outweighs the impact of additional data centres still needs to be investigated. In the fashion industry, more and more designers are experimenting with digital fashion. This development, combined with the prediction that we will spend a significant proportion of our time in virtual worlds, is leading some commentators to speculate about the substitution of physical for digital clothing.[105] [106] The fashion industry has a high impact on the environment, and such a development could mean significant reductions in the use of raw materials and resources.

[102] Li e.a., ‘Considering the Consequences of Cybersickness in Immersive Virtual Reality Rehabilitation’, January 2023.
[103] Zallio en Clarkson, ‘Designing the Metaverse’, 1 December 2022.
[104] Rathenau Instituut, ‘Beter beslissen over datacentra’.
[105] Sidorová, ‘Will Digital Fashion One Day Replace the Real One?’, 29 October 2021.
[106] Renwic, ‘In The Future Your Clothes Will Be Made Out Of Pixels’, 31 December 2019.

3.9 Conclusion

If accompanied by the large-scale collection of physical and behavioural data by companies, widespread adaptation of immersive technologies could have a major impact on privacy, self-determination, democracy, and safety. In addition, widespread digitalisation, which XR is a part of, also poses more generic risks that endanger inclusivity, participation, non-discrimination, and potentially sustainability.

4 Tools for policy

4.1 Introduction

Immersive technologies are more in touch with our senses than smartphones and computers, allowing (partially) virtual experiences to feel lifelike. But these technologies also involve the collection of physical and personal data, revealing very intimate information of its users. A user's eye movements can be utilised by an XR developer to make a 3D world move along with what a person is looking at. This same eye movement can reveal physical or mental conditions, or someone's sexual preference. This kind of information being misused against XR users and society is a very real risk.

The European Union (EU) is developing legislation to curb the risks associated with widespread digitalisation. This legislation will also impact the development and application of immersive technologies. However, besides setting limits, the EU also promotes the market for digital technologies, which includes immersive technologies. The premise for this is that citizens and businesses can benefit from the advantages that digitalisation can offer. Policymakers and politicians find themselves in a difficult position when it comes to navigating the policies around immersive technologies. On the one hand, they want to set limits to undesirable technological developments, markets and applications. On the other hand, they want to capitalise on the opportunities that XR can offer businesses and citizens.

In this chapter, we discuss a selection of European laws aimed at managing risks associated with immersive technologies. These include the General Data Protection Regulation (GDPR, or AVG in Dutch), the Artificial Intelligence Act, and the Digital Services Act (DSA).[107] We do this to identify remaining gaps in risk management, and to offer options for action for policymakers (see chapter 5). We also briefly discuss three incentives from the Netherlands and the EU that influence the development of immersive technologies. We also discuss the Digital Markets Act (DMA) and its explicit aims to create a fairer business environment in the digital domain. Furthermore, we discuss an investment from the Growth Fund to the *Creative Industries Immersive Impact Coalition* and the *European Initiative on Virtual Worlds*, as those instruments are specifically aimed at realising the opportunities of immersive technologies.

[107] However, the policy instruments and laws mentioned in this chapter are not the only ones that can be applied to immersive technology. A review by Kai Zenner, policy assistant to MEP Axel Voss, shows that there are some 70 established European laws that can play a role. See: Zenner, Marcus, en Sekut, 'A Dataset on EU Legislation for the Digital World', 5 July 2023.

4.2 Legislation on data collection, processing and application

In this section, we discuss three key legal instruments that address risks in the digital domain: the General Data Protection Regulation (GDPR), the Artificial Intelligence Regulation, and the Digital Services Act. We do this by using the cybernetic feedback loop (see Figure 3). We analyse how each of these instruments regulate the collection, processing, and application of XR data.

Box 3 GDPR, AI Act and DSA in a nutshell

The **GDPR** has been in effect since May 2018 and protects people's privacy when parties process their personal data.

The AI Act (AIA) was proposed by the European Commission (EC) in 2021 and succeeded by versions of the Council of the EU (the Council) and the European Parliament (EP). At the time of writing, the three are negotiating towards a final version in a so-called *trilogues*. The law aims to ensure secure AI systems that respect fundamental rights while encouraging innovation. The law imposes rules on providers and users of AI systems. Different versions of the AI Act each contain their own definition of AI systems, but the EP version explicitly refers to virtual environments in the definition: ‘artificial intelligence system' (AI system) means a machine-based system that is designed to operate with varying levels of autonomy and that can, for explicit or implicit objectives, generate outputs such as predictions, recommendations, or decisions, that influence physical or virtual environments." (Article 3.1 EP proposal AI Act).).

The Digital Services Act (DSA) is a European regulation that regulates intermediary service providers, such as online platforms and search engines. XR services are not explicitly mentioned in the DSA, but certain XR services may fall under the definition of intermediate trade service, such as XR platforms or XR streaming services. The DSA aims to promote a safe, predictable and reliable online environment.

Collect

The first step in the cybernetic feedback loop is data collection. In Table 1, we list the types of data that can be collected by XR devices, such as eye movement and body posture. We use the term physical and behavioural data to refer to the totality of this data.[108] In chapter 3, we have seen that the privacy and autonomy of users and non-users of XR becomes jeopardised by the large-scale collection of physical and behavioural data enabled by immersive technologies.

The GDPR imposes rules on developers of XR devices, XR applications, and users on how to handle the collection of physical and behavioural data.[109] Wat is done with the data, and under what conditions, depends on the context in which this data is collected, the ability of third parties to analyse data, and the purpose for which the data is collected. To make this subject more manageable, we will focus on consumer applications in this chapter.

The GDPR distinguishes different categories of data. Physical and behavioural data collected and processed through XR can fall into different categories, each with its own form of protection. Figure 7 shows the different data categories that physical and behavioural data can fall under.

An XR provider is allowed to collect general personal data based on various grounds . For example, if this is necessary for the operation of the device, or if there is consent through a contract between provider and user (in practice, this means accepting the terms of use).[110]

Special data on matters such as health, religious beliefs, sexual orientation, or ethnic origin receive extra protection. Their collection and processing is prohibited under the GDPR unless one of the 10 grounds for exception is met. Explicit consent is one of those grounds.[111] As shown in Figure 7, not all data that can be collected through XR falls within the category of special data. For example, data on a person's gender, financial status, interests and emotions, and neurodata do not always fall within this category.

