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DEVELOPMENTS IN THE FIELD

Human Rights Risks from Immersive Technologies

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Abstract

Immersive technologies, such as augmented reality (AR) and virtual reality (VR), allow people to immerse themselves in a complete virtual environment, or enhance the physical world with digital elements. Also referred to as extended reality (XR), these technologies create experiences that feel real, whether fully or partially virtual. The impact of XR on human rights and society is linked to a large-scale consumer breakthrough, which could pose significant human rights risks. This article discusses these risks through the lens of four public values rooted in human rights instruments: privacy, autonomy, non-discrimination and a clean and healthy environment. It highlights the urgency for governments to protect and companies to respect the rights of both XR users and non-users. The aim is to initiate discussions on early interventions, avoiding missteps seen during the rise of social media, when benefits were encouraged, while risks were overlooked.

Keywords: autonomy; human rights; immersive technologies; privacy risk; mitigation

I. Introduction

While the metaverse hype may be over, some of the major technologies behind it, so-called immersive technologies, are still heavily invested in by big technology companies like Meta and Apple. A recent study by the Rathenau Instituut shows these technologies are accompanied by considerable human rights risks.[1] Partly based on the study, this article aims to raise awareness and understanding among business and human rights scholars about the characteristics of these technologies, technological trends and human rights risks involved. Early interventions are needed to avoid missteps made during the rise of new technologies such as social media, when benefits were encouraged, while risks were overlooked.

II. Immersive Technology

Immersive technologies allow people to immerse themselves in either a complete virtual environment or enhance the physical world with digital elements. The two predominant

The Rathenau Scan Immersive Technologies https://www.rathenau.nl/en/digitalisation/immersive-technologies was summarized, amended and updated to create this paper. The original report was written at the request of the Ministry of the Interior and Kingdom Relations, to inform the Dutch government's policy agenda on immersive technology. The methods used are literature review, expert interviews and a workshop with policy-makers.

[1] A more detailed explanation of the state, workings and limitations of the technique, and a more comprehensive overview of the potential benefits and risks, as well as policy options, can be found in Rathenau Instituut, *Immersive technologies* (2023).

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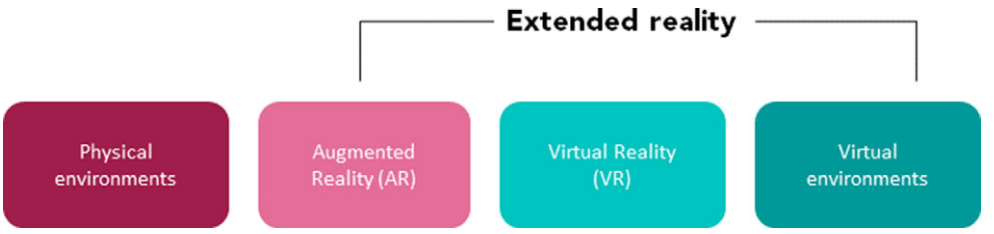


Figure 1. Extended reality continuum.

technologies are augmented reality (AR) and virtual reality (VR). AR provides a virtual layer over the physical world, like the smartphone game Pokémon Go; VR creates an entirely virtual three-dimensional (3D) environment. Immersive technologies are also known as extended reality (XR) because the physical environment is extended by merging or replacing it with a virtual one (see Figure 1).

Immersive technologies offer new kinds of experiences that feel real, even if fully or partially virtual. Through sensors, VR headsets, AR glasses and haptic devices, XR is literally more in touch with the skin than are laptops or smartphones. XR engages multiple senses, creating a feeling of 'presence,' resulting in lifelike and emotional experiences. Therefore, the distinction between fake and real does not seem apt for describing immersive experiences. More fitting would be to distinguish the physical from (partly) virtual experiences, which can all feel equally real from the user perspective.

A. Market Developments

In 2022, Meta, the company behind Facebook, WhatsApp and Instagram, was the global market leader in VR headsets, with a share of 81 per cent. Chinese DPVR and ByteDance, the company behind TikTok, both had a seven per cent share in 2022, making them the second and third biggest market players.[2] Apple made its XR debut in February 2024. The number of VR headsets sold in 2022 amounted to 9.1 million worldwide, according to statistical research firm Statista.[3] By comparison, 1.4 billion smartphones were sold that year.[4]

There is a large gap between the optimistic predictions about the XR market in previous years and its actual size in 2022: $30 billion.[5] In 2017, Consulting firm McKinsey & Company predicted that the XR market would yield $60 billion in profits by 2022. Earlier, XR analytics firm Digi-Capital estimated it to be $150 billion by then.[6] Nevertheless, predictions for the future XR market remain substantial: the European Commission quotes predictions of a €800 billion market by 2030. Statista, however, now estimates it to be worth $62 billion in 2029, so predictions vary.[7]

[2] Thomas Alsop, 'Extended Reality (XR) Market Size Worldwide from 2021 to 2026' *Statista* (March 2023), https://www.statista.com/statistics/591181/global-augmented-virtual-reality-market-size/ (accessed 29 August 2023).

