



Bipartisan Policy Center

Thinking Ahead About XR

**CHARTING A COURSE FOR VIRTUAL,
AUGMENTED, AND MIXED REALITY**

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DISCLAIMERS

The findings and conclusions expressed herein do not necessarily reflect the views or opinions of our partners, convening participants, BPC's founders, its funders, or its board of directors.

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Introduction

A construction worker has started her first day of work and is learning to weld using a virtual reality (VR) training module. The module lets her pick up welding tools and weld a metal beam in a virtual environment while giving her instructions on what to do at each step. She is not new to VR and had used it as part of an exposure therapy treatment program that helped her get past her fear of heights by exposing her to them in a virtual setting.

Despite her familiarity with VR, she is concerned about the information the employer might be collecting about her with the VR headset. She heard the VR headset collects information about her eye movement, which someone could use to infer sensitive information about her health and mental state. Yet she is grateful that VR is making such training more accessible and that recent expansion of broadband and 5G capabilities in her town made such VR programs possible. However, she is worried her town's broadband expansion happened later than others in the region and exacerbated regional inequities.

After her training session, the construction worker receives a pair of augmented reality (AR) glasses. She is excited to use them because they overlay virtual labels over the boxes that she must move from place to place at the construction site. However, she is concerned that her glasses might also capture sensitive data about bystanders near the construction site on their way into a neighboring medical building and uncertain about what safeguards are in place to protect their privacy.

The construction worker heads home from work navigating with her AR glasses' GPS. While listening to a local radio station, she hears a politician talking about whether industry has set the appropriate standards for immersive technologies and whether policymakers should intervene with new legislation and regulation. Her teenage son uses VR to socialize with his friends, but she is not sure the parental controls she put in place are enough to protect him from harmful content. As the politician finishes his talk, the construction worker thinks about her experiences with immersive technologies and wonders whether the industry and policymakers had been designing, deploying, and building policy around VR and AR tools with people like her in mind.

* * *

The fictional story above highlights how immersive technologies, like VR and AR, can affect regular people and some of the challenges and opportunities they present. Immersive technologies are gaining a mass audience, and

people are using them for various purposes, including health care, retail, and manufacturing. Society must take time to think through the implications. Industry standards and government policy can play a critical role in shaping the development and use of these technologies.

The Bipartisan Policy Center partnered with the XR Association to bring together stakeholders and experts from civil society, industry, academia, and elsewhere to study and identify the relevant issues immersive technologies bring. The effort included public and private events to learn about the technology and the likely political debates that will arise over the coming years. BPC saw both exciting opportunities and potential as well as challenges and concerns that are critical to address proactively.

This report will summarize much of what BPC learned and provide some guidance on a path forward. BPC believes the challenges around issues, such as privacy and security, are real, but we also believe the technologies' potential to improve quality of life and create economic opportunity are significant. We believe society should make strong efforts to ensure that the benefits of immersive technologies are broadly shared across the public. Finally, we believe that the technology will indirectly impact many who do not use it directly themselves.

Technology generally moves too fast for policymakers to fully react, but a proactive approach to identifying and addressing the challenges can still help minimize harm and maximize the benefits of technology. The issues in this report are only part of an opening conversation and not meant to be the final word. We hope others read this to help guide their thinking. The development of thoughtful policies for immersive technologies requires input from a diverse range of stakeholders and experts.

What Are Immersive Technologies?

“XR” is an umbrella term for immersive technologies that encapsulate virtual reality (VR), augmented reality (AR), and mixed reality (MR). Below we will explore these technologies and provide hypothetical examples of their use.

VIRTUAL REALITY

VR is a technology that offers a fully immersive, three-dimensional environment that can be interacted with in real time in a seemingly physical manner through a computer interface. VR headsets incorporate people’s sense of sight and hearing, while haptic technology can allow users to incorporate their sense of touch.

Figure 1 shows a VR simulation. The user is a college student learning about astronomy. By wearing their headset and using their controller, they immerse themselves into a virtual space where they conduct various space station simulations and explore planets in the distance. The student interacts with this virtual environment and moves around “space” without leaving the classroom or their own home.

Figure 1: Virtual Reality



AUGMENTED REALITY

AR technology allows users to view and experience digital information in physical space using tools such as head-mounted devices, glasses, or mobile devices. For example, users can see virtual objects superimposed on an image or live video feed. Using AR, a user can integrate location-specific information such as the names of tall buildings, directions to the nearest restaurant, or wait times at a bus stop.

Figure 2 helps illustrate how AR works. A city has created an AR app that helps tourists find their way around the streets using an app by imposing images on their screens. The green kangaroo in the figure is a virtual object superimposed by the app onto the physical world. While the user's device points onto the streets, the kangaroo can appear to guide the user toward the zoo and point out interesting facts about the city on the way there.

Figure 2: Augmented Reality



MIXED REALITY

MR technology merges real and virtual worlds to produce new environments and visualizations where physical and digital objects coexist and interact in real time. MR allows for more physical and virtual content interactions relative to both VR and AR.

Figure 3 shows a use case for MR. Two teenagers play ping pong competitively but are regularly on the road traveling without a ping pong table. Their MR headset allows them to simulate a game of ping pong by superimposing a virtual table, ball, and scoreboard (all seen in black and green) on the real world.

The users use their own hands and paddle to interact with these virtual objects and play ping pong.

