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Risks and Challenges for Inclusive and Equitable Immersive Experiences

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AR/VR has the potential to make both digital and non-digital services more inclusive and equitable. To achieve that goal, industry leaders and policymakers should take steps to mitigate potential unintended consequences.

KEY TAKEAWAYS

- Particularly in marginalized or underserved communities, users may face risks and challenges that discourage or preclude them from using AR/VR technologies.
- Offline biases can manifest in virtual spaces, such as stereotypes based on race or gender. Information gathered or inferred about a user in AR/VR also could reveal sensitive personal information that puts them at risk of discrimination.
- To address these challenges, the AR/VR stakeholders will need to consider issues such as health, privacy, and safety, as well as bias, discrimination, harassment, and abuse.
- AR/VR also presents unique accessibility challenges for people with disabilities. Standard accommodations for two-dimensional media are insufficient to address accessibility needs in three-dimensional spaces.
- Potential barriers to accessing or adopting AR/VR technologies may include insufficient broadband connections, affordability, or digital literacy gaps.
- To design inclusive immersive experiences, developers and organizations using AR/VR should consider a wide range of user needs and preferences, including diverse avatar options and user controls for safety and privacy.

INTRODUCTION

Augmented and virtual reality (AR/VR)—immersive technologies that enable users to experience digitally rendered content in both physical and virtual space—have the potential to transform the way individuals work, learn, and interact. By mitigating barriers imposed by physical distance, they can bolster economic opportunity by allowing employees to collaborate from anywhere in the world, make critical services such as healthcare and education more accessible, and create new channels for social connections. Further, their ability to manipulate elements of partially or fully virtual spaces allow them to more easily accommodate a diverse set of user needs, from accessibility features to privacy preferences.

In short, immersive technologies have the potential to make both digital and non-digital services and spaces more inclusive and equitable. However, there are important challenges that industry leaders and policymakers will need to consider to maximize the availability of immersive technologies across a wide range of demographics and to mitigate potential unintended consequences. In particular, they should consider:

AR/VR Equity & Inclusion Series

- Privacy, health, and safety risks that could adversely affect AR/VR users and non-users.
- Financial, physical, technical, and societal barriers different user groups face to adopting or using AR/VR devices and applications.
- Bias and discrimination risks in critical areas such as employment, education, and government services.

Attention to these considerations will benefit many users by reducing the potential for malicious use of the technology or other unintended consequences that could impede progress in AR/VR adoption. Indeed, employers, educators, and government agencies will expect solutions to many of these challenges before they widely adopt AR/VR technologies.

To address these challenges, those designing and implementing the technology will need to understand the perspectives and lived experiences of a diverse array of individuals. In particular, if they hope to ensure AR/VR advances inclusiveness and equity, they should pay attention to voices from vulnerable, marginalized, or otherwise underserved individuals and communities sometimes underrepresented in the past in discussions around both policy and product development. This includes—but is by no means limited to—communities of color, people with disabilities, the LGBTQ community, abuse survivors, people who are physically or socially isolated, children, older adults, low-income individuals, and other groups that already face heightened risks of harm and exclusion in the "real world."

There are already notable efforts underway in both industry and policy to consider possible mitigation approaches and proactively develop and implement AR/VR solutions that reflect the needs of a broad range of users. This report highlights some of the top considerations that developers, policymakers, and implementing organizations should include in these efforts. Drawing from interviews with stakeholders with both expertise in and lived experiences of some of these challenges, it explores the concerns that of top importance to equity and inclusion

advocates when it comes to AR/VR technologies. It then discusses the implications of these risks and challenges for AR/VR innovation and adoption across sectors.

This report is the second in a three-part series exploring the issues of equity and inclusion in AR/VR.

RISKS AND CHALLENGES FOR VULNERABLE USERS IN AR/VR

Individuals and organizations across sectors are just beginning to discover the potential of AR/VR for entertainment, productivity, education, and communication. This user base is continually expanding: One estimate predicts that about 18 percent of the U.S. population will use VR and 28 percent will use AR at least once per month in 2021.[1] However, there are still challenges that may discourage or preclude a significant number of users and broader communities—largely already marginalized and underserved individuals—from accessing and fully utilizing these technologies. These include heightened privacy, health, and safety concerns; barriers to access to and inclusion within immersive experiences; and the potential to compound rather than mitigate bias and discrimination in both virtual and physical spaces. Individuals and communities that face heightened risks to personal safety and autonomy in daily life because of factors such as age, race, gender, sexuality, disability, or other aspects of their identity will be particularly sensitive to these concerns. For example, minority communities may be more likely to face bias, discrimination, and harassment due to factors such as their race or religion; thus, they may be more vulnerable to harms from violations of their privacy that reveal sensitive or potentially identifying information that they did not choose to disclose.

