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Working in the metaverse: what are the risks?

A rapid review of the literature

Pierre Bérastégui

Pierre Bérastégui is researcher at the European Trade Union Institute (ETUI) in Brussels, Belgium.

Introduction

The metaverse is a three-dimensional virtual space in which users can interact with objects and other users with the help of a digital avatar. It can be accessed by means of head-mounted displays (HMDs) that either fully immerse the user in a virtual world (i.e. virtual reality, or VR) or superimpose virtual elements onto the real word (i.e. augmented reality, or AR). The idea of a virtual space mimicking the real world gained traction in late 2021, when Facebook had rebranded to become 'Meta' and launched its metaverse 'Horizon World'. After a promising start, the interest in Horizon World faded, prompting Meta's competitors to revisit their marketing strategy. The emphasis is now on hardware – with the development of increasingly sophisticated AR headsets – whose purpose is decidedly more work-oriented (Bérastégui 2024). Major developers such as Apple and Microsoft are now positioning their immersive solutions as productivity tools. Meta has followed suit with the launch of its new HMD for business and professional users. Although practical work applications remain limited today, extended reality (XR) is now framed by GAFAM as the future of remote working and, as such, the next major evolution in the way we work. In this context, the anticipation and recognition of hazards arising from immersive workplaces that could impair the health and safety of workers is of critical importance. This technical brief aims to synthetise the available evidence on occupational health and safety risks associated with the use of XR (covering both AR and VR) technologies. To this end, a rapid review of the academic and grey literature was conducted, leading to the identification of five broad categories of hazards.

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Physical hazards

Multiple studies have highlighted issues related to the distance between the eyes and the screens of HMDs. The screen is only a few centimetres from the eyes and covers a large proportion of the field of vision, greatly increasing exposure to light – especially blue light – compared to a traditional screen. The discomfort it causes, long known as 'computer vision syndrome' (CVS), includes headaches, dry, itchy eyes and blurred vision. A recent study showed that, in order to prevent these symptoms, a session should last no longer than 55 70 minutes (Kourtesis et al. 2019). A French survey has suggested that this limit is not always observed for professional uses, as the average length of a VR or AR session was shown to be 75 minutes when deployed in public spaces, 79 minutes for health care and rehabilitation purposes, and 66 minutes in walk-in immersive 3D environments (ANSES 2021).

Blue light is known to supresses the production of melatonin, a hormone that plays a key role in regulating sleep patterns (Tähkämö et al. 2019). Depending on the wavelength or intensity, exposure to blue light can also cause temporary or permanent damage to some structures of the eye, especially the retina (Cougnard-Gregoire et al. 2023). Although there is no evidence to suggest that normal screen use is deleterious to the human retina, little is known about these impacts in the context of modern XR technologies.

The high rate of modulation in the light emitted by VR headsets, in a frequency range of 79-90 hertz, is considered to be a risk factor for seizures in individuals with photosensitive epilepsy (ANSES 2021). Additionally, extreme gaze angles within VR headsets have been found to be associated with an increased risk of heterophoria – a condition where an individual's eyes point in different directions while at rest (GOV.UK 2020). Overall, there is a lack of evidence on the potential long-term effects of immersive environments on the eyes or the visual system as a whole.

Another source of discomfort involves the disparity between the information received by the vestibular and visual systems. The eyes sense movement, but the inner ear, which gives us our sense of balance, tells the brain that the body is still. This dissonance can trigger cyberkinetosis, which refers to virtual reality sickness with symptoms similar to motion sickness: headaches, dizziness, nausea and disorientation. Depending on the type of content, between 20% and 95% of users are thought to be affected (Stanney 2021). Simulations that involve more motion are more likely to induce cyberkinetosis than static applications. In some cases, symptoms can last for several days after exposure and are felt as postural ataxia – a feeling of unsteadiness or drunkenness that is made worse by moving the head. Evidence shows that the likelihood of cyberkinetosis is increased in HMDs with wider fields of view and in virtual environments with higher visual realism. These findings together suggest a possible trade-off between immersion and cyberkinetosis. Systems running too slowly or with an unstable frame rate are also more likely to cause cyberkinetosis.

When it comes to mitigation measures, the use of proprioceptive vibrations has been found to minimise the likelihood of cyberkinetosis occurring, while generating an adjustable depth of field according to the user's gaze or reducing rotational motions diminish the severity of symptoms (Easa 2021). Additionally, there is strong evidence to support the use of a habituation mechanism, although the effects of habituation do plateau after prolonged exposure (GOV.UK 2020). Moreover, a recent study suggests that reductions in cyberkinetosis produced by repeated exposure may be content-specific, as shown by the fact that the benefits did not generalise from one experience to another (Palmisano and Constable 2022). Finally, sensory adaptation may pose a risk to the user if it temporarily affects eyesight, balance or coordination following use (see section below on safety hazards).