Figure 3: Mixed Reality

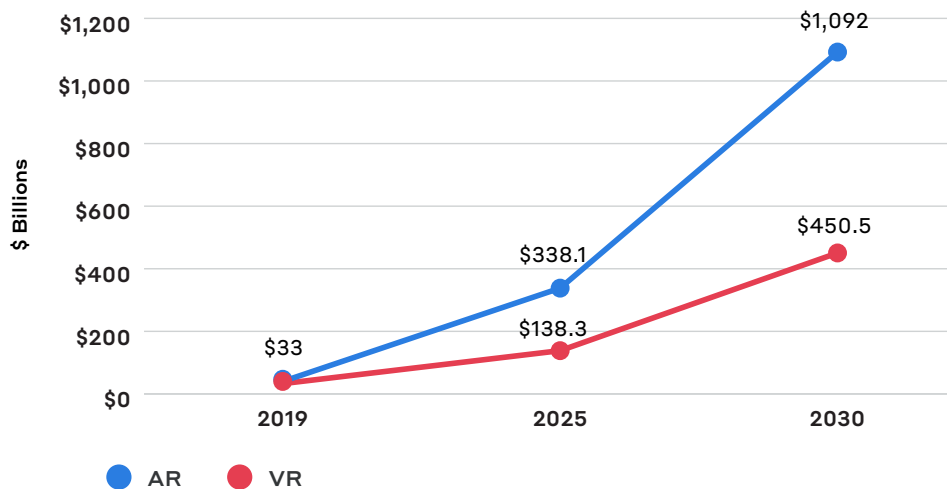


Why Should People Care?

The immersive technologies industry is growing rapidly, as more of the U.S. population is adopting XR tools. These tools have many applications, such as workforce training, remote collaboration, novel customer experiences, and more immersive learning opportunities. XR tools' design is also evolving and contributing to its adoption. For instance, XR headsets are becoming smaller and more user friendly, attracting new user bases. The design and user experiences are also becoming more realistic and easier to maneuver.

Statista predicts that in three years, VR market revenue will grow from less than \$5 billion to more than \$12 billion.¹ PwC estimates XR will add as high as half a trillion dollars to the U.S. GDP, and \$1.5 trillion to the global economy by 2030 (see Figure 4).² Further, PwC projects by 2030 more than 2 million jobs will be enhanced by VR and AR technologies.³

Figure 4: VR and AR Projected Contribution to Global GDP

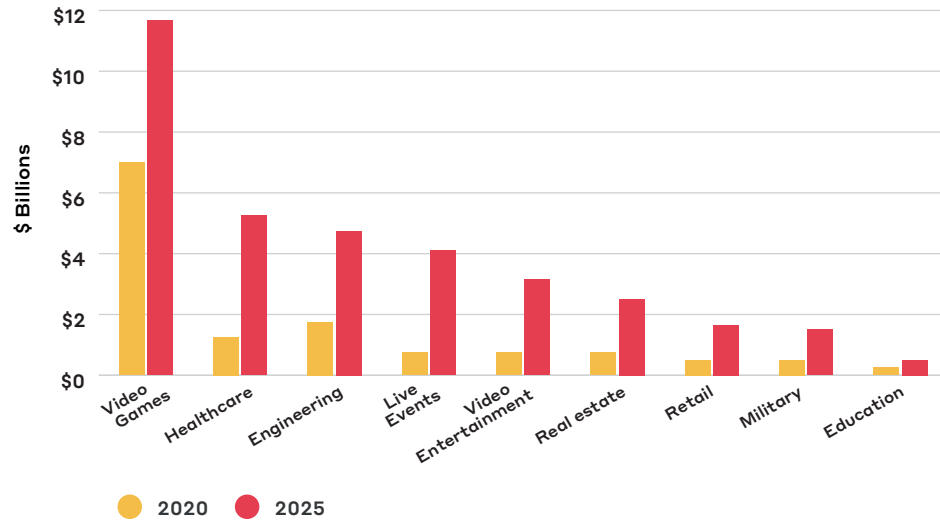


Source: [PwC](#)

XR was introduced in the 1960s with the development of the Sword of Damocles, a head-mounted display of computer-generated graphics.⁴ In the late 1990s, AR was introduced to a large portion of the population when the National Football League (NFL) debuted the yellow line that marks a first down during live broadcasts.⁵ However, while rapid growth in the XR market first took off in gaming and entertainment industries, analysts project future expansion will

take place across many sectors, including health care, education, and real estate (see Figure 5).⁶

Figure 5: VR and AR Market Size Estimates for 2020 and 2025



Source: [Goldman Sachs](#)

In health care, surgeons and doctors are training using VR to perform tasks in high-stress, time-sensitive situations in an immersive environment, such as training to extract transvenous lead.⁷ Similarly, they can use AR to keep their hands free during a procedure by overlaying patients' information in their line of sight. For example, Medivis, an FDA-approved AR surgical system used in the operating room to help surgeons perform complex tasks, partnered with the Department of Veterans Affairs (VA) to advance medical solutions for those who served.⁸

Immersive technologies provide alternatives to some in-person workforce trainings that can be too dangerous, costly, or impractical to perform in the physical world. According to one estimate, XR tools could boost workforce training and development by nearly \$300 billion by 2030.⁹ XR tools can apply to a variety of training settings, from public-speaking to pro-sports to military simulations.^{10,11,12} For example, Austin, Texas invested in VR training programs to help EMTs train for extreme real-world events through simulation.¹³ Many public-private partnerships like this are forming to invest in immersive training experiences (see the following case study for another example).

