WORLD ECONOMIC FORUM

Immersive Media Technologies: The Acceleration of Augmented and Virtual Reality in the Wake of COVID-19

WHITE PAPER

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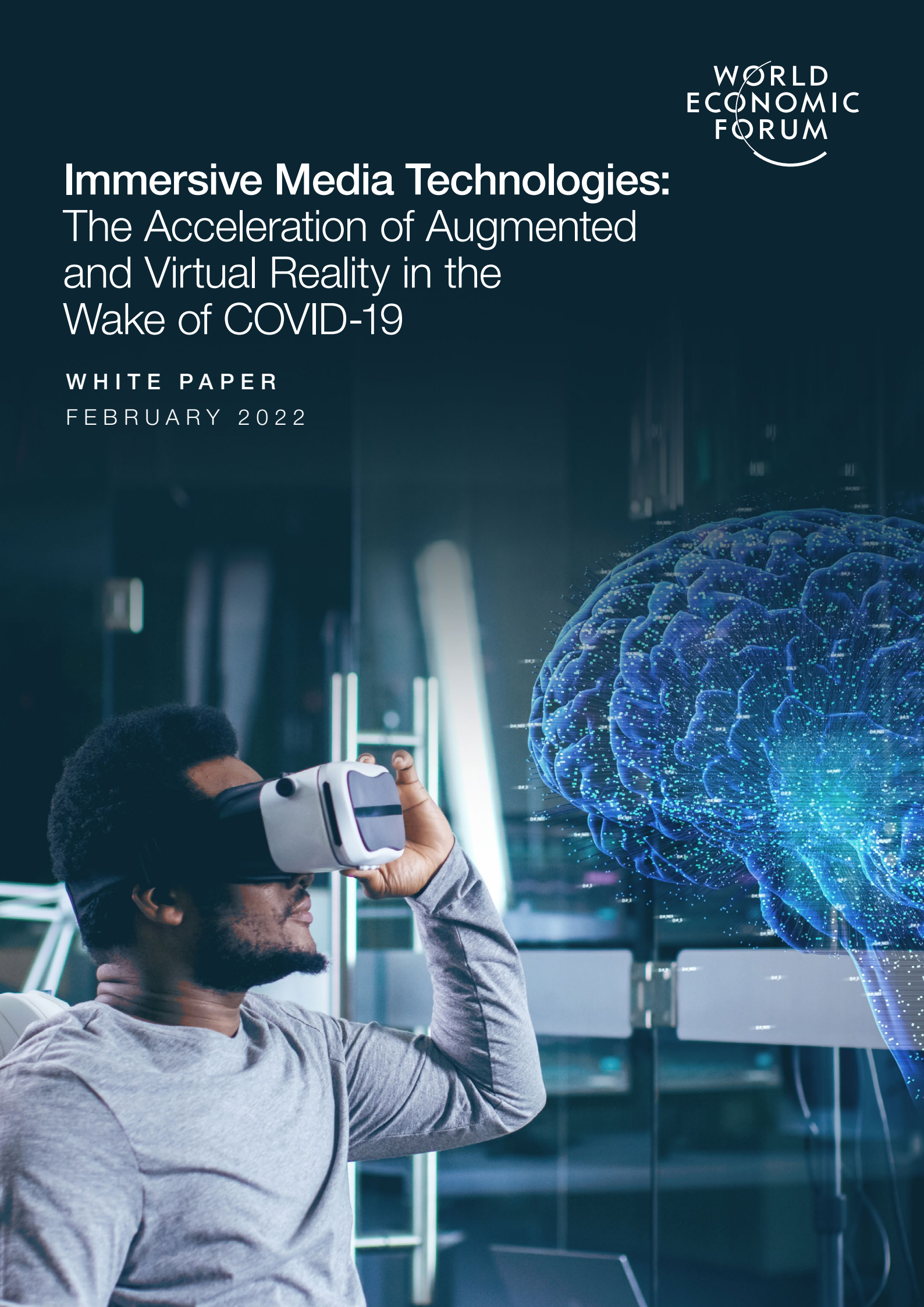

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Executive summary

The COVID-19 pandemic has sped the adoption of immersive technologies, notably in education and training, virtual events, and the arts and entertainment.