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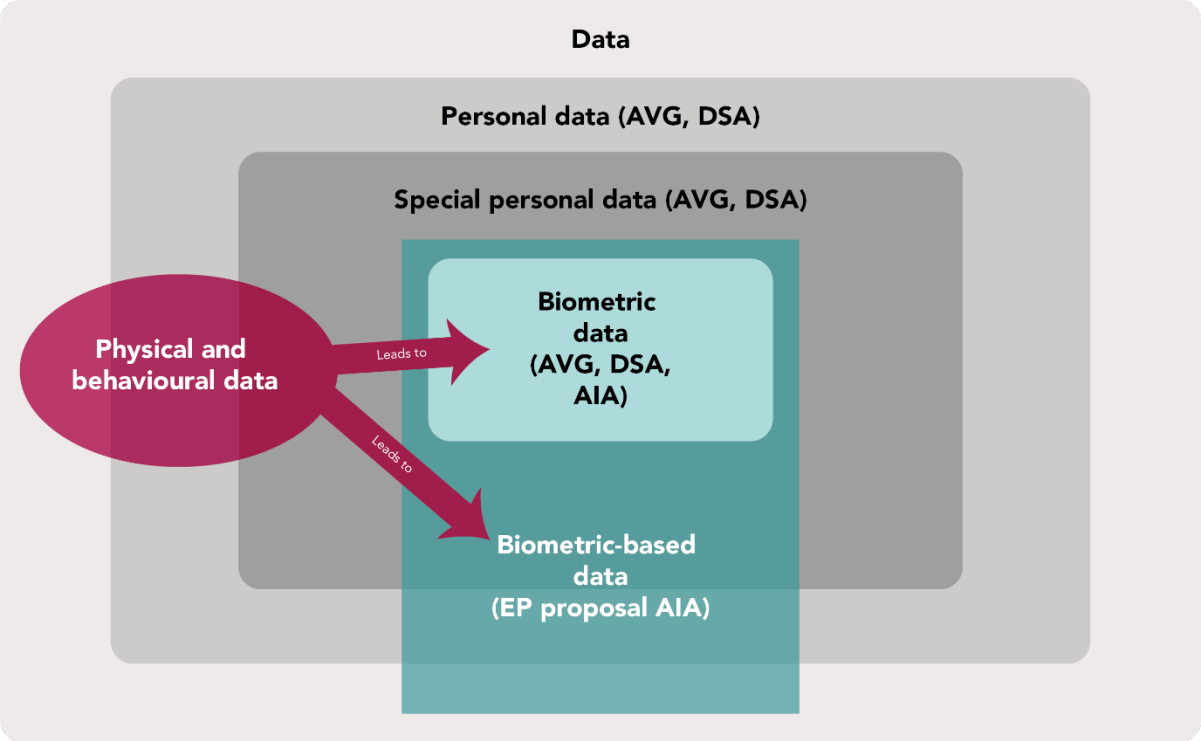
[108] Annex 2 shows the sensors eyewear in the current market is equipped with, which allow these eyewear to collect physical and behavioural data.

[109] European Parliament and Council of the European Union, Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of individuals with regard to the processing of personal data and on the free movement of such data and repealing Directive 95/46/EC (General Data Protection Regulation), 27 April 2016.

[110] See Article 6 of the AVG for the different processing grounds.

[111] See the website of the Personal Data Authority for the bases for consent: https://www.autoriteitpersoonsgegevens.nl/themas/basis-avg/avg-algemeen/grondslagen-avg-uitgelegd#speciale-regels-voor-bijzondere-persoonsgegevens

Figure 7 Different data categories that may include physical and behavioural data [112]



Consent plays a crucial role in the collection of user data by XR providers. Such consent, according to the GDPR, must meet a number of requirements: it must be freely given (i.e. not under pressure), be unambiguous (i.e. the result of an active action), informed (i.e. accessible and clearly formulated) and specific (each processing purpose requires separate consent).

Giving and obtaining legally valid consent under the GDPR, poses a number of practical problems in the context of XR. First, the combination of many different activities (gaming, going to concerts, working, etc.) in different virtual spaces, using different data processing techniques, produces a multitude of possible purposes. So how can privacy terms related to XR be made accessible and unambiguous? And how feasible is obtaining legally valid consent statements in XR?

The requirement of free and informed consent is difficult to understand when it comes to collecting data on unconscious behaviour. Where social media users consciously post content, XR users have little control over subtle micro-movements like a sideways glance or smile, let alone their pupil reflex or heart rate. How does one give voluntary and informed consent to process measurements of behaviour you don't know you are exhibiting?

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[112] With the policy instruments in which they appear in brackets. GDPR stands for General Data Protection Regulation, DSA for Digital Services Act, EP for European Parliament and AIA for AI Act.

Another question is how consent can be obtained from non-users. Theoretically, the GDPR also should protect bystanders, if they are identifiable, who are (unknowingly) part of an immersive experience. If the person cannot be identified, or is in a personal or domestic context (e.g. because an AR filter is placed on a friend at home), then the GDPR will not be involved. However, exactly how AR filters may be used in public spaces is still unclear.

Analyse

The next step in the cybernetic feedback loop is to analyse data, such as deriving emotions based on facial expressions, or preferences and opinions based on viewing and clicking behaviour. In Chapter 3, we have seen that the privacy, self-determination and non-discrimination rights of users and non-users of XR are jeopardised when physical and behavioural data are processed in a certain way, for example by identifying someone or deriving an emotional state of mind. The GDPR contains rules that restrict the processing of data.

After processing, physical and behavioural data of XR users can again fall into different categories of personal data according to the GDPR (see Figure 7). It can become special personal data if a medical condition is derived from someone's eye movements. Biometric data is a specific category of such special data. Physical and behavioural data can be processed into biometric data when a technical processing step takes place that allows identification or verification of the data subject. This processing step results in a set of biometric data. This data may only be used by an XR provider if it has the legally valid consent of the user. Obtaining this consent is subject to the same practical problems as mentioned above.