Users who engage in immersive environments have also been found to experience slight changes to their physiological state, with their heart rate, skin temperature, electrodermal activity and perspiration being affected (GOV.UK 2020). Further research is needed into the occupational health and safety implications of such changes.

Ergonomic hazards

The poor ergonomics of HMDs has been repeatedly flagged as an area of concern, although user studies are still limited. During prolonged use, the often suboptimal distribution of weight in consumer-level HMDs is likely to cause musculoskeletal disorders and injuries. The bulk of the weight in most HMDs is borne by the brow and the nose, leading the user gradually to tilt the head forwards. Over time, this posture may increase the burden on the cervical spine, causing tension in the neck (Easa 2021). Additionally, the narrow field of view in some HMDs can result in more head movements, further increasing the risk of musculoskeletal disorders of the neck and shoulders.

The development of lighter headsets with better weight distribution may help reduce the physical burden caused by HMDs on the musculoskeletal system. However, the opposite trend is currently being observed: HMDs tend to become heavier as the screen resolution, and therefore the required power of the central processing unit, increases. Between 2014 and 2024, the weight of the HMDs produced by Meta/Oculus steadily rose from 380 g (Oculus Rift DK1) to 722 g (Quest Pro). Further elements to be considered are the additional strain placed on the neck when the user is required to maintain a particular posture to complete an action in the immersive environment, as well as the additional inertia force generated when the user executes a head movement. These issues contribute to lowering the acceptable weight threshold for safe operation.

A further ergonomic issue that has been reported is facial skin irritation associated with the area where the headset foam interface comes into contact with the skin.

Safety hazards

VR HMDs block out visibility of the real world, which exacerbates the risk of self-sustained injuries during use. These injuries may be caused by colliding with real-world objects or tripping over the VR system cables. Recent developments in HMDs have significantly reduced the risk of colliding while being immersed in a VR environment, such as self-contained HMDs (i.e. with no wires or cables attached) or the use of virtual boundaries to help the user stay within the cleared area.

Short-term effects following VR use have been found to include a reduced depth of perception, a decreased reaction time and trouble focusing. Such impaired cognitive and perceptual functioning can, in turn, result in self-sustained injuries involving, for example, slipping, tripping or falling hazards. In fact, there is some evidence pointing to the negative effect of VR on balance and coordination following prolonged use (GOV.UK 2020), as well as a number of case studies showing that even low-impact falls can cause significant injuries. For example, Warner and Teo (2021) reported a case of a low-impact VR-related fall resulting in spinal cord injury, hypoglossal nerve injury, vertebral artery dissection and traumatic brain injury. There is also a potential risk of serious consequences if an individual were to engage in an activity such as driving or performing tasks where precise hand-eye coordination is required immediately following immersion in a virtual environment (GOV.UK 2020). Finally, the sound cues provided in many immersive environments may effectively cut off audio stimulation from the real world, posing further safety issues for users.

AR HMDs should, in all likelihood, be less conducive to safety hazards, as the real-world surroundings remain partially visible during use. There is evidence, albeit limited in extent, that AR also has a negative effect on reaction time following use, raising similar concerns regarding the safety of subsequent activities requiring precise hand-eye coordination (GOV.UK 2020).

Further research is needed on the effects of immersion on balance and hand-eye coordination, in particular regarding the duration of the effects and how they might impact the performance of safety critical tasks, such as driving or operating machinery.

Biological hazards

HMDs subjected to extended use are colonised by high levels of bacterial contaminants, equivalent to or exceeding those found on computer keyboards in similar settings. Because of their design, HMDs tend to collect sweat which, coupled with the heat generated by the device, create a perfect breeding ground for different bacteria. A study isolated *Staphylococcus aureus* strains possessing high levels of antibiotic resistance from the nosepieces and foreheads of VR headsets used by several individuals during a software development course (Creel et al. 2020). Even in healthy individuals, *Staphylococcus aureus* can cause serious infections, such as bloodstream infections, pneumonia, or bone and joint infections. A variety of other bacterial contaminants were detected. Although known to be a part of the normal flora of most humans, they can still cause opportunistic infections in immunocompromised users or users with other risk factors.

Sterilisation with 70% ethanol has been proved to be an effective way of reducing the risk of contamination and infection from VR headsets, but further research is needed to generalise this method to other pathogens, such as viruses. These findings highlight the importance of observing sanitation procedures and, consequently, of providing users with information regarding those procedures. As some users have reported that cleaning HMDs properly can be a challenge (Easa 2021), the development of accessories in the form of replacement headset face masks and protective foam padding is proving to be a promising avenue for the prevention of biological hazards.