It has been almost two years since the COVID-19 pandemic first disrupted global economies, forcing businesses to examine its impact. Immersive media businesses, which use technologies such as augmented reality (AR) and virtual reality (VR) that create or imitate the physical world through digital simulation, have been no exception.

The World Economic Forum Global Future Council on Augmented Reality and Virtual Reality, which is comprised of interdisciplinary thought leaders in immersive technology and immersive media, has assessed COVID-19's impact on these technologies. The results show that the pandemic has sped the adoption of immersive technologies by several years, with a transformative impact on various industries. In addition, a recent McKinsey & Company survey reveals that COVID-19 has accelerated the digitization of customer interactions, also by several years.[1] For example, industries, organizations and institutions once reluctant to adopt certain technologies, such as museums, were suddenly forced to reimagine experiences in the digital world to survive the global shutdown.

This White Paper highlights some of the industries and sectors that have accelerated the adoption of immersive technologies. It outlines the enhanced use of these technologies in education and medical training, virtual events, and art and entertainment during the COVID-19 pandemic.

In the area of education, these tools have allowed personal connection through a digital medium, filling tremendous gaps in teaching and school attendance. In fact, in higher education, 85% of first-year medical students at Case Western Reserve University (USA) indicated that the use of mixed reality to teach their anatomy classes made their experience "equivalent to" or "better than" the in-person class. Surgeons have adopted online VR/AR technology to allow students and colleagues to observe and assist in complex surgical scenarios. Moreover, user participation at many immersive technology educational events also increased in the past two years.

Besides providing notable benefits in education, immersive technologies are helping to build a sense of interpersonal sharing, gathering and sociability at a time when many feel isolated. Beyond the surge of videoconferencing tools, extended reality platforms have added a new, creative dimension of virtualizing life beyond the mundane, benefiting from a sense of shared presence that cannot be achieved with video calls. VR helps deliver togetherness, which is particularly powerful and necessary in an age of physical isolation.

Immersive technologies are also permeating the arts and entertainment. As a result of significant disruptions to attendance at sporting events during lockdowns, the sports industry had to determine how to bring fans to the game virtually. One of the emerging technologies used by the industry is volumetric video. This technology takes fans to the centre of sports action, providing views from unprecedented angles.

Additionally, this White Paper considers the importance of safety and privacy as these immersive technologies progress. The Global Future Council is committed to ensuring continued awareness of the possible negative consequences of the technology, while encouraging the development of these exciting new tools that have proven extremely useful during the global pandemic. The past two years have helped to increase the early adoption of these technologies and proved that they can support keeping everyone better connected.

1 Education

Successful learning has traditionally relied on a personal connection between students and teachers or mentors. The pandemic has made such human interaction both dangerous and challenging.

Asynchronous ("independent") learning is a core part of many educational programmes. Yet, over the last two years, students around the world have had to perform more asynchronous educational hours than ever before. A couple of years ago, few could have imagined students instructed from home, solely using technology for their synchronous hours with teachers and classmates. But because of the ability of augmented reality (AR) and virtual reality (VR) to provide connection through a digital medium, these tools became urgently necessary within education. This has been especially apparent in areas of education that require hands-on or in-person learning, such as apprenticeships.[2]

As a result, companies such as TransfrVR, a VR apprenticeship model, raised $12 million in series A funding in the middle of the pandemic.[3] This successful capital raise was based on its ability to effectively generate virtual training experiences within manufacturing that result in high-level learning and on-the-job performance.

Immersive technologies such as AR and VR create or imitate the physical world through digital simulation, giving the user a unique way to experience and understand the related concepts. They also integrate virtual content with the physical environment, allowing the user to engage with the blended reality. That AR and VR technologies have helped close the education gaps created by the COVID-19 pandemic[4] should be viewed with optimism. These technologies offered an array of services to assist in successfully transforming remote education into a more immersive experience.