Apply

The third step in the cybernetic feedback loop is the application of the previously collected and analysed data. Think of generating 3D worlds, or showing personalised ads. In Chapter 3, we saw that several public values become jeopardised when applying physical and behavioural data gathered through immersive technologies. In particular the values of self-determination, democracy, participation, inclusiveness and non-discrimination. Both the AI Act and the DSA contain provisions that address these matters.

In the negotiations on the AI Act, several proposals are being discussed that would ban certain applications of XR if they use AI, as they pose unacceptable risks. One proposed ban deals with systems that use subliminal techniques. These are influencing techniques of which data subjects are not aware, and that may harmfully disrupt their

behaviour. A specific definition of this is still lacking. Therefore, it is still unclear exactly which XR applications would fall under this ban.

Another proposed ban concerns AI systems that use people's vulnerabilities to cause them to engage in harmful behaviour to themselves or others. The EP proposal for the AI Act focuses specifically on vulnerabilities due to age or disability, which could offer protection from harmful VR games to minors. In the EP proposal, the ban covers all vulnerabilities of individuals. As a result, it could also cover XR recommendation systems that profile based on gender or addiction sensitivity.

The EP has made further proposals that would ban various AI applications relevant to XR. First, the EP proposes a ban on biometric systems for real-time remote identification in public places. These are physical places accessible to the public, therefore do not include online VR worlds and AR applications.[113] This would prohibit the use of AR with facial recognition in public spaces altogether in many cases, whereas the GDPR would currently still allow it with explicit consent.

Secondly, the EP wants to ban biometric categorisation systems that classify individuals by sensitive features or characteristics. In both cases, the EP adds the term 'biometrics-based data' as an extension of the stricter category of 'biometric data' (see Figure 7). Biometrics-based data is data resulting from specific technical processing of a person's 'physical, physiological or behavioural signals'. According to the EP, this includes facial expressions, movements, pulse rate, voice, DNA patterns and signatures. It is irrelevant here whether the processing enables identification or verification.[114] Recommendation systems that profile using biometrics-based data, or AI that monitors students' ability to concentrate in VR classrooms are then likely to be banned.[115]

The EP also wants to ban AI systems that detect emotions in the areas of law enforcement, border management, the workplace and educational institutions.[116] With these proposals, the EP calls a halt to a number of high-risk applications that may become possible via XR.

The AI Act also includes a list of so-called high-risk AI systems, which must meet specific requirements.[117] Where the EP wants to ban AI systems used for biometric identification or categorisation, the EC and ER count them among high-risk systems. Other high-risk systems on the list potentially relevant to XR, are AI systems used for management and operation of critical infrastructure, education and vocational training, employment and workforce management and support to the judiciary. In all these areas,

[113] Paragraph 18 and Article 3 under 39 AIA EC version, ER version, EP version.
[114] Paragraph 7, 7b and 33a (Amendments 21, 23, 63) and Article 3(1)(33a), 34 and 35 (Amendments 187, 191 and 192) AIA EP version.
[115] Bailenson, 2018 and Rahman, 2022.
[116] Article 5(1)(ba) (new) (Amendment 217) and Article 5(1)(dc) (new) (Amendment 226) AIA EP version.
[117] Annex III AIA EC version, ER version, EP version.

both promising and high-risk applications of immersive technology are in use or likely to be used (see Chapters 2 and 3).

Providers of such systems may soon have to comply with hefty regulations. For example, systems must have a ‘risk management system’ and a ‘leaflet’ for users. There will also be requirements for technical resilience, data training and management, human oversight, and cybersecurity.[118] These requirements aim to protect non-discrimination and privacy. The EP takes it further, with a mandatory fundamental rights impact assessment.[119] Ultimately, much is going to depend on the standards yet to be completed, which will, for example, specify when there are ‘appropriate risk management measures’.[120]

AI systems with limited risk in all categories only have to meet certain transparency requirements. These requirements make sure that users are not misled. People interacting with AI systems should soon be made aware of this, especially when they encounter an AI-generated avatar or chatbot algorithm.

In addition, the EC and ER proposals include transparency obligations for emotion recognition systems and biometric categorisation systems (the EP proposal elaborates this, as described above). Users of such systems (i.e., not providers) must inform data subjects.[121]

The DSA also contains provisions that address the use of physical and behavioural data by XR platforms. For example, the DSA prohibits profiling based on special data for the purpose of displaying advertising.[122] However, the DSA does not prohibit all forms of profiling based on special personal data. This may be changed by the AI Act (see above). This act does require very large online platforms (such as Facebook and YouTube) and search engines (such as Google Search and Bing) to create at least one version of their recommendation systems that does not use profiling.

Furthermore, the DSA contains several provisions that improve the information position of users of so-called intermediate trade services. These may include certain XR services, such as a social meeting platform in XR. These services must be transparent in their terms and conditions about their method of content moderation and algorithmic

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[118] Article 8 to 15 AIA EC version, ER version, EP version.
[119] Article 29 a (new) (Amendment 413) AIA EP version.
[120] In the design of the "harmonized standards" are involved, among others: the EC, European standards organisations (CEN, CENELEC and ETSI), national standards organisations such as Forum Standaardisatie, and European stakeholder organisations. Only when the AI regulation is final, a draft version is started. After this, stakeholders through national standards organisations are allowed to give advice. Before the law comes into force (probably early 2025), the standards will be published in the Official Journal of the European Union. For more information see Pouget, z.d., McFadden et al., 2021 en Veale & Borgesius, 2021.
[121] Article 52(1) and (2) AIA EC version, ER version, EP version, European Parliament News, 2023 and Murphy et al., 2021. Note: A system can simultaneously fall into a high risk category.
[122] Article 26(3) European Parliament and Council of the European Union, Regulation (EU) 2022/2065 of the European Parliament and of the Council of 19 October 2022 on a Single Market for digital services and amending Directive 2000/31/EC (Digital Services Regulation), October 2022. This follows the GDPR definitions of profiling (AVG, Article 4(4)) and special categories of personal data (AVG, Article 9(1).

decision-making.[123] In addition, XR platforms must make advertising clearly identifiable and clearly inform users why they are being shown certain advertisements.[124] XR platforms should also not create misleading interfaces that limit users' ability to make choices.[125] This should counteract deceptive design (also known as *dark patterns*).[126]

Finally, platforms with at least 45 million monthly users must identify and combat systemic risks.[127] No XR platforms have been identified as major parties at the time of writing, but that may happen in the future. These are systemic risks in relation to freedom of expression and information, including disinformation and manipulation. Additionally, relevant for immersive technologies are risks to personal data protection and non-discrimination. It is still open to what detail XR platforms should map the impact of their services and how they should act accordingly. This requires continued attention from policymakers and regulators.