Case Study: Firefighters, NIST, and AR

It's the early hours of the morning, and a fire engine company arrives on site of a warehouse fire. The firetruck's pump panel is in front of the company's firefighter engineer. The flames rise high as he positions the pump panel to protect the sides of the burning building. Once in place, multiple lines deploy. Each of these consists of a hose line—some with a fog nozzle and others with a smoothbore tip.

More lines are deployed to protect nearby buildings, each with a different degree of mitigation and a different nozzle, and by extension, pressure. The engineer must know where all the lines are hooked up to, where they are running toward, what kind of nozzle they have, and what kind of pressure they require—all within mere minutes of arriving on the scene.

Typically, firefighters are trained to perform this task via a lecture-based format with a PowerPoint and some hands-on activities. A pilot program brought forth by the National Institute of Standards and Technology (NIST), in tandem with RTI International and the White Cross Fire Department, aims to train these firefighters using AR technology.¹⁴ The goal of this approach is to develop the skills necessary to navigate the pump panel and connect the hydrant to the hose with a more innate sense using muscle memory.

This approach would mostly rely on the visuals provided by the AR system paired with audio for a more immersive experience. The experience could also be spoken in multiple languages with the idea of increasing the inclusivity of the training to accommodate for firefighters whose first language is not English.

This research on the effectiveness of this program is preliminary, so it would be difficult to draw too strong of conclusions at this point. However, if this program is successful, it could enhance the skill set of the firefighters and provide a unique approach to training that allows for repeated experiences in several similar scenarios using immersive technologies.

Other industries are innovating their advertising and marketing strategies to integrate immersive technologies. In retail, mobile apps using AR overlay virtual versions of furniture, clothing, and accessories in a user's home or on their body, enabling customers to check objects for sizing and aesthetics.¹⁵ In the real estate industry, VR is being used to create virtual tours of homes, providing prospective buyers with the opportunity to get a feel for a property without needing a real-world visit to the site.

The tourism industry is starting to adopt VR to immerse people into places too dangerous, far away, or unlikely to visit. For example, people can take a virtual trip to the International Space Station, explore the Great Barrier Reef, or view a famous work of art like the Mona Lisa up close.¹⁶ VR can make these kinds of experiences more accessible to a larger population of people.

As you can see, mainstream adoption of XR tools is already starting to happen. Several academic models around technological adoption show how it is a complex phenomenon driven in part by social perceptions.¹⁷ These models suggest that if we want to encourage further adoption of immersive technologies, it is critical to address many of the challenges and concerns people have about them regarding issues such as privacy, security, and inclusion. Current mistrust about the internet and digital platforms may amplify the need to build trust in XR by addressing these issues. The next section of this report will look at some of these challenges to help better inform readers about some of the relevant issues.

Policy Issues

Over the last year, BPC conducted research and hosted a series of private convenings to learn about the important XR policy challenges that society should address to optimize the technology's benefits and minimize its harms. This section will look at several important issues discussed at our convenings among stakeholders and experts and what we learned. Given the nature of this exercise, the issues discussed are nonexhaustive, but we believe it provides useful insights and a launching-off point for further important discussions about the future of XR. These issues are often interconnected, so people should not consider them in isolation. For instance, it is hard to decouple data privacy from data security. Further, trade-offs can sometimes arise between these issues that should be carefully considered. For instance, the question of how closely to track users to police abusive behavior on an XR platform can raise trade-offs between user privacy and safety.

PRIVACY

During BPC convenings, participants regularly cited privacy as a top concern with XR tools. They focused on user privacy, especially protecting sensitive biometric data, and bystander privacy as specific challenges. Privacy protections will be key to building trust in immersive technologies.

The right of a user to control what information they share about themselves is a common definition of user privacy.¹⁸ Regarding technology, areas of user privacy can include user location, financial information, and biometric data. XR devices rely on sensitive data inputs to function and enhance users' experience, but these data inputs also raise legitimate privacy questions around the technology. For example, a VR device can use sensitive biometric data such as iris and retina scans, fingerprints and handprints, face geometry, and voiceprints. If collected and poorly secured, a breach of a person's biometric data can expose sensitive information that cannot be meaningfully reset, in contrast to the breach of data like a bank password.

Biometric data raises important concerns about what inference someone might be able to make about an individual using their data. Based on data collected by technologies using eye tracking, such as XR, research shows that someone with enough technical expertise and access to this data might be able to infer sensitive information about a user, such as their age, gender, and certain health characteristics.¹⁹ This can expose information a user might prefer not to reveal and further raises the possibility of discrimination in sensitive areas, such as hiring and insurance, based on a protected characteristic.

Avatars used in XR also raise user privacy concerns that might not be obvious at first glance. Avatars are 3-dimensional, digital representations of individual users in immersive environments that users can use to express themselves in a virtual space. A user may want to apply features identical to their real-world self to their avatars, such as height and other physical attributes, or they might try something completely different, such as being a robot. However, avatars can potentially expose information about a person based on an avatar's looks. Some users might be concerned that revealing a certain characteristic about themselves in their avatar, such as their race, gender, or age, may expose them to harassment or bullying and want to keep this information private.