2 Medical training and procedures

Projecting 3D renderings of human organs on patients using mixed reality renders humans "transparent" and enables clinicians and students to "see inside" the human body.

The pandemic has also dramatically disrupted medical training. Case Western Reserve University (USA) and Stanford University (USA) moved their anatomy education into AR/VR technology with great success.[5,6] They used these new technologies to teach medical students core material and the critical skills of communicating with and assessing patients, with Stanford running a programme in Kenya. All 185 first-year medical students at Case had their anatomy classes using mixed reality, with 85% reporting that it was "equivalent to" or "better than" the in-person class.

Because of COVID-19 restrictions, healthcare students could not participate in the important task of patient assessment during in-person rounds. To provide additional opportunities for engagement, the University of Michigan (USA) and the Imperial College of London (UK) hosted the first "Mixed Reality Grand Rounds", where a physician used a HoloLens, Microsoft's mixed reality head-mounted smart glasses, and Zoom, bringing students bedside to interact with the patient, view imaging, discuss laboratory work and observe the physical exam.[7]

Surgeons also adopted online AR/VR technology to allow students and colleagues to observe and assist in complex surgical scenarios.[8,9] Early in the pandemic, healthcare systems suffered under the crush of the first wave of COVID-19 patients. The Israel Center for Medical Simulation (MSR) at Sheba Medical Center's Rehabilitation Hospital in Tel Aviv, recognizing a lack of teachers to train staff on new ventilators and equipment, turned to technology to solve this problem. Using Microsoft Guides interactive mixed reality training simulations, MSR taught about 60 physicians, biomedical engineers and nurses how to operate ventilators for COVID-19 patients.[10] MSR was not alone: Microsoft saw a 13-fold increase in remote assistance, using HoloLens since January 2020 across its largely enterprise user base.

According to Christoph Leuze, co-director of the Stanford University Wu Tsai Neurosciences Institute Visualization Lab, projecting 3D renderings of human organs on patients using mixed reality renders humans "transparent" and enables clinicians and students to "see inside" the human body. This will allow physicians to view and understand the anatomy in a digital form that is nearly identical to the actual anatomy, thus making it easier for healthcare providers and medical students to accurately see and point to important anatomy. Being able to solve this fundamental need of medical caregivers is another significant reason the medical field is an important adopter of mixed reality.

Leuze also sees using mixed reality as an opportunity for improved collaboration within the medical community. By allowing multiple, remote medical caregivers to see the same real and virtual content without looking away to another screen allows for more natural interactions between multiple medical caregivers and remote experts. This was perhaps best demonstrated during a recent Microsoft 24-hour on-line surgery event, where surgeons around the world performed 13 surgeries wearing the Microsoft HoloLens 2 mixed-reality headset. This allowed the surgeons "to visualise and operate via hologram; share their real-time view of the surgery, benefitting from remote peers' expertise on different clinical cases; and train their peers remotely".[11] This type of collaboration and knowledge distribution was never possible before.

3 Virtual events

Traditionally, conference events have entailed a number of expenses, such as for registration, travel and accommodation. Social events, including weddings, graduations and births, have often meant booking flights and hotels, and making dining reservations. In 2020, however, such in-person events were cancelled *en masse*. Even the Mobile World Congress 2020, the most important trade show of the mobile communications industry, was cancelled at the last minute. Cancellations of tradeshows, conferences, concerts, weddings, graduations and baby showers soon followed.

It has been encouraging to see how quickly human ingenuity and technology rescued such events. Beyond the surge of videoconferencing tools, extended reality platforms have added a new, creative dimension of virtualizing life beyond the mundane. User participation at many educational events has increased in the past two years, including the use of VR, such as at the Institute of Electrical and Electronics Engineers (IEEE) Conference on Virtual Reality, the IEEE International Symposium on Mixed and Augmented Reality, and the International Conference on Artificial Reality and Telexistence & Eurographics Symposium on Virtual Environments, providing learning opportunities and access to educational resources for individuals around the globe.