Supervision

In the Netherlands, much of the supervision will be the responsibility of the Autoriteit Persoonsgegevens (Personal Data Authority or AP) and the Autoriteit Consument en Markt (Consumer and Market Authority or ACM). They cooperate with other relevant regulators through the Samenwerkingsplatform Digitale Toezichthouders (Digital Regulators Cooperation Platform or SDT). A session with regulators revealed that there are still questions about the division of roles and cooperation in the enforcement of the various policy instruments (see Appendix 1). For example, it appears to be challenging to determine which regulator is responsible for scrutinising an XR service. This is partly because it depends on the type of service, the type of data being collected, the location where data is stored and how that data is processed. With immersive technologies, many regulators do not have enough knowledge to properly assess these elements.

4.3 Incentive measures

Besides measures that mitigate risks, there are also several policy instruments aimed at improving the chances for Dutch and European companies on the XR market. We will discuss the investment from the Creative Industries Immersive Impact Coalition (CIIIC) growth fund and the European Initiative on Virtual Worlds, as these instruments specifically target immersive technologies. We also briefly discuss the Digital Markets Act (DMA), as one of its goals is to achieve a fairer business environment in the digital domain. This will create more opportunities for European companies to compete and innovate.

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[123] Artikel 14 DSA.
[124] Article 26 DSA.
[125] Article 25 DSA.
[126] Patterns that purposely or effectively deprive users of the ability to make informed choices.
[127] Article 34 en 35 DSA.

Growth fund

The Dutch government stimulates the XR industry through the National Growth fund and top sector policies.[128] The Growth Fund will invest 200 million euros in the CIIIC in the period of 2024-2028. The CIIIC is an initiative of CLICKNL, the top consortium for Knowledge and Innovation of the creative industry. Project partners are the ministries of OCW and EZK and creators, representatives of application domains, knowledge institutions and partners from the XR industry. The CIIIC aims to stimulate applications in gaming, media & entertainment, the manufacturing industry and government services.[129] The coalition plans to do this by developing training modules for the application of immersive technologies. Furthermore, the CIIIC wants to conduct research on the impact of XR on users and facilitate experimentation centres.[130]

According to the Growth fund, the CIIIC addresses a number of bottlenecks in the Dutch XR industry, such as a shortage of knowledge and human capital, and an overly fragmented ecosystem. The Growth fund expects that with the CIIIC, global growth can be maintained.[131]

European Initiative on Virtual Worlds

In June 2023, the European Commission published the Initiative on Web 4.0 and Virtual Worlds.[132] The Commission envisions Web 4.0 as a world in which digital and physical environments blend fluidly with the help of AI and XR. The Commission wants to develop an open web 4.0, in which users can freely switch between networks and platforms with freedom of choice.[133] The Commission is committed to a situation where European companies can grow and develop innovative applications.[134] Part of the effort is to capitalise on opportunities offered by virtual worlds in the health, education & training, cultural and digital services industries.

If the CIIIC project and the European strategy are successful, Dutch knowledge about XR will increase and a European market with (technical) market standards will emerge in which European companies can grow and develop new XR applications. With this, the strategy aims to combat European dependence on multinational platforms for XR hardware, software and applications.

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[128] Rijksoverheid, 'Nationaal Groeifonds'.
[129] CLICKNL, 'CLICKNL'.
[130] CLICKNL.
[131] Rijksoverheid, 'Creative Industries Immersive Impact Coalition (CIIIC). Projects round 3'.
[132] The Commission distinguishes Web 4.0 from Web 3.0. Web 3.0, according to the Commission, is about decentralisation and increased ownership for users.
[133] European Commission, 4.
[134] European Commission, 4.

DMA

De Digital Markets Act (DMA) is a European regulation that introduces rules on how gatekeepers are allowed to do business in the EU. Gatekeepers are large digital platforms that provide 'core platform services' such as online search engines, social media and operating systems.[135] [136] Goals include a fairer business environment, increased supply, better services and fairer prices.[137] Although some gatekeepers do offer XR services, none are currently large enough to be covered by the law. Because that may change in the future, we discuss some key points below:

- Gatekeepers may no longer direct users toward making a specific purchase and thereby benefit themselves.[138] This means that on a social VR media platform, all advertisements of virtual products should be equally visible.
- The DMA makes it easier for users to switch to alternative providers. For example, future XR gatekeepers may no longer mandate the use of proprietary app stores (such as Oculus).[139] This may mean that users will not be limited to the use of the pre-installed game store on VR glasses, but may also install an alternative. In addition, users should be allowed to effectively transfer data to alternative services.[140]
- Gatekeepers are no longer permitted to combine collected data with data from third-party or other provider-owned platforms.[141]

In short, in the case of large-scale adaptation of XR, the DMA theoretically makes it more difficult to create or maintain dominant market power in the XR sector. This reduces the risk of digital dependence.[142]

4.4 Conclusion

The policy field around immersive technologies is in flux and is focused on protecting the public values at stake in widespread adoption of these technologies. In particular, the combination of the GDPR, DSA, and AI Act (especially in the EP version) seems to limit the potential for influence and manipulation based on physical and behavioural data collected in XR.

At the same time, there are also several policy gaps and ambiguities. For example, a variety of potentially highly sensitive physical and behavioural data may indeed be

[135] Article 2 European Parliament and Council of the European Union, Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector, and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Regulation), 14 September 2022.
[136] These services may also be available via XR devices, such as a social VR media platform, an operating system for headset operation, or a VR Appstore (think Google Play or Oculus).
[137] European Commission, 'Verordening inzake digitale markten', z.d.
[138] Article 6 lid 5 DMA.
[139] Article 6 lid 3 DMA
[140] Article 6 lid 9 DMA.
[141] Artikel 5 lid 2 DMA.
[142] Hupont Torres e.a., *Next Generation Virtual Worlds*, 60, 2023.

collected by XR providers if users give their consent. With the resulting risk of function creep and misuse of data. There is also uncertainty about the protection of neurodata.