Bystander privacy is another major concern with XR, especially with AR glasses. An XR device may record information about a bystander's activities that they might not want or even be aware is being recorded by others. This can be especially important in sensitive locations such as private property or a civic space. Bystander privacy raises concerns about what meaningful consent for a bystander looks like and the best way to protect users who are sensitive to having their property or themselves recorded.

Participants from BPC convenings highlighted how XR devices present notable privacy challenges in the workplace. Specifically, participants raised concerns about the risk of overly intrusive monitoring of employees due to any power asymmetries between workers and their employers, and about how an employer using XR for training or collaboration might collect and use sensitive employee data, such as if that employee has a disability.

Some Possible Solutions to Consider

Participants at BPC convenings made several recommendations on ways to help preserve privacy. These included facial blurring, geofencing, privacy by default, anonymizing avatars, non-identifying usernames, design aspects such as light signaling to suggest that an AR device is recording, reducing the specificity of location tracking services, providing user-based opt-out options, minimizing data collection to only what is necessary, and defining and requiring meaningful consent. Reviewing existing laws and addressing policy gaps surrounding privacy policy was also discussed.

SECURITY

Technology is constantly evolving, and security must evolve with it to ensure users are well-protected. XR devices are becoming the gateway to many useful applications that collect sensitive user information. Security is often a key factor in protecting users' sensitive data and privacy when XR devices collect and store information about them.

Although XR is an emerging technology, it still connects to and utilizes legacy technologies, such as those that make up the modern internet and mobile computing devices. The security risks of XR are similar in many ways to those of other computing devices: malware attacks, data breaches, and data theft. Addressing these existing security challenges is important to tackling many of the security risks with XR devices.

Further, technologists must address the security of a user's biometric data. There are numerous risks to the user, including the inability to reset sensitive biometric data the way they can reset a password if the data is breached. Additionally, many security systems rely on biometric data to verify user identity. In a bid to increase security of these systems, many rely on unique features (such as fingerprints, voiceprints, etc.) to make it more difficult to assume another person's identity. This intensifies the need to secure biometric data.

Another security issue posed by VR environments is the potential for an immersive experience to be manipulated by a hacker. For example, a user defines a virtual boundary created in VR to keep the user in a safe physical space free of obstructions while they are in a VR environment. A malicious hacker can change these boundaries on an unsecure device to make the user more likely to have an accident in a physical environment, such as tripping over furniture in a room or wandering into traffic outdoors. Further security implications may arise if malicious actors gain access to information about a person's private home with its entrances and exits.

Some Possible Solutions to Consider

Participants at BPC's convenings made several recommendations to address security concerns. Some recommendations participants made include safeguarding vulnerable data via encryption, autodeleting data that is no longer needed, and storing data on the device itself rather than a centralized repository. Others mentioned creating and following guidelines and policies to strengthen such actions. Under a more policy-based approach to security, participants recommended compliance with relevant existing laws and guidelines, modernizing and filling any gaps when appropriate, restricting the use and distribution of unauthorized data, and informing users of risks that they assume when using the technology.

ECONOMIC ISSUES

The internet and digitization have significantly impacted society and the economy. Immersive technologies intensify this digitization and should have considerable effects on labor markets, business models, and broader society.

If history is a guide, jobs will be both enhanced and disrupted by immersive technologies and often in unpredictable ways. For instance, several decades

ago, as ATMs saw widespread adoption, many observers worried that the new technology would decrease bank teller jobs.²⁰ However, counterintuitively the number of bank tellers actually increased as the nature of the job shifted from handling cash to marketing and advising customers on the bank's products and services. Outcomes like these have been hard to predict with past technologies and will likely be hard to predict with immersive technologies. Regardless, immersive technologies are already affecting many jobs, and it is best to prepare the workforce for these changes.

Specifically, the workforce should prepare itself to take advantage of the benefits of immersive technologies and build resilience against any potential disruption. Historically, education and workforce training have played key roles in boosting worker productivity and helping foster economic growth.²¹ Education and training should not just focus on making workers more familiar with immersive technologies but should also focus on building complementary skills to the technology. For instance, immersive technologies might create demand for people who can communicate information more visually and spatially. Therefore, improving workers' visual and spatial communication skills might complement immersive tools, resulting in greater worker productivity and job security. Immersive technologies themselves have been and can continue to be used for worker training programs, as highlighted earlier in this report, so it's important to identify and replicate those that work.

Companies are still developing business models around immersive technologies. Policy decisions around issues such as antitrust, privacy, intellectual property, and legal liabilities will have major implications for corporate monetization strategy and R&D investments. The business models used can affect factors such as the price, quality, privacy, and use cases for XR tools, so people should be aware of any relevant trade-offs.

The industry should be mindful of the role of marketing in its business model and consider its implications. A participant at the BPC convenings highlighted how corporate marketing strategies could affect which users adopt the technology and can have major implications for inclusion. For instance, if a company markets XR primarily to gamers, then it might discourage non-gamers from using the technology. This might have further implications for product design. For instance, XR companies might prioritize features like display resolution and graphical performance over durability and battery life. Another participant argued that if XR tools remain unaffordable to many, the industry should not market XR tools as a way to level playing fields for lower-income communities. This raised questions about the distributional effects of XR, which will depend heavily on the affordability of the technology.