Anticipating these barriers will allow developers and organizations to build and implement more effective AR/VR solutions and prevent negative impacts or drawbacks that could have been relatively easily avoided. Because the technologies are still relatively new, developers can learn from the pitfalls of digital communications technologies that came before them, and produce products with user safety, accessibility, and other considerations in mind.

Table 1: Key Considerations, Risks, and Challenges AR/VR Technologies Present for Vulnerable and Marginalized Communities

Considerations	Risks & Challenges	Potentially Vulnerable Groups	Responses
User Privacy	Third parties could use collected data to infer sensitive or private information about a user, which could also lead to bias, discrimination, and risks of personal harm	Users with both visible and non-visible disabilities; Racial and religious minorities; Other marginalized groups that are vulnerable to discrimination based on aspects of their identity	Give users control over how and when applications and devices infer and share sensitive data or potentially identifying information
Bystander Privacy	Malicious users could use the recording and data collection capabilities of AR devices to stalk and harass others; Law enforcement use of these devices or access to	Abuse survivors and other individuals who face heightened risks of stalking and harassment; Individuals who do not want to be identified or	Include safeguards and codes of conduct that limit users' ability to record or gather data in sensitive spaces; Implement standards for law enforcement use that

Considerations	Risks & Challenges	Potentially Vulnerable Groups	Responses
	user data could endanger First and Fourth Amendment rights	recorded in sensitive locations	ensure civil rights protections
In-World Safety	Vulnerable and marginalized users are often the target of harassment and abuse in multi-user AR/VR experiences; Because of the immersive nature of VR, users can feel like they are personally experiencing any violence, abuse, and even sexual harassment against their avatar	Women; Racial minorities; LGBTQ users; Users with disabilities; Other users who face heightened risk of harassment and abuse both on- and offline	Allow users to create private spaces; Allow users to select which aspects of their identity to present (or hide) through avatar selection; Provide users with real-time safety tools; Implement monitoring and enforcement practices
Physical Safety & Comfort	Immersive experiences can lessen or fully replace a user's sensory connection to physical space, putting them at greater risk of accidental physical harm; Devices can cause physical discomfort or dangerous physiological responses, particularly among groups who may be underrepresented in the product development process	Users with disabilities or other sensory limitations; Users who are unable to comfortably use wearable AR/VR devices	Implement safety measures to provide situational awareness while in an immersive experience; Include a diverse set of users in product development and testing
Accessible Design	Immersive experiences present accessibility challenges that may not arise in two-dimensional media; Not all users will be able to use AR/VR devices in an optimal environment: Those who have limited physical space or range of motion, or are in a noisy environment, may not be able to fully engage with virtual experiences	Users with disabilities; Other users who may not be able to meet ideal conditions for using AR/VR devices and applications	Allow users to customize experiences to meet accessibility or situational needs; Include multi-sensory accommodations that take advantage of AR/VR capabilities such as three-dimensional visuals, immersive audio, and haptic feedback; Allow users to utilize additional accessibility hardware when necessary

Considerations	Risks & Challenges	Potentially Vulnerable Groups	Responses
Technical Requirements	Users who lack a reliable high-speed Internet connection are not able to use many AR/VR applications	Users in rural, low-income, and other underserved communities	Provide alternative means of access, including offline options
Non-Technical Barriers	The cost of AR/VR devices remains prohibitively high for many potential users; Existing digital knowledge gaps could discourage already marginalized and underrepresented users from utilizing new technologies including AR/VR	Low-income households; Older adults; Other individuals or communities facing financial and knowledge barriers to access	Invest in digital equity and connectivity; Integrate user education into immersive experiences
Representation	Lack of diverse representation in AR/VR experiences could exclude or discourage users who do not see their own identities and experiences represented in these spaces; Requiring users to reflect their real-world identity in AR/VR could put already vulnerable users at risk of bias, discrimination, and harassment	Users who are underrepresented in virtual experiences	Offer diverse options in avatar selection; Include rules and community standards that prohibit malicious misrepresentation
Bias & Discrimination	Implicit and explicit bias and discrimination that exists in the "real world" will inevitably transfer into virtual experiences, leading to the potential for discrimination in virtual workplaces, classrooms, or public spaces; AR/VR solutions could also lead to de facto discrimination against individuals who face barriers to accessing and participating in virtual experiences	Individuals with disabilities; Racial and religious minorities; Women; Other users and individuals who are already subject to "real world" bias and discrimination	Create rules and guidelines that mitigate effects of bias and discrimination within virtual experiences; Offer accessible alternative means of access, including physical locations, for virtual services and experiences