VR events have also increased in popularity.[12] Large-scale corporate events from companies like HTC and Microsoft have been virtualized with interesting effects in virtual and mixed reality that allow for unexpected interactions akin to live, in-person events. Even Black Rock City, where people gather for the annual Burning Man event, now has a digital twin in VR. This allows more people to participate in viewing and experiencing the digital art installations.

When people can meet as avatars in VR, they benefit from a sense of *shared presence* that cannot be achieved with video calls; they are instantly capable of co-creating shared experiences and memories, as if they were physically together. VR helps deliver togetherness, which is particularly powerful and necessary in an age of physical isolation.[13]

4 The arts and entertainment

With the challenge of COVID-19, many creative in-person events have had to be reimagined virtually with the use of technology. For example, La Biennale di Venezia, also known as the Venice Film Festival, had its "immersive segment" hosted entirely in VR. The glamorous gondola arrivals and world-class exhibitions were available to anyone with a VR headset.

The music industry also took advantage of VR's attributes. The virtualized performances of A-list talents, such as John Legend, Travis Scott, The Weeknd and Lil Nas X, were produced in interactive virtual environments, entertaining tens of millions of people beyond the limitations of reality.

In entertainment, the inability to congregate in venues for sporting events was one of the greatest disruptions. In the United States, the 2020 National Basketball Association (NBA), Women's NBA and Major League Baseball seasons were suspended, and the Indianapolis 500, a major automobile race held in Speedway, Indiana, was postponed. Moreover, the 2020 Summer Olympics were rescheduled for 2021. As a result of these significant disruptions, the sports industry had to determine how to bring fans to the game virtually. One of the emerging technologies used by the industry is volumetric video. This technology takes fans to the centre of sports action, providing views from unprecedented angles, including aerial perspectives and referees' vantage points. Leagues and broadcasters used "True View" to give spectators new, detailed experiences, presenting a format that heightened storytelling and deepened analysis while continuing to connect with the fans.[14]

The lesson is that immersive media can improve the viewing experience by allowing fans to explore an event and view it from multiple angles instead of from one single, unchanging angle.

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5 Upcoming applications and technological breakthroughs

> The global VR market is projected to grow from $6.1 billion in 2020 to $20.9 billion by 2025.

Five years ago, sales of VR and AR headsets were optimistically predicted to achieve three times that of current sales numbers. However, early VR and AR success can still be observed, and recent third-party research foresees accelerated VR and AR adoption. For example, *Forbes* cites research showing that, based on consumer data and trends, the global VR market is projected to grow from $6.1 billion in 2020 to $20.9 billion by 2025, and the global AR market from $15.3 billion in 2020 to $77.0 billion by 2025.[15]

AR/VR headsets have indeed come a long way in the past few years, with improved technologies (e.g. waveguide/organic light-emitting diode [OLED] displays, sensors/spatial mapping, graphics rendering) as well as more consumer-oriented designs, such as untethered and low-cost devices. The problem of "VR sickness" has been significantly reduced, and support for interactive content creators is rapidly advancing, using high-end game engines like Unity and Unreal. Furthermore, real-time performance-tracking solutions that track faces and hands, which were still research prototypes a few years ago, are now becoming an integral part of commercial solutions.[16,17]

In the past few years, the professional automotive, defence and healthcare sectors have benefited most from consumer-grade AR/VR solutions, with an estimated $19 billion spent globally in 2020.[18] For example, vehicles are designed with the help of VR systems, and car manufacturers are increasingly using AR/VR solutions to enable remote assembly tasks and training. The use of VR is well established for training systems, such as flight simulators, in the military. Additionally, the US Army is quickly adopting commercial AR/VR headsets for immersive combat training (e.g. US Army's Synthetic Training Environment), as it provides new capabilities for scalable, repeatable, safer and more cost-effective simulation using virtual battlefields.