[3] Thomas Alsop, 'Virtual Reality (VR) Headset Unit Sales Worldwide from 2019 to 2024' *Statista*, https://www.statista.com/statistics/677096/vr-headsets-worldwide/ (accessed 17 June 2024).

[4] Federica Laricchia, 'Number of Smartphones Sold to End Users Worldwide from 2007 to 2022' *Statista* (21 July 2023), https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/ (accessed 1 September 2023).

[5] Alsop, 'Extended Reality (XR) Market Size Worldwide from 2021 to 2026.'

[6] Mckinsey, 'Augmented and Virtual Reality: The Promise and Peril of Immersive Technologies McKinsey' (2017), https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/augmented-and-virtual-reality-the-promise-and-peril-of-immersive-technologies (accessed 29 August 2023).

[7] Verified Market Research, 'Metaverse Market Size and Rorecast' (March 2023), https://www.verifiedmarketresearch.com/product/metaverse-market/ (accessed 1 September 2023); Statista, 'AR & VR Worldwide. Statista Market Forecast' *Statista*, https://www.statista.com/outlook/amo/ar-vr/worldwide (accessed 30 May 2024); European Commission, *An EU Initiative on Web 4.0 and Virtual Worlds. A Head Start in the Next Technological Transition* (2023), 4.

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The impact of immersive technologies on human rights and society in general is strongly related to a large-scale consumer breakthrough, which has yet to happen. If it does, however, the human rights risks could be significant, both for consumers and non-consumers.

B. Use Cases

XR is already being applied and experimented with in sectors such as healthcare, training and education, entertainment, infrastructure, industry and art. Use cases include VR police training, trauma therapy, experiments with AR for anatomy lessons, 3D virtual environments for bridge design in international teams and AR assistance for order picking in distribution centres.[8]

These applications build on two main benefits of XR experiences, which stem from the strong feeling of presence and emotion: 'being' together despite physical distance, and life-like, seamless experiences through (partly) virtual scenarios. A third advantage often mentioned is efficiency, especially in the logistics sector, for instance, by delineating an optimal route using virtual signage within distribution centres, for employees to efficiently fulfil order picking.[9] However, available studies on applications often used a small number of participants; therefore, conclusions should be taken with caution, and additional research is needed.

C. Data Collection and Analysis in XR

To understand the impact of XR on human rights, it is crucial to understand the interaction between users, software and devices. The Cybernetic Feedback Loop, a model developed by the Rathenau Instituut, describes this interaction in three steps: data collection, data analysis and application (see Figure 2 for an example).[10]

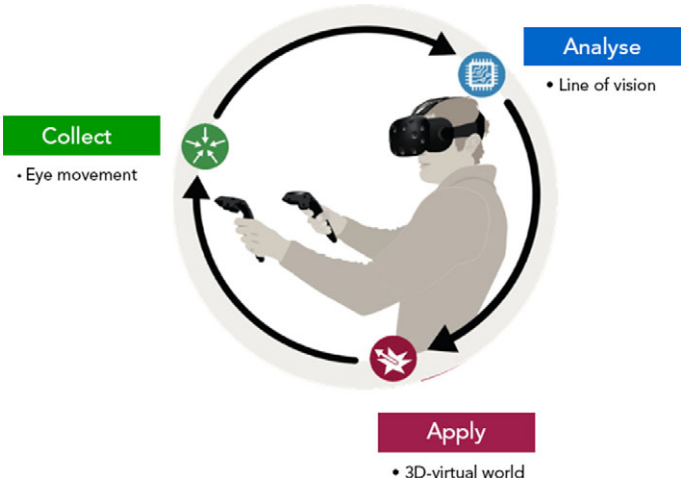


Figure 2. Cybernetic Feedback Loop.

[8] Rathenau Instituut, *Immersive Technologies.*

[9] Bjorn Schwerdtfeger, Rupert Reif, Willibald A. Gunthner, Gudrun Klinker, Daniel Hamacher, Lutz Schega, Irina Bockelmann, Fabian Doil, and Johannes Tumler, 'Pick-by-Vision: A First Stress Test' *2009 8th IEEE International Symposium on Mixed and Augmented Reality*, (2009), 115.