Some Possible Solutions to Consider

BPC convening participants mentioned education and workforce training programs as ways to leverage the economic benefits of XR and address the challenges. They further mentioned reviewing existing laws and policies around issues like R&D subsidies, antitrust, and intellectual property. Finally, they mentioned responsible marketing strategies by industry to ensure inclusive adoption and growth in the XR market.

ACCESS AND ADOPTION

Immersive technologies have seen tremendous growth in recent years thanks in part to expanding technology applications. Still, many populations face access barriers, including affordability, digital divides, and technical literacy.

A barrier to widespread adoption of XR technologies is the cost of hardware. Leading virtual reality headsets are a serious investment, ranging from hundreds to thousands of dollars for individual use. In addition to the cost of the device, buyers must account for considerable expenses such as the cost of services, training, batteries, and extensions. Mobile and web applications are alternatives to accessing some XR content, but users' experiences are limited by the capabilities of such devices, especially for images intended to be 3-dimensional.

Already, over the past decade, the price of XR devices has dropped significantly. The Oculus Rift, a popular personal XR device, when it was first released in 2016, was priced around \$600,²² but consumers can now purchase its successor the Oculus Quest 2 for \$300.²³ Certain factors could play a role in further reducing the costs of the technology. For example, investments in AR and VR technology are likely to increase as profitable use cases develop, causing greater adoption, scaling production levels, and decreased prices for the consumer. The expansion of 5G networks can also help drive costs down as it increases storage capacity, processing power, and power preservation.²⁴

XR technologies are typically reliant on access to high-speed broadband. Some low-resolution AR applications may require bandwidth from 25Mbps, while other high-resolution experiences require upward of 100Mbps or more. In comparison, streaming a video online requires just 3Mbps or 5Mbps for high definition.²⁵ An estimated 19 million Americans do not have broadband access or are underserved (less than 25Mbps download/3Mbps upload speeds).

Even for the many Americans who do have access to broadband, affordability and technical literacy are often barriers to adoption. Nearly one-quarter of the entire population does not subscribe to broadband services at home.²⁶ From installation to monthly service fees, the cost is one of the main reasons people choose not to subscribe to internet services. Areas that have experienced limited

broadband services correspond with low technical literacy populations,²⁷ another barrier to access for XR. As an emerging technology, XR requires high levels of technical literacy and learned skills. Without experience or proper training, some users may find the technology challenging to use. The National Skills Coalition reported nearly one-third of workers in the United States lack digital literacy, meaning they have not grasped more than the most basic computer tasks.²⁸ The National Skills Coalition further reports how these gaps disproportionately affect workers of color and point to structural factors, such as long-standing inequities in access to high quality K-12 education, as a reason for this gap.²⁹

Some Possible Solutions to Consider

BPC convening participants discussed building digital infrastructure, finding ways to lower costs, and increasing technical literacy education as important factors for facilitating access and adoption. Part of the solution to improve equitable literacy could be an expansion of community labs, skill-building initiatives at universities, public-private partnerships, vouchers for training programs to help prepare the workforce, and XR training tools for non-tech savvy individuals. The National Governors Association proposed a policy pathway to help states close technological and digital resilience gaps.³⁰ Efforts to minimize the literacy gap will provide more communities with the skills to benefit from XR technologies. Further, building infrastructure to support XR capability can be vital, and both public and private investments can play a role.

EQUITY AND INCLUSION

Technological change can have serious implications for equity and inclusion. It can exacerbate or mitigate existing inequities, and early decisions about the technology can have long-term consequences. Getting ahead of XR issues can help ensure developers design the technology to be more inclusive from the start.

The challenges faced by people with disabilities provide a good example of this phenomenon. XR presents many noteworthy solutions for those living with disabilities. For example, it can enable those with mobility challenges to experience new places. In some instances, it can provide people with a visual or hearing impairment an opportunity to receive job training. People can also use the technology to overcome mental health concerns through exposure therapy. Oppositely, XR technologies present some challenges regarding user accessibility and inclusivity. XR technologies typically require mobility, vision, dexterity, and hearing, and are generally not well-designed for those with a handicap or need for assistive technology.

Developers are still adapting the XR technologies to fit the growing needs of a diverse range of users. Just as bias and exclusionary practices in the real

world can translate to the internet, these harmful practices can also enter the XR space. For instance, if an employer uses a VR simulation as part of the hiring process, biometric data might reveal that person has a disability or other sensitive factors that could result in implicit bias or discrimination.³¹ Developers are looking at privacy settings, encryption, employers' compliance with existing anti-discrimination laws, and removal of alternate accounts that were previously banned as ways to protect marginalized individuals. Developers are also looking at ways to build inclusivity into XR tools through practices such as giving users the ability to further customize their avatar according to their desired gender, race, age, and other identifiers. Preventative solutions are necessary to protect expanding user bases from potential harms.

XR is also being used for training designed to help build empathy. Training in VR simulates the real world and gives trainees immersive experiences from new points of view. For example, some state government agencies use XR to train caseworkers to understand biases affecting their decision-making and allow them to confront their preconceptions in a simulated environment before altering a client's life.³² People are still studying and debating the efficacy of XR-based bias training. As a report by the Information Technology and Innovation Foundation notes, "there is some debate among equity and inclusion advocates about the efficacy and value of such embodiment interventions, due to uncertainty about their outcomes as well as concerns that they could replace direct engagement with the communities being represented."³³ Further examination of these types of training should take place to understand the potential of the technology.