In the health sector, in addition to the previously discussed use of AR headsets by surgeons, VR simulations have been successfully adopted for treating post-traumatic stress disorder. Patients have shown 40% improvement in immersion therapy clinical trials that involved walking on treadmills using images of the type of trauma experienced.[19]

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Early success in consumer apps include a number of VR and AAA video-game titles that have grossed over $1 million[20] (e.g. Half-Life: Alyx, Beat Saber). In fact, Beat Saber announced reaching the $100 million revenue milestone in October 2021, reflecting the revenue growth trajectory in the ecosystem.[21] Social VR applications, such as VRChat, are also becoming more popular, as well as fitness apps like Supernatural.

AR applications without headsets and deployed on smartphone platforms are more widely adopted, with a projected 1.4 billion users worldwide by 2023, according to Statista.[22] The most popular AR applications are mainly camera filters and video effects (e.g. Snapchat and TikTok), as well as AR games (e.g. Pokémon GO). Snapchat had 306 million daily active users as of the third quarter of 2021,[23] and Pokémon GO generated $5 billion in revenues over its first five years.[24]

AR/VR solutions are still expensive and inconvenient to wear, and untethered solutions still have limited performance. Nevertheless, tech companies, and researchers in both industry and academia, are advancing hardware and software with impressive new capabilities every year. Furthermore, content developers, media companies and start-ups are experimenting with new immersive experiences and interactive applications to fill the void of virtual content. Innovative experiences, beyond games and simulations, include telepresence applications (Facebook/Spatial.IO/Alt Space VR) to replace traditional video conferencing, VR painting apps (e.g. Tilt Brush, Quill) and immersive documentaries.

In terms of hardware development, key advances are expected in such areas as lightweight form factors, higher resolution (8K displays, such as those from Pimax), larger fields of view, inward facing/eye-tracking cameras, longer battery life, better motion sickness resistance and improved Wi-Fi connectivity. Promising technologies, such as micro-OLEDs (possibly in 2023), will enable the development of smaller displays for smart glasses that can be directly integrated on top of silicon wafers without glass substrate. This decreases lens thickness and increases energy efficiency.

High-end game engines, such as Epic Games' Unreal 5, will power many of the next generation of interactive applications with hyper-realistic content, but more powerful graphics processors will be needed for untethered AR/VR displays. Neural rendering technologies are already being tested for the realistic rendering of digital humans to address the "uncanny valley effect" of computer-generated avatars for key applications, such as virtual telepresence and immersive live events. Meta Reality Labs has recently demonstrated its Codec Avatar technology, which allows real-time, face-to-face conversation between photorealistic avatars in VR but requires a complex capture system to digitize a person's likeness. Additionally, Pinscreen Inc. has shown how a single photo can be used to create a complete 3D avatar, and how photorealistic expressions can be generated using paGAN, its neural face-rendering engine.

Other important advances include the real-time volumetric capture of performances of people

without the need for a complex capture studio with depth sensors or multiple cameras. The authors of a European Conference on Vision paper have proposed a real-time volumetric teleportation system based on a single webcam, allowing the digitization of an entire person in real-time from a single view.[25] The potential impact of such technology is that remote real-time 3D videos are now possible without using multiple cameras, and only a single webcam is enough to predict a person's entire body in 3D, including the back.

For VR content, two main types of solutions dominate the market: one is 6-DOF (degrees of freedom) solutions, where a person can freely walk and rotate their head inside the immersive experience, and the other is 3- DOF experiences, where a 360-degree panoramic view is possible. Typically, 6-DOF solutions use a game engine for rendering and require significant cost and time for producing the content, while 3-DOF content can be captured using a 360 camera.

Promising artificial intelligence (AI) technologies, such as neural radiance fields (NerFs) introduced in 2019, use deep neural networks to encode entire scenes and complex objects, as well as rendering using a volumetric sampling approach. Recently proposed real-time variants have shown potential for 6-DOF content digitization and viewing from real-world imaging.