It is difficult to obtain an overall picture of the policy gaps that remain when it comes to the risks of immersive technologies. Whether a given risk is covered depends on many criteria that may vary from case to case: what kind of data is involved, what kind of processing is involved, and what kind of application is involved? In addition, the protection provided by the current policy instruments depends on the further interpretation of the various European policy instruments (DSA, DMA and soon the AI Act). And, of course, on the effectiveness of enforcement and supervision.

We have also discussed a number of incentives that create opportunities for the Dutch and European industry in the XR market. But with investments in immersive technologies and wider adaptation of these technologies in society, the risks we discussed in Chapter 3 become more plausible. In the next and final chapter, we offer suggestions on how to avoid them.

5 Options for action

In this Rathenau Scan, we described what immersive technologies are and how they work (Chapter 1). We described the opportunities for applications in different societal domains (Chapter 2) and we analysed the risks to society and public values (Chapter 3). Risks to privacy, self-determination, democracy and health stem from the specific characteristics of immersive technologies. The far-reaching digitalisation of our society, of which immersive technologies are a part, poses risks to participation, inclusivity, non-discrimination and sustainability.

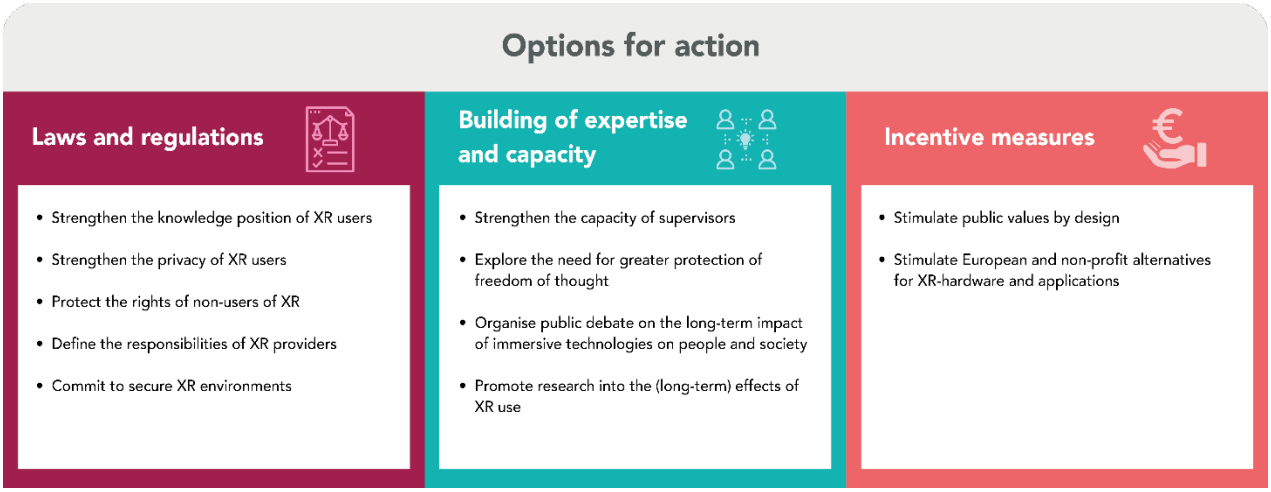
Immersive technologies can become very personal and can collect even more physical and behavioural data about us than current computer and smartphone technology. In doing so, people reveal very intimate information about themselves that can be used against their own or public interest. In addition, the blurring of the boundaries between the physical and virtual worlds contributes to hyper-personalisation, which can lead to the erosion of a shared, common reality.

It remains difficult to predict whether immersive technologies will break through on a large scale. So far, the realised market size of XR has consistently fallen short of forecasts, and a large-scale consumer breakthrough has yet to happen. Tech companies and investors have an economic interest in a future in which XR is adopted on a large scale. In the current situation, where immersive technologies have not yet broken through on a large scale, the opportunity arises to adjust the further development and implementation of the technologies from the interest of public values.

The policy analysis (Chapter 4) shows that existing and forthcoming legislation already limits opportunities for influence and manipulation based on physical and behavioural data collected in XR. But there are also gaps and uncertainties. We have identified several incentives that seek to increase opportunities for European companies in the XR market. But with a larger market, the risks become more serious.

In this chapter, we offer policymakers and politicians several options for action to mitigate the risks around immersive technologies and to seize opportunities. We divide the action options into three categories: legislation and regulation, knowledge and capacity building, and incentives.

Figure 8 Options for action for policymakers and politicians



5.1 Laws and regulations

Strengthen the information position of XR users

XR devices collect various types of physical and behavioural data, many of which require user consent under the GDPR. As we saw in Chapter 4, the required consent as related to XR raises several practical questions. If users are not aware of what data is being collected about them and what the data is used for, the consent given is not meaningful. At the very least, according to the GDPR, providers must explain in an understandable way what type of personal data is collected, how it is processed, for what purpose and for how long it is kept. In practice, this does not happen sufficiently. Information about the analysis and processing of data by currently available XR devices proved difficult to access during this study.

In order to strengthen the information position of XR users, it is recommended that data traffic between XR glasses is independently investigated, consumers are informed of the results, and providers are held to their obligations when it comes to the provision of information consent.

Strengthen the privacy of XR users

Very intimate information can be derived from physical and behavioural data, such as eye, head and body movements, heart rate and brain activity, which all can be collected via XR devices. As we saw in Chapter 4, the combination of the GDPR, AI Act and DSA certainly provides protection against certain types of data analysis and application. But if large-scale data collection continues, there is a risk of misuse through function creep and manipulation, even if prohibited by law.