Some Possible Solutions to Consider

BPC convening participants believed developers can often address inclusivity challenges early in the design process to help ensure the technology is inclusive and safe for all users. However, participants further pointed out how inclusivity is an ongoing process that requires regular testing and updating of a product design. Designers, developers, creators, and testers of the technology should represent demographically diverse communities and understand a wide range of inclusivity and accessibility-related concerns. Further, before changes are made to government policies, decision-makers would benefit from hearing various perspectives to develop the best policies and regulations for all stakeholders and adopters of the technology. Moreover, existing regulations, especially anti-discrimination laws, provide an important layer of protection for marginalized groups and should be reviewed to see if they need to be updated to better account for emerging technology.

SAFETY

Ensuring the safety of XR tools is critical to building public trust. In many cases, performing a dangerous task in a simulated environment is likely much safer than the real-world alternative. However, immersive technologies do not come without their own safety risks. Comprehensive safety measures to protect individuals' physical well-being and safety online are essential to the widespread adoption of XR tools.

Physical safety is vital for XR tools. While VR users may feel as though they are in a new space, their physical bodies are still in the same physical space, which can increase the risk of tripping or bumping into an object. To protect users and objects in their house during this dissociation, many VR headsets create a preestablished boundary or space in which the user can move once a headset is on. Also, most VR headsets come with warnings and safety information so users can assess their own risks based on preexisting conditions and be diligent about their surroundings and physical well-being while wearing the devices.³⁴ People have raised other physical concerns around the ergonomics of XR devices and their effects on users' muscles and joints. New studies are helping redesign the technology to improve comfort and user experience.³⁵

Mental safety is another important issue to address in XR. Participants from BPC convenings discussed the need for greater public policy and standards to address harmful and unwanted content online with a participant noting that multi-user XR applications could have greater safety risks than single-user experiences. Interactions among users could result in harassment and bullying, which can be dangerous and traumatic, but often exist online in VR. Harassment and manipulation in virtual spaces has parallels to experiences in digital forums and other online platforms. One study by Extended Mind found that 36% of males and 49% of females who regularly use immersive technologies reported experiencing sexual harassment in VR.³⁶

Some Possible Solutions to Consider

Participants discussed the importance of safeguards to protect physical and mental safety with immersive technologies. These included preestablished physical boundaries, warning labels, guidelines, and more R&D to protect physical safety. For mental safety, they include content moderation, reporting abuse, blocking certain users, setting virtual buffers, and placing appropriate privacy restrictions. Developers should regularly update their XR products and standards for using them with physical and mental safety in mind, and they are still exploring ways to create proactive safeguards for online use.³⁷

Children's Safety

Despite the potential for XR tools to revolutionize educational and developmental experiences, children are particularly sensitive to the potential

risks of XR and need appropriate safeguards. Research is important, and a report from Stanford University notes, “Researchers, scholars, and VR developers need to examine the developmental issues related to the intersection of the immersive features and content of IVR (immersive virtual reality) further to determine what use of the technology are appropriate for which ages and how IVR can be used to enhance youth’s lives.”³⁸ Some of the concerns related to XR that may benefit from further research include any potential impacts on children’s brain development, visual impairment due to prolonged exposure to screens, and psychological development.^{39,40} Any potential effects XR might have on children should be given special consideration by relevant stakeholders.

Some Possible Solutions to Consider

BPC participants expressed the need to put in place extra safety precautions for children. Research is going to be critical in understanding many of the relevant challenges in addition to standards and guidelines. Many in the VR industry set guidelines recommending a minimum age limit of 12 or 13 for VR use.^{41, 42} Age limits are not standardized or regulated, but many XR manufacturers agree to these norms. The Entertainment Software Rating Board (ESRB) established a rating system to help parents determine if a video game is appropriate for their children. The XR industry can apply similar standards to immersive applications, but other factors specific to XR may be cause for more serious regulation or restrictions.

Path Forward

In 1945, Dr. Vannevar Bush issued a report titled *The Endless Frontier* to the president of the United States.⁴³ The report highlighted the role of science in reaching many national goals and providing a guideline for thinking about it in the context of public policy. The role science played during World War II was a major motivator for this report, but it also highlighted the importance of science for both military and nonmilitary purposes. The emergence of many technologies during this era, such as radar, jet engines, and nuclear power, made science and technology a critical aspect of society. The report stirred considerable interest in the role science and technology played in society and encouraged policymakers to be proactive.

Science and technology are still critical, and a holistic approach to technology policy is appropriate. The debates around immersive technologies should take place as part of the broader technology policy discussion. Immersive technologies are just one set of the many emerging technologies we are seeing today. Artificial intelligence, blockchain, neurotechnology, and other emerging technologies are also reshaping society and raising important questions. Each technology poses its own unique challenges, but they also interact with other technologies in ways that can have significant effects. For instance, the fusion of AI and robotics has given us more nimble robots that can work better alongside humans to manufacture cars. Public policy should be mindful of these interactions. For instance, neurotechnology may become deeply infused with VR and AR, creating accessibility opportunities for those with disabilities, but also posing new threats to privacy and safety. If this happens, questions about neural rights will be critical to policy considerations around immersive technologies.