[10] Rathenau Instituut, *Urgent Upgrade. Protect Public Values in Our Digitized Society* (2017).

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Table 1. Possible types of physical and behavioural data processed through XR devices

Collect	Analyse	Apply
• Eye movements • Images of the user's environment • Location 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

All XR devices need to collect and analyse data from users and their surroundings to run an immersive experience; that is, to render and constantly adjust virtual elements based on user behaviour. Within the scope of our research, it is impossible to say with certainty what kind of data are collected by current XR devices. However, it was feasible to develop an overview (Table 1) of *possible* types of analysis and application of physical and behavioural data collected through different XR devices, based on information about sensors on existing XR devices, prototypes in development and existing data processing practices on smartphones and smartwatches.

III. Three Technological Trends

Three main trends in the technological development of XR impact human rights: datafication, hyper-personalization and manipulation.

A. Datafication

Immersive technology is accelerating data collection and analysis. More and more information, of an increasingly intimate nature, is being processed. As Table 1 shows, hand movements, pupil reflexes and potentially brain activity can be used to match the XR experience to the physical environment, as well as to infer states of mind, characteristics and preferences.

Besides click behaviour or search history collected from desktop browsers and smartphones, companies behind XR systems can profile users based on information about physical and behavioural activities that is collected predominantly unconsciously, e.g. movements, pupil reflexes, heartbeat, et cetera, can be monitored by measuring systems in XR headsets. Technology companies are also developing (experimental) combinations with brain

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computer interfaces to make XR experiences more interactive.[11] Measuring neuroactivities can lead to the processing of even more sensitive types of data, also known as neurodata.

B. Hyper-personalization

The (prototype) XR glasses, Galea, analyse brain and muscle activity. According to the company, the purpose is to measure emotions, stress levels and arousal. As a possible application, Finnish XR company Varjo mentions changing the colour of a virtual environment to alert users of their stressed or fatigued mental state.[12] Such technological developments contribute to the immersiveness of the virtual world and make user experiences hyper-personal. The integration of generative AI into XR also furthers hyper-personalization, for example, with personalized advertisements in XR environments, or with applications such as Replika, which provides users with a digital 'friend, partner or mentor' that tailors itself to each user and with whom users can share AR experiences.[13] This far-reaching form of personalization can further exacerbate the personal 'bubbles' people are already experiencing as a consequence of social media algorithms, and complicate shared perceptions of reality.

C. Manipulation

Finally, technical advancements in XR make it easier to manipulate user experiences in both virtual and physical environments. This can be illustrated with Pokémon Go, which manipulated users' perception and behaviour. The AR game managed to move players from public spaces to commercial locations in the physical world by planting game components there, nudging them to spend money. User movement in public spaces sometimes causes public nuisances due to the gathering of many Pokémon Go players, and causes harm when people are playing the game while driving.[14]

IV. Risks for Human Rights

States have obligations to protect XR users and non-users against arbitrary human rights interferences by XR companies, which in turn must respect human rights. To effectively discuss the rights most affected by the technological characteristics and trends of XR, they are clustered below around four important values: privacy, autonomy, non-discrimination and a clean and healthy environment.

A. Privacy

Article 12 of the Universal Declaration of Human Rights (UDHR) covers the rights to private life and correspondence, freedom from surveillance and data protection. Although certain types of data processing are necessary for XR to function, the amount of data currently

[11] See, for example, Tech at Meta, 'Inside Facebook Reality Labs. Wrist-based Interaction for the Next Computing Platform' (18 March 2021), https://tech.facebook.com/reality-labs/2021/3/inside-facebook-reality-labs-wrist-based-interaction-for-the-next-computing-platform/ (accessed 1 September 2023).

[12] Joseph Artuso, 'Neurotechnology and VR Combined. Meet Galea' *Varjo* (15 November 2022), https://varjo.com/vr-lab/combining-vr-and-neurotechnology-with-openbcis-galea/ (accessed 28 September 2023).

[13] 'Replika,' https://replika.com (accessed 1 May 2024).

[14] Redactie, 'Burgemeesters treden op tegen Pokémonjagers: avondklok in Jurbise, nachtelijk verbod in Lillo' *De Morgen* (26 September 2016), https://www.demorgen.be/nieuws/burgemeesters-treden-op-tegen-pokemonjagers-avondklok-in-jurbise-nachtelijk-verbod-in-lillo~bcd5129a/ (accessed 9 May 2025); Mara Faccio and John J. McConnell, 'Death by Pokémon GO. The Economic and Human Cost of Using Apps While Driving' (2020) 87:3 *Journal of Risk and Insurance* 815–49.