Psychosocial hazards

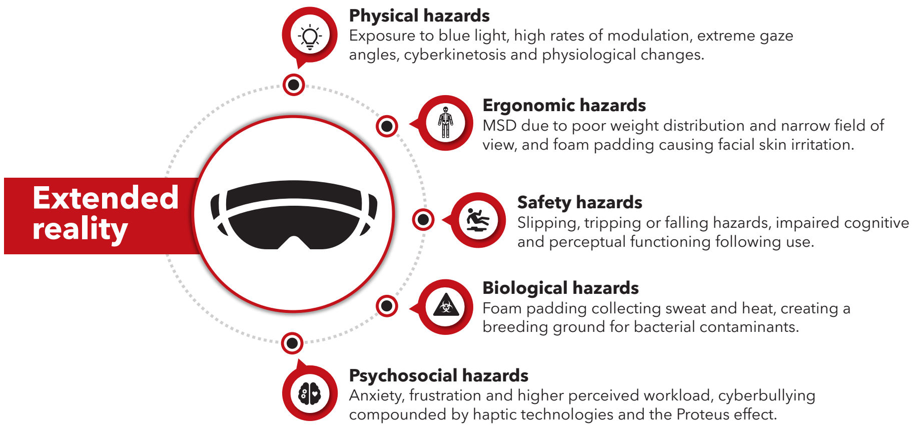
Recent evidence suggests that the poor usability of modern HMDs may be detrimental to mental health. A study compared the experience of participants who spent a 40-hour working week in VR and another in a traditional office environment (Biener et al. 2022). Using a standard VR configuration available on the market today, the study showed a 35% increase in perceived workload when work was performed in the immersive environment. Participants reported greater feelings of frustration (42%), anxiety (19%) and eye strain (48%), with two of them dropping out of the study on day one because of a severe migraine, nausea and anxiety. Another significant finding was the cumulative nature of adverse impacts over the week, especially in relation to workload and nausea. These results suggest that contemporary VR solutions for consumers are still far from having the levels of usability required for sustained use in work settings.

The development of increasingly realistic environments poses risks related to unwanted contact. Cyberbullying has been highlighted as a key challenge by scholars, as immersive environments allow users to interact in previously unimaginable ways (Upadhyay et al. 2023). There have been several incidences of bullying and assault on the metaverse platforms (Dwivedi et al. 2023). Cyberbullying can take various forms, such as harassment and trolling, which can have a severe emotional and psychological impact on the victims, or it can take a more physical form as a result of the ongoing development of sensing technologies. Haptic technology, for instance, can create the experience of 'touching' objects in virtual environments and could be used to provide a sense of virtual contact between two avatars, triggering physical sensation. In this context, providers will most likely face a dilemma because introducing protective measures may reduce the immersiveness of the experience.

The use of an avatar can have a significant influence over people's behaviour in computer-mediated environments. It has been repeatedly demonstrated that users adjust their behavioural patterns to match their avatar's external appearance (Peña et al. 2022). For instance, users tend to be more confident and extraverted when using avatars that are considered tall and attractive. Known as the Proteus effect, this may have a magnifying effect on cyberbullying in immersive environments where every interaction is mediated by an avatar. In fact, studies have shown that XR technologies elicit a stronger Proteus effect than those relying on standard 2D screens (Beyea et al. 2022). There is also evidence that confrontational behaviour performed by a virtual character induces high levels of anxiety in immersive environments compared to a flat-screen display, mainly due to differences in the perceived sense of physical space (Dickinson et al. 2021).

A limited number of studies have examined the impact of the prolonged use of XR technologies on the perception of reality. One study has shown that it is possible to induce a distortion of the perception of reality in healthy subjects temporarily, without having any detrimental effect on their health and perceived well-being (cited in ANSES 2021).

Figure **Overview of occupational health and safety hazards associated with the use of extended reality technologies**



Source: author's own compilation.

Conclusion

XR technologies share a complex risk profile, spanning many different categories of hazards (see the figure above). Such complexity is reflected in the growing integration of physical and virtual spaces. The creation of a compelling immersive experience hinges on a blended combination of hardware and software components, both of which bring their own, unique set of challenges for OSH. The nature of the research on this topic is gradually evolving from speculation and anecdotal report to empirical studies looking at specific hazards in a more systematic manner. Yet research is still scarce, including on many of the hazards covered in this brief, but also on others that have yet to be empirically investigated. For instance, very little is known about the impact of prolonged and repetitive exposure to XR technologies in work contexts – including in relation to derealisation, social isolation and work-life balance. Additionally, further research should depart from investigating individual hazards and focus more on 'full sets' of hazards, as risk factors are known to be highly interdependent. This is all the more important because ongoing technological developments in XR, such as haptic feedback, are hinting towards a growing integration of virtual and real-world experiences. Monitoring these developments and strengthening the evidence base will be critical to ensure that immersive environments are safe by design, including in the context of work applications.

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