We see several courses of action to protect the privacy of XR users. One such option is to broaden the concept of 'biometric data' derived from the GDPR. 'Biometric data' receives special protection in the GDPR, but as we saw in Chapter 4, the definition is quite limited. In the context of the AI Act, the EP proposes to broaden this concept. However, the definition is also found in the GDPR and the related DSA, so it is recommended to look for opportunities to broaden the definition there as well. This would offer special protection to a larger portion of physical and behavioural data that can be collected via XR, such as pupillary reflexes and neurodata.

Another option is to prohibit the collection of certain types of data, as the risks of misuse are too great. Important concerns here are, again, pupillary reflex and neurodata collection. Both types of physical and behavioural data can reveal so much intimate information that policymakers and politicians should question whether it is safe to do so in large-scale consumer applications.

A third option is to bring attention to the ‘prior consultation’ requirement under the GDPR. This means that when new ways of data use by XR providers lead to overtly large or unaccountable risks, they must first seek permission and advice from the regulator, the Personal Data Authority.[143] Such risks exist for XR-BCI combinations and the analysis of pupillary reflexes. We do not know whether these consultations have already taken place, but if not, the Personal Data Authority could proactively alert providers to this obligation.

Protect the rights of non-users of XR

Non-users of XR devices have no way to read a privacy notice when confronted with sensors of XR users in public spaces. If XR devices and applications were to break through into society on a large scale, it could affect the privacy and self-determination of non-users, such as when others apply an AR filter to them, or when the character of a public space changes significantly because XR users use it differently (think Pokémon-Go). Policymakers and politicians might consider making it clear to the developers of XR devices and applications which uses of XR in public spaces they consider (un)desirable, thereby being able to guide continued development. Given the risks to self-determination and democracy, a ban may even be considered.

If XR were to break through on a large scale, the rights of non-XR users are also at stake in another way. As society continues to digitise, the gap between those who can benefit from digital technology and those who cannot is widening. This underlines the importance of the ‘Everyone can participate’ policy initiated by the government.[144] This should not just be about teaching digital skills. The option to not participate should also remain available.

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[143] Article 36 AVG and Autoriteit Persoonsgegevens, z.d.
[144] Ministry of General Affairs, "Work Agenda on Value-Driven Digitization - Report - Rijksoverheid.nl," Nov. 1, 2022.

Define the responsibilities of XR providers.

We have seen that with a potential breakthrough of immersive technologies, serious societal risks arise and public values come under pressure. With a major societal impact, comes a major social responsibility for companies to prevent and mitigate risks.[145] There are several routes to establishing and enforcing the responsibility of XR providers with laws and regulations. Below we discuss two laws under development within the EU at the time of writing.

The AI Act can provide protection with respect to a variety of current and potential applications of immersive technologies that pose risks to (mental) privacy, self-determination, security, and health. Several proposals put forward by the European Parliament succeed in doing so, including the following proposals:

- An expansion of biometric data protection to include 'biometric-based data,
- an expansion of the prohibition of subliminal techniques,
- a broadening of the prohibition of the abuse of human vulnerabilities,
- a ban on the use of biometric systems for real-time remote identification in public places,
- transparency on interaction with AI systems, such as an AI-generated avatar or chatbot algorithm in XR, and
- a requirement for providers of high-risk AI systems to conduct a fundamental rights impact assessment.

In addition, policymakers and regulators need to pay specific attention when the standards for AI systems are being constituted, as these will determine what will be considered an appropriate risk measure.[146]

Even if the above laws and regulations are adopted, policymakers and politicians will have to consider the need for further regulation. Because this is a rapidly developing field, not all potential AI risks are yet known, and XR is not specifically or directly addressed in the AI Act.[147]

The Corporate Sustainability Due Diligence Directive – also currently in trilogue in Europe – offers an opportunity to set a legal precedent when it comes to the social responsibilities of large XR providers. This emerging law places an obligation on large companies to identify, act on and be accountable for their societal risks. Using the principle of 'due diligence', this law offers room to address future risks as well. Companies that do not (yet) fall under certain regulations can thus at least be given a basic responsibility to respect human rights and the environment.[148]

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[145] OECD, 'Guidelines for MNEs - Organisation for Economic Co-Operation and Development'; B-Tech, 'The UN Guiding Principles in the Age of Technology - A B-Tech Foundational Paper', 2020.
[146] Veale and Borgesius
[147] See: Car, Madiega, en Niestadt, 'Metaverse. Opportunities, risks and policy implications', 7, 24 June 2022.
[148] Ministry of Foreign Affairs, "NCP Analysis of Draft CSDD using OECD Guidelines - Publication - National Contact Point OECD Guidelines," July 26, 2023; European Commission, 'Corporate Sustainability Due Diligence Directive', 23 February 2022.

Invest in safe XR environments

Research has identified several security risks stemming from immersive technologies, including identity abuse, virtual vandalism, virtual sexual assault and rape. Given the risks of individual harm and risks to the mutual trust of citizens and democratic processes, identity abuse is a key concern.[149] The Cabinet indicated in a June 2023 Cabinet response to two studies that a ban on impersonation was going too far.[150] It is therefore important to explore how users in XR can maintain control over their own image and prevent identity abuse.

Virtual vandalism is not currently criminalised.[151] This could be solved by using a technology-independent interpretation to broaden the legal understanding of harm to include virtual harm.

Furthermore, given the real risk of virtual sexual assault and rape, it may be helpful to examine, using concrete (future) scenarios, what gaps remain for protection against virtual sex crimes with the new Sexual Offenses Bill. The government could also consider providing clarity on the interpretation of this law in relation to virtual sex crimes.[152]

Clarifying standards at a time when a technology has not yet broken through can offer developers guidance. It also gives users visibility into what is and is not permissible, and can deter potential offenders.

5.2 Knowledge and increasing capacity

Strengthen the capacity of supervisors

The combination of much new legislation from the EU and rapidly developing technologies such as XR and generative AI, presents a huge challenge for regulators. They need funding and knowledge to monitor XR devices and applications.