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collected and the sensitive information that can (potentially) be derived from it are not justified from a privacy rights perspective.

First, some of the big technology companies developing XR base their revenue models on data analysis and advertisements. This incentivizes them to keep adding new sensors to the already large variety their devices contain, resulting in data processing on a much larger scale beyond that of current smartphones.

Second, as illustrated by Table 1, an increasing amount of intimate information is or could be derived from the data collection, compromising subjects' privacy. Data thought to be anonymous proves to be far from it in practice. For instance, a 2023 study showed that based on five minutes of head and hand motion collected by VR devices, a user could be uniquely identified with 94.33% accuracy in less than two minutes, out of a pool of more than 55,000 users. With this, the scientists demonstrated VR biometrics' comparability to facial recognition and fingerprint identification systems.[15]

Other research shows physical and behavioural activities that are monitored, for example, measuring eye-tracking, can be linked to age, gender, ethnicity, sexual preference and medical diagnoses such as attention deficit hyperactivity disorder (ADHD) and autism.[16]

Third, collected data may be used for other purposes than initially collected, creating 'function creep.' Examples from current widely used technologies illustrate the risk of function creep when data are collected. For example, the app Muslim Pro reminded users when to pray and showed them Mecca's direction based on their location data, but then the US military accessed and used these data to inform special operations abroad.[17] Companies that process more and more information should realize that the more data that is collected, the higher the aforementioned risks are.

Lastly, risks that apply to users of immersive technologies may also apply to non-users, since sensors of immersive devices also analyse the user's surroundings.

B. Autonomy

Human rights instruments protect both physical and mental autonomy. More generally, Article 3 of the UDHR refers to the right to life, liberty and security (or inviolability) of a person. Through intuitive and covert influence, XR can be used to manipulate users, putting pressure on their *mental* privacy and self-determination.

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 how they respond to certain cues.[18] This means the sensitive data and inferences discussed above could be used to hyper-personalize (partly) virtual environments and nudge users towards consumption, but also to influence their ideas and views, for instance via computer-generated avatars.[19]

[15] Vivek Nair, Wenbo Guo, Justus Mattern, Rui Wang, James F. O'Brien, Louis Rosenberg, and Dawn Song, 'Unique Identification of 50,000+ Virtual Reality Users from Head & Hand Motion Data' (2023), 895.

[16] Suchismita Pahi and Calli Schroeder, 'Extended Privacy for Extended Reality. XR Technology has 99 Problems and Privacy is Several of Them' (2022) 4 *Notre Dame Journal on Emerging Technologies*; Gerulf Rieger, Brian M. Cash, Sarah M. Merrill, James Jones-Rounds, Sanjay Muralidharan Dharmavaram, and Ritch C. Savin-Williams, 'Sexual Arousal. The Correspondence of Eyes and Genitals' (2015) 104 *Biological Psychology* 56–64.

[17] Joseph Cox, 'How the U.S. Military Buys Location Data from Ordinary Apps' *Vice* (16 November 2020), https://www.vice.com/en/article/jgqm5x/us-military-location-data-xmode-locate-x (accessed 15 September 2023).

[18] Simon Elias Bibri and Zaheer Allam, 'The Metaverse as a Virtual Form of Data-driven Smart Cities: The Ethics of the Hyper-connectivity, Datafication, Algorithmization, and Platformization of Urban Society' (2022) 2 *Computational Urban Science* 2–22.

[19] Fiachra O'Brolcháin, Tim Jacquemard, David Monaghan, Noel O'Connor, Peter Novitzky, and Bert Gordijn, 'The Convergence of Virtual Reality and Social Networks. Threats to Privacy and Autonomy' (2016) 22:1 *Science and Engineering Ethics* 1–29.

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C. Non-discrimination

Article 2 of the UDHR states that everyone is entitled to the rights and freedoms set out in the Declaration, without distinction. Examples of protected discrimination grounds are race, sex, language, religion and political opinion.

First, widespread adoption of immersive technologies could amplify the risk of digitalization in general: the growing 'digital divide,' a widening gap between those who benefit from digital technology and those who do not, because they have unequal access to the technology, or are impacted more by its drawbacks.