This report will not examine the interaction of these technologies too deeply, given the breadth of such an exercise and uncertainty about it, though it urges readers to be aware of this dynamic. Policymakers and experts should regularly assess the broader technological ecosystem when making policy for immersive technologies. Specifically, looking at existing policy and policy gaps is important for emerging technologies like XR.

Metaverse

While no consensus definition of the term “metaverse” exists, many believe it could eventually be the next phase of the internet and experienced largely through immersive technologies. The connection of the internet and various XR devices could result in the creation of a metaverse where a larger number of people can interact together in a 3D environment. For instance, the metaverse could include entering a virtual meeting room using a VR headset to make a presentation to co-workers, then moving together to a virtual convention without leaving the comfort of one’s home.

The policy challenges of immersive technologies will almost certainly carry over to the metaverse. Issues like access, privacy, security, and inclusion with XR could magnify or change when a significant population of people is taking part in an immersive experience together. For instance, interoperability may become critical when large groups of people interact online using XR and want to easily move avatars and other items from one metaverse platform to another. Further, various other technologies, such as artificial intelligence and blockchain, will likely play a key role in the metaverse. For instance, blockchain-enabled tools might help underpin commerce by tracking ownership of a piece of digital art an artist wants to sell in the metaverse, and AI might help enable tools to search digital artwork.

Technology is moving fast, and society needs to be prepared. Multistakeholder convenings can provide a path forward on matters pertaining to the metaverse and better understanding the challenges it will bring. They can provide a roadmap for future government policies and industry standards to address potential concerns, amplify benefits, and build public trust.

EXISTING POLICIES AND GAPS

Technology often outpaces existing policy and pushes policymakers to catch up. However, many existing policies and regulations apply to emerging technologies but need to be reviewed to determine whether they are adequate, need modification, or have major gaps. This should be an ongoing, rather than one-time, process, especially given the dynamic nature of technology. BPC’s roundtable convenings and research tried to identify laws and regulations that might apply to immersive technologies and potential gaps.

Government R&D

At a basic level, many government research and development (R&D) programs apply to immersive technologies. Government agencies like the National Science Foundation (NSF) make grants to forward research into immersive technologies. For instance, the NSF's America's Seed Fund program has VR and AR listed as one of the topics it funds.⁴⁴ The R&D policies of the federal government are critical to the future of the technology. Policymakers can review funding levels and the targeting of funds for research into immersive technologies. Research should not just focus on technological issues; it should also consider issues such as societal impacts, accessibility, health effects, and ethics.

Government Procurement and Financing of XR

Government agencies often procure and finance XR tools as part of their larger mission. For instance, government agencies have been using XR tools and will regularly determine which ones properly meet their needs. According to an Accenture report, 78% of federal technology leaders agree that "XR is very or extremely important for meeting agencies' mission needs," while 86% agree that it will be "very or extremely important by the end of 2026."⁴⁵ Government decisions on procurement and financing will play a large role in driving the adaptation and design of XR tools. For example, policymakers' decisions around what types of XR-based treatments the Centers for Medicare & Medicaid Services and the Department of Veterans Affairs cover and offer will play a major role in XR adoption in the health care space.

Workforce Training Programs

Workforce training programs are starting to consider and incorporate XR technologies. For instance, the state of Alabama partnered with an immersive technologies startup to provide VR-based training at community colleges.⁴⁶ The program is available free of charge to people interested in a career in the relevant trades, including high school students, veterans, and the unemployed. Immersive technologies can play an important role in fostering workforce training and an evidence-based approach to their efficacy is vital.

Digital Infrastructure Needs

Digital infrastructure, such as broadband, is key for the access to and adoption of immersive technologies. \$65 billion to expand access to high-speed broadband was included in the \$1.2 trillion bipartisan infrastructure bill passed in 2021. The bill allocates \$14.2 billion for emergency funding to help cover the cost of broadband services for low-income Americans. Efforts like these, if done correctly, can help bridge the digital divide, so more people can have the strong internet service required to use immersive technologies.

Privacy

Privacy protections for users of XR tools have been a key point of debate, with many pointing to existing laws and noting some gaps. The Health Insurance Portability and Accountability Act (HIPAA) and the Children’s Online Privacy Protection Act (COPPA) are among the laws that put in place some user privacy protections. HIPAA places privacy protections for patients’ health data, while COPPA places privacy protections for children under 13. However, policymakers wrote these laws prior to the recent growth in XR and may need to review and modernize. Further, a major policy gap BPC convening participants identified is the lack of a comprehensive federal privacy law. A comprehensive privacy law has been a topic of discussion in Congress for a while, but many can’t agree on the specific details. At our convenings, some pointed to how some states have taken to regulating privacy in the absence of federal legislation and noted laws such as the Biometric Information Privacy Act (BIPA) in Illinois. Others pointed to Europe and the General Data Protection Regulation (GDPR) for a foreign example of an international privacy law. Questions exist as to how well these laws are tailored for data collected by XR tools specifically, especially given recent debates around neurorights.⁴⁷

Tort and Labor Laws

BPC convening participants noted tort laws and labor laws when discussing protections for consumers and workers. Tort laws give the harmed party a means to get monetary compensation for being harmed, while labor laws create government protections for workers. A BPC convening participant pointed to the Occupational Safety and Health Administration (OSHA) as a place to look to for worker safety when using XR tools. Participants discussed the adequacy of tort and labor laws—asking questions about whether and how to modernize them, given technological changes.