Our research provides some suggestions for this:

- Working with scenarios of concrete, hypothetical situations of rights violations in relation to XR can help regulators clarify their role and more sharply identify which

[149] Rathenau Instituut, 'Responsible VR. Protect consumers in virtual reality', 2019; Schermer en van Ham, 'Regulering van Immersieve Technologieën', August 2021.
[150] *Kamerstukken II* 2022/2023, 26 643, nr. 1041, appendix II
[151] Schermer en van Ham, 'Regulering van Immersieve Technologieën', August 2021.
[152] The JRC, the European Commission research agency that has conducted research for the EU on opportunities and risks of virtual worlds, also writes that legislation may need to be reinterpreted. See: Hupont Torres e.a., *Next Generation Virtual Worlds*, 34, 2023.

parts of immersive technologies will fall under the GDPR, DSA, DMA and upcoming AI Act, for example.
- EU oversight of the DSA and soon AI Act could explicitly call attention to platforms with immersive elements and insist on risk assessments and mitigation plans where necessary.
- Periodic monitoring of the effectiveness of supervision and enforcement in the context of immersive technology could help identify any gaps in supervision in a timely fashion.

Explore the need for greater protection of freedom of thought

In Chapter 3 we described the risks associated with the ability of neuro technologies, such as BCI, to measure users' brain activities. There has already been an international debate about the need for protection of neuro-rights. In France[153], Spain[154] and Great-Britain[155] there are already initiatives in place to protect citizens against the risks of analysing brain activities.

We urge joining the international debate on neuro-rights and to explore whether adjustments to human rights frameworks are desirable and can guarantee freedom of thought. A UN report on neuro-rights is expected to be published in 2024 and will be the subject of a debate.[156]

Organise the public debate about the long-term impact of immersive technologies on people and society

In 1997, the development of biomedical technology led to the Convention on Human Rights and Biomedicine (Oviedo Convention). This convention protects human dignity when it comes to technology in our bodies.[157]

The same protection of human dignity does not yet exist for immersive technology, which does not yet crawl inside our bodies, yet is very close to our senses. Hyperpersonalisation and the introduction of even more digital technology into our daily lives can drastically change how we interact with each other. This means that the promotion and application of immersive technologies should take a close look at how it

[153] International Bioethics Commission, ‘Ethical issues of neurotechnology’, 2021.
[154] La Moncla, ‘The Government Adopts the Digital Rights Charter to Articulate a Reference Framework to Guarantee Citizens" Rights in the New Digital Age’, 14 July 2023.
[155] Department for Science, Innovation and Technology, ‘Regulatory Horizons Council’, 30 November 2022.
[156] UNESCO, ‘Ethics of Neurotechnology’, 17 July 2023.
[157] Van Est, R. & J.B.A. Gerritsen, with the assistance of L. Kool, Human rights in the robot age: Challenges arising from the use of robotics, artificial intelligence, and virtual and augmented reality – Expert report written for the Committee on Culture, Science, Education and Media of the Parliamentary Assembly of the Council of Europe (PACE), The Hague: Rathenau Instituut 2017

contributes to public values, and what is potentially lost. For example, immersive technologies should contribute to more human contact, and not less.

By engaging society early on in thinking about the potential impact and desired development of immersive technologies, policymakers and politicians can contribute to technological citizenship, empowering citizens and consumers.

Promote research on (long-term) effects of using XR

There is virtually no visibility into the long-term mental and physical health effects of consumer use of XR. Many researchers point to the many research questions about the risks that would need to be answered (see Chapter 2).

There is also uncertainty about the expected environmental effects. Currently, there are several claims about the environmental gains that could be achieved with immersive technologies, for example by reducing people's travel movements and consumption of products. On the other hand, the software processes a lot of data, which consumes a lot of energy and resources. It is recommended to calculate different scenarios of the use of immersive technologies to obtain a realistic picture of the possible environmental gains and costs of a future with immersive technologies.

5.3 Incentive measures

Stimulate public values by design

When XR hardware, software and applications are still being developed, is exactly the right time to consider risks to public values in the initial design. The software code of immersive technologies can shape online environments and influence user behaviour. For example, developers can choose to develop a privacy bubble option, which allows users make sure that there is no way to chat with them privately. They can make it impossible to get too close to another user's avatar, or developers can set a speed limit at which the devices can be safely used to prevent them from being used in traffic. [158] [159] Manufacturers can choose to equip immersive devices with as few sensors as possible so that a minimal amount of data is collected. This data can be analysed on the device (on device processing) to protect the user's privacy.

When governments encourage the development of immersive technologies through grants and other investments, they ask that proposers demonstrate how they contribute socially, and what they do to avoid risks.

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[158] Fernandez en Hui, 'Life, the Metaverse and Everything', 24 March 2022.
[159] Culliford, "Facebook Owner Meta Adds Tool to Guard against Harassment in Metaverse," February 4, 2022.

Encourage European alternatives to XR hardware and the development of public immersive spaces

One of the risks we describe in this scan is the continued or increasing dependence on private parties for XR services. One way to limit that risk is by encouraging European alternatives and investing in non-profit open source alternatives. In its vision on virtual worlds, the European Commission states that it is committed to a European market in which European companies can scale up and compensate internationally. That would solve part of the problem. Furthermore, it is important that these companies base their products on public values, otherwise the aforementioned risks will materialise.

In addition, it could be useful to already start working on a public XR space in the Netherlands. For example, the non-profit network Pubhubs is creating a community platform as an alternative to the use of social media by public institutions. Such an approach helps include public values in the design phase, discover what challenges people face and create additional policy. This contributes to building knowledge and capacity for immersive technologies within the Netherlands, ultimately establishing an independent position.

5.4 Conclusion

This chapter outlined a number of options to limit the risks of immersive technologies. However, these technologies come with several inherent risks that will persist to some extent once the technologies are widely adopted. This involves the intimate data that is or will be collected in the future. Once this data is available, they can be used for purposes against the public interest. We know that this is a real risk from the many examples we have previously discussed (see Chapter 3).

Politicians face difficult choices about various fundamental issues: how can immersive technologies help strengthen public values (for example in therapeutic applications that demonstrably yield health benefits). Where should these technologies *not* be applied at all, because they affect public values too much (for example: large-scale adoption of data-collecting XR devices in schools)? Are there certain types of data, such as neurodata and pupillary reflexes, that should never be collected, because they reveal so much personal information, and abuse is a realistic concern? To what extent is further hyper-personalisation desirable in public spaces, or should certain domains remain XR-free?