Secondly, online harassment can be exacerbated. Harassment of groups already considered marginalized in gaming and VR, such as ethnic minorities, women and the LGBTQIA+ community, is an emerging (but understudied) problem. It ranges from racist and sexist comments to virtual violence and virtual touching without consent. In a study based on personal experiences of participants, it is noted that, unlike in other (two-dimensional [2D]) online social spaces, because of the focus on embodiment and immersion, these behaviours in social VR resemble offline harassment.[20]

Thirdly, XR devices and environments can be non-inclusive. For example, cybersickness appears to be experienced considerably more by women than men, possibly because XR headsets are designed for a male target group, which has a wider eye distance.[21] Furthermore, XR experiences sometimes lack diversity in avatar options, making it difficult for underrepresented users to translate their identity through virtual visual cues (such as wheelchairs or accurate portrayals of race). This could even lead to minorities renouncing XR, furthering the lack of representation and the digital divide.[22] Currently, insufficient research exists on how discrimination manifests itself in XR. An ethnographic study that included interviews with industry experts showed more knowledge is needed to design safe, accessible and inclusive immersive environments.[23]

D. Clean and Healthy Environment

In a general comment from 2019, the International Covenant on Civil and Political Rights (ICCPR) stated that 'environmental degradation, climate change and unsustainable development constitute some of the most pressing and serious threats to the ability of present and future generations to enjoy the right to life,' as protected by Article 6 of the ICCPR and Article 3 of the UDHR.[24] In 2022, the United Nations General Assembly adopted a resolution encompassing 'the human right to a clean, healthy and sustainable environment.'[25]

The data collection and processing for XR requires energy from data centres. Large-scale XR use will lead to the creation of many more data centres. Some innovators have claimed the opposite by speculating that XR applications could reduce travel CO2 emissions by improving remote collaboration, or replace part of the pollution of the fashion industry with

[20] Guo Freeman, Samaneh Zamanifard, Divine Maloney, and Dane Acena, 'Disturbing the Peace: Experiencing and Mitigating Emerging Harassment in Social Virtual Reality' (2022) 6:CSCW1 *Proceedings of the ACM on Human-Computer Interaction* 1–30.

[21] Xin Li, Ding-Bang Luh, Ruo-Hui Xu, and Yi An, 'Considering the Consequences of Cybersickness in Immersive Virtual Reality Rehabilitation: A Systematic Review and Meta-Analysis' (2023) 13:8 *Applied Sciences* 1–27.

[22] Ellysse Dick, 'Risks and Challenges for Inclusive and Equitable Immersive Experiences' (2021).

[23] Matteo Zallio and P. John Clarkson, 'Designing the Metaverse. A Study on Inclusion, Diversity, Equity, Accessibility and Safety for Digital Immersive Environments' (2022) 75 *Telematics and Informatics* 101909.

[24] United Nations Human Rights Committee, *General Comment No. 36. Article 6: Right to Life* (2019).

[25] United Nations General Assembly, *The Human Right to a Clean, Healthy and Sustainable Environment* (2022).

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a digital, more sustainable one.[26] But whether this outweighs the impact of additional data centres is unclear and needs to be studied.

V. Conclusion

VR and AR technologies are 'immersive' because of the life-like experience they offer, and the emotion and feeling of presence they invoke, resulting in an extension of reality. This makes XR suitable for all kinds of applications, ranging from entertainment to training to logistics. Big technology companies, including Meta and Apple, are investing heavily, with some predicting that these technologies will see a mass consumer breakthrough and will replace smartphones in the future. However, as this article has shown, the characteristics of XR together with the technological trends of datafication, hyper-personalization and manipulation also bring about significant risks for human rights, including risks to privacy, autonomy, non-discrimination and a clean and healthy environment.

This article has shown the urgency for governments to fulfil their duty to protect and companies to fulfil their responsibility to respect the rights of both XR users and non-users. The first harmful uses are already being witnessed. Technological developments are heading towards increased data processing, virtual environments are becoming hyper-personalized and more and more advanced manipulation techniques can be deployed. But a large-scale consumer uptake of XR has yet to come, which makes this the ideal time for policymakers and developers to take action and determine how to adjust and redirect the further development of immersive technologies from a human rights perspective.

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Competing interests. The Authors declare none.

[26] Zuzana Sidorová, 'Will Digital Fashion One Day Replace the Real One? The Future of Fashion in Technology,' *SLOVFLOW* (blog), October 29, 2021, https://slovflow.com/will-digital-fashion-one-day-replace-the-real-one-the-future-of-fashion-in-technology/ (accessed 20 November 2023).

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