Civil Rights Laws

Civil rights laws designed to prevent discrimination and to foster equity and inclusion will play a role with immersive technologies. These laws are critical and need to be reviewed to ensure they are well-designed to counter any discrimination that might occur as the result of the adoption of immersive technologies. For instance, reviewing how these laws would treat discrimination against a protected class in the virtual space or discrimination based on inferences from biometric data from a VR headset is important.

Additional Areas for Review

An exhaustive review of all the laws pertaining to XR is a significant undertaking and beyond the scope of this report. However, other existing laws and policies need to be reviewed to see whether they should be modernized and if any policy gaps exist. A review should include whether a government agency

should leverage XR tools for its internal processes, such as using VR to help foster collaboration between co-workers in different locations.

STANDARDS, FRAMEWORKS, AND OTHER SIMILAR TOOLS

Standards, frameworks, and similar tools (such as guidelines and best practices) are more flexible relative to government laws and regulations, but they lack the government's enforcement power. They are often critical with emerging technology when flexibility is key. Several organizations have attempted to put in place standards, frameworks, and similar tools applicable for XR technologies including:

- The National Institute of Standards and Technology (NIST) put out both a privacy⁴⁸ and a cybersecurity framework⁴⁹ in January 2020 and April 2018, respectively. The frameworks are voluntary and designed as a tool for organizations to manage their privacy and cybersecurity risks. While not specific to XR, many of the framework's ideas can apply to XR.
- The XR Safety Initiative released an XRSI privacy and safety framework⁵⁰ in November 2020. The framework aims to expand the definition of personal data to include biometrically inferred data and incorporates ideas from NIST's privacy framework, the General Data Protection Regulations (GDPR), Family Educational Rights and Privacy Act (FERPA), and Children's Online Privacy Protection Rule (COPPA). Further, the framework aims to adapt itself to new regulations and requirements as they arise and is currently being updated to version 2.0.
- The CyberXR Coalition published the Immersive Technology Standards for Accessibility, Inclusion, Ethics, and Safety⁵¹ in May 2020 with core principles based on Trust, Inclusion, and Accessibility (TIA). The overarching goal of this standard is achieving "Human Centric Design." While the standard is more general in its application to all emerging immersive technologies, the "culture, and care" mindset applies to XR.
- The Institute of Electrical and Electronics Engineers (IEEE) released several reports, with many containing recommendations, regarding XR last year: Ethics in Education,⁵² Social and Multi-User Spaces in VR: Trolling, Harassment, and Online Safety,⁵³ The Erosion of Anonymity and Privacy,⁵⁴ and Global Ethics.⁵⁵ Each of these recommendations and analyses addresses a different area in society, though the overarching goal is maintaining an ethical standard surrounding privacy protection.
- The XR Association, an industry trade group, published several reports containing its recommendations for best practices⁵⁶ when using XR, including ones focused on equity in the workplace⁵⁷ and health and safety.⁵⁸

It also released a three-part chapter series focused on issues such as fundamental design principles,⁵⁹ safety and inclusion,⁶⁰ and accessibility.⁶¹

- The Web Content Accessibility Guidelines (WCAG),⁶² developed through the World Wide Web Consortium (W3C)⁶³ process, is scheduled to publish a draft in June 2022. There have been two previous iterations, one in 2008 and one in 2018, which both introduce “success criteria” as technical standards. Based on accessibility, WCAG is designed for web content developers, tool developers, accessibility evaluation tool developers, or others who desire a standard for web or mobile accessibility. The WCAG standards are not specific to XR, though the working group recommendations proposed by W3C are specific to XR, and when used together, the two provide recommendations for tool and technical accessibility.⁶⁴

These documents help start important discussions about addressing the challenges in the XR space. While this report will not evaluate their efficacy or which should be used, their success will depend both on meaningfully addressing the relevant challenges and their getting meaningfully adopted by industry.

Finally, we will note that important questions exist about whether and when government intervention and enforcement are necessary on top of any standards and frameworks, which are questions we don’t answer in this report. However, if well designed and meaningfully adopted by industry, standards and frameworks can play a large role in building public trust, improving the XR experience, and maintaining adaptability to shifting circumstances that require a rapid response.

Conclusion

Immersive technologies have seen rapid growth in recent years. They have raised and will continue to raise many policy issues that government officials, industry, and civil society will continue to debate. These issues are complicated and immune to simple solutions, but discussion today is important to address the challenges of tomorrow. Our report aims to jumpstart this conversation. We encourage stakeholders to further engage on these issues and especially encourage meaningful engagements between the XR industry and civil society to get ahead of these issues. Moreover, debates around immersive technologies would benefit from greater public awareness and encourage media outlets, industry, civil society, and academia to help educate people in a way that does not give in to utopian nor dystopian sensationalism. The broader public's input is critical to the future of XR and keeping them informed is crucial to this process. Finally, if policymakers and industry appropriately address the challenges of XR, immersive technologies can help enhance human potential and increase quality of life, while respecting civil liberties, encouraging safety, and promoting inclusion. However, this is not inevitable and requires proactive effort, considerable research, meaningful engagement, and smart public policy.

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