Because immersive technologies have not yet been implemented on a large scale, policymakers and politicians now have the opportunity to steer the development and adaptation of these technologies. A common fear among policymakers is that

regulations will inhibit innovation, but there is also another possible perspective. [160] The Rathenau Instituut previously wrote an essay about the relationship between policy and technical innovations. We showed that regulation can also play a stimulating and guiding role in technological innovations. Consider, for example, the innovation-stimulating effect of the strict emission standards for vehicles or the (implicit) ban on light bulbs. Regulations can also prevent controversial innovations: consider, for example, the ban on cloning.[161] Policies can discourage certain development directions by banning the collection of specific types of data and criminalising behaviour. The challenge for policymakers and politicians is to determine how the government wants to adjust the innovation dynamics surrounding immersive technologies, based on its obligation to protect the rights of citizens and public values.

[160] Minister voor Rechtsbescherming en Minister van Justitie en Veiligheid, 'Kamerstukken II 2022/2023, 26 643, nr. 1041', 16 juni 2023, 16 June 2023.
[161] Rathenau Instituut, 'Met beleid vormgeven aan socio-technische innovatie. Essay in opdracht van de directie Kennis en Innovatie Strategie van het Ministerie van Infrastructuur en Milieu', 2016.

Appendix 1 (Dutch). Consulted policymakers, experts and regulators

Participants working session policymakers, 16 May 2023

1. Bram de Rijk, ministerie van Infrastructuur en Waterstaat
2. Constantijn van der Eijk, (voormalig) ministerie van Binnenlandse Zaken en Koninkrijksrelaties
3. Dorine Dollekamp, ministerie van Binnenlandse Zaken
4. Ervin Ehlert, ministerie van Infrastructuur en Waterstaat
5. Gerard Munters, Belastingdienst
6. Jeroen Vonk, Sociale Verzekeringsbank
7. Lars Hulzebos, Uitvoeringsinstituut Werknemersverzekeringen
8. Lieske van Hemert, Belastingdienst
9. Marian Luursema, Politie
10. Noor Huijboom, ministerie van Binnenlandse Zaken en Koninkrijksrelaties
11. Pauline Arts, Rijkswaterstaat
12. Shaif Ismail, ministerie van Binnenlandse Zaken en Koninkrijksrelaties

Expert session participants, 13 June 2023

1. Bart Schermer, Considerati
2. Christiaan Fruneaux, De Chrononauten
3. Eugene Kuipers, Fectar
4. Francisca Wals, ministerie van Binnenlandse Zaken en Koninkrijksrelaties
5. Frederike Mandes, Hogeschool Rotterdam
6. Gijs Huisman, Technische Universiteit Delft
7. Harmen van Sprang, Sharing Cities Aliance
8. Isabelle Udo, VideOrbit Studio
9. John Walker, SURF
10. Rivka van de Sande, ministerie van Binnenlandse Zaken en Koninkrijksrelaties
11. Rufus Baas, Metaverse Werkplaats
12. Sander Veenhof, SNDRV
13. Sebastiaan Crul, Freedom Lab
14. Tilo Hartman, Vrije Universiteit Amsterdam
15. Tom Demeyer, Waag
16. Shaif Ismail, ministerie van Binnenlandse Zaken en Koninkrijksrelaties
17. Sylvie Dijkstra-Soudarissanane, TNO

Participants session supervisors, 21 August 2023

1. [Naam bekend bij Rathenau Instituut], Rijksinspectie Digitale Infrastructuur
2. Fiona Vening, Reclame Code Commissie
3. Jan Willem Zevenhuizen, Inspectieraad
4. Jorien Scholtens, Commissariaat voor de Media
5. Justin Hoegen Dijkhof, College voor de Rechten van de Mens
6. Sela Kooter, Commissariaat voor de Media
7. [Naam bekend bij Rathenau Instituut], Rijksinspectie Digitale Infrastructuur
8. [Naam bekend bij Rathenau Instituut], Autoriteit Persoonsgegevens

Interviewees

Artificiële Intelligentie Verordening

1. Floris Kreiken, ministerie van Binnenlandse Zaken en Koninkrijksrelaties
2. Monika Milanovic, ministerie van Binnenlandse Zaken en Koninkrijksrelaties

Wet inzake Digitale Markten

1. Judith Nivard, ministerie van Economische Zaken en Klimaat
2. Mijntje Jansen, ministerie van Economische Zaken en Klimaat

Wet inzake Digitale Diensten

1. Caroline de Vries, ministerie van Economische Zaken en Klimaat
2. Maarten van Waveren, ministerie van Economische Zaken en Klimaat
3. Rivka van der Sande, ministerie van Binnenlandse Zaken en Koninkrijksrelaties

Appendix 2. Popular XR-devices available on the market

Name	Year	Developer	Sensors	Application
Hololens 2	2019	Microsoft	Depth camera, IMU, eye tracking	Augmented reality, industrial applications
Meta Quest 2	2020	Meta	Gyroscope, accelerometer, proximity sensor, 4 infrared cameras, front-facing cameras	Gaming, VR experiences, social interaction, education
Pico 4	2021	ByteDance	Gyroscope, accelerometer	Gaming, VR experiences
HTC Vive Pro 2	2021	HTC	SteamVR tracking, gyroscope, accelerometer, proximity sensor (proximity), interpupillary distance sensor	Gaming, professional use
Meta Quest Pro	2022	Meta	Gyroscope, accelerometer, proximity sensor, 5 infrared eye and face tracking sensors	Gaming, professional use, development
Varjo XR-3	2023	Varjo	LiDAR, cameras for eye tracking, cameras for position tracking	Professional use, simulation, training
Magic Leap 2	2023	Magic Leap	Depth camera, RGB camera, 3 cameras for position tracking, ambient light sensor, 2 cameras for eye-tracking, accelerometer, gyroscope, altimeter, magnetometer	Augmented reality, entertainment, professional use
Sony Playstation VR 2	2023	Sony	Accelerometer, gyroscope, camera-based tracking, IR cameras for eye tracking	Gaming, VR linked to PlayStation with USB-C cable

Source: Rathenau Instituut, based on technical specifications of XR devices

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