The next-generation headsets and immersive technologies will be based on smaller/better headsets, advances in AI, and innovations in 5G and edge computing. Improved graphics capabilities, computer vision systems, content creation tools and capture technologies are expected in the near future.

6 Privacy and safety

The role of privacy and safety remains front and centre in any discussion of technology, notwithstanding the global pandemic. Most electronic devices can be (and are) harvested for a user's behavioural data. AR and VR systems, however, present unique concerns related to privacy and safety. For example, most VR systems capture detailed information about body movement, eye gaze and other first-person behaviours. That information could be used to identify individuals and characteristics that might be interesting to third parties.

AR and VR systems are also unique in terms of the realistic and intimate nature of the interactions, both for the user and potentially for others nearby. For example, users of AR systems might choose to virtually denigrate unknowing nearby individuals or even exercise virtual harm against them. Realistic, intimate virtual actions directed towards real individuals in the real world could lead to real consequences. As such, it is important to ensure that as the benefits of a particular technology are highlighted, an equal amount of time is spent considering privacy and safety implications and incorporating mechanisms that will protect the users and society at large.

As previously mentioned, the use of immersive media for visualization, collaboration, training and unprecedented experiences across several industries is a fast-developing area with tremendous value. As human senses are naturally three-dimensional, spatial computing and immersive technologies offer endless possibilities for better learning, productivity and creativity outcomes in every way. Yet, as observed with other technologies, such as social media, every technology can have negative use cases and bad actors. Thus, the possible consequences of any emerging technology need to be understood and they should be addressed in advance of mainstream adoption.

7 Conclusion

While the COVID-19 pandemic has clearly impacted people's lives on an individual basis, it has severely disrupted or completely shut down entire businesses, institutions, organizations, industries and sectors of the world economy, and it has done so much more quickly and for much longer than anyone anticipated.

And yet, the pandemic has unexpectedly brought about what could be viewed as fortuitous investments in technologies that facilitate new digital and virtual ways of doing many of the things previously done in person. In particular, while AR and VR technologies have long offered the promise of rich and beneficial individual and group experiences, the pandemic has significantly accelerated the development and use of technology in many areas, including business, education, medical training and practice, live events and cultural experiences. In addition to spurring improvements in the technology, the accelerated use has begun to change perceptions about its acceptability in general and, in particular, as an alternative to in-person interactions that might otherwise be costly and inconvenient or have a negative environmental impact.

New technology has often given rise to unexpected negative consequences, such as some of the societal issues observed with social media. With the rapid development and adoption of AR and VR technologies, it is already possible to recognize the potential for some unexpected and unique privacy and safety issues. The World Economic Forum Global Future Council on Augmented Reality and Virtual Reality is committed to being vigilant and continuing to work to address the possible negative consequences of the technology, while encouraging the development of these exciting new tools that have proven extremely useful during the global pandemic. The past two years have helped to increase the early adoption of these technologies and proved that they can support keeping everyone better connected.

Contributors

Lead authors

Pearly Chen
Vice-President, HTC, Taiwan, China

Mark Griswold
Professor of Radiology; Director, Interactive Commons, Case Western Reserve University, USA

Hao Li
Founder and Chief Executive Officer, Pinscreen, USA; Distinguished Fellow, University of California, Berkeley, USA

Sandra Lopez
General Manager and Chief Marketing Officer, Advertising, Microsoft, USA

Nahal Norouzi
Postdoctoral Scholar, University of Central Florida, USA

Gregory Welch
Professor and AdventHealth Endowed Chair in Healthcare Simulation, University of Central Florida, USA

Yu Jingyi
Vice-Provost, ShanghaiTech, People's Republic of China

World Economic Forum

Stéphanie Nassenstein
Lead, Event Design, Global Programming

Endnotes

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World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744
contact@weforum.org
www.weforum.org