Privacy, Health, and Safety

For immersive experiences to benefit a broad range of individuals and communities, AR/VR devices and applications should consider the options that different types of users may need to feel comfortable and secure. Given the scope and scale of data collection, the feeling of being "really there" in both positive and negative immersive experiences, and the physical requirements of AR/VR devices, some user privacy, health, and safety needs may fall through the cracks if safeguards are not put in place. To the greatest extent possible, developers should design immersive experiences that take into consideration these needs, particularly for their most vulnerable users and their communities. This will establish a strong baseline for privacy, health, and safety in and around AR/VR solutions.

Ensuring User and Bystander Privacy

For many vulnerable and marginalized communities, disclosing a part of their identity could put them at risk—so the ability to determine when, how, and with whom they share information about themselves is important. AR/VR presents unique and heightened privacy risks due to the scope, scale, and sensitivity of the data these technologies require to operate.[2] Notably, these risks extend beyond device users: AR devices and applications may capture non-user bystanders or private spaces when processing audio, visual, or spatial data about a user's surroundings; or provide a user with real-time, potentially aggregated information that might reveal otherwise private details about others. Without safeguards in place, malicious actors could also use these technologies to stalk, harass, and otherwise violate others' privacy and autonomy.[3] If AR devices and applications further aggregate audiovisual recordings with other potentially identifying information, these capabilities can put particularly vulnerable users, such as abuse survivors, or others who may not want to be identified or recognized in certain spaces, at acute risk of harm.[4] Because of this, those developing and implementing AR solutions for consumer or public use should consider potential transparency mechanisms to protect bystander privacy. Currently, the most widely used approach is using an LED light or other visual indicator to notify bystanders that a device is recording—but as these devices evolve, there will be significant opportunity for developers to explore more innovative approaches to transparency and choice.[5]

The persistent recording and processing capabilities of AR devices, as well as the significant amounts of potentially identifying information collected during VR experiences, could have consequential implications for civil rights. For example, law enforcement use of AR devices that can gather and aggregate real-time information could unduly endanger First and Fourth Amendment rights, particularly in communities that are already disproportionately targeted by law enforcement.[6] Similarly, data gathered from a VR device or application, if shared, could reveal a significant amount of personal information about a user. Additional safeguards are necessary to protect Fourth Amendment rights when it comes to government and law enforcement access to real-time information and user data.[7]

The multimodal data collection inherent to AR/VR technologies, including motion and eye tracking, location and spatial mapping, and even biographical or identifying data shared by a user, often correlates strongly with personal information many people would prefer to keep private. Biometric inputs, such as gaze or movement, can allow AR/VR devices and applications to infer details such as race, gender, age, or disability. This could remove individuals' ability to determine when, how, and to whom they disclose aspects of their identity. [8] "We know that information about people's identities can be used against them," said Cynthia Bennett, a

researcher at Carnegie Mellon University's Human-Computer Interaction lab, "so there's a lot of concerns that definitely need to be well thought out" when considering user privacy.[9] For example, if an employer used a VR simulation as part of its hiring process, the data gathered during a session could reveal that a candidate has a disability, which could lead to implicit bias or hiring discrimination against that candidate. Although the candidate may have legal recourse under anti-discrimination laws, this type of involuntary disclosure undermines their personal autonomy and choice over the personal information they share with employers. User privacy measures, such as restricting third-party access to this information, can mitigate the potential for these technologies to lead to unintentional discrimination or malicious misuse of individuals' potentially sensitive information.

Protecting Users Against In-World Harassment and Abuse

Harassment and abuse is a concern across communications technologies, from social media platforms to private messaging services. These risks are certainly not unique to VR, or even to digital media, especially for users in already vulnerable and marginalized groups, including women, people with disabilities, racial minorities, and members of the LGBTQ community. Other platforms and communications tools have struggled with the unintended consequences of their services on the mental and emotional well-being of users experiencing harassment and abuse. But the highly adaptable nature of AR/VR, including multi-user experiences, could allow developers and implementing organizations to preemptively put effective safeguards in place if they have a comprehensive understanding of the potential for misuse.

User safety considerations are particularly important in the context of VR due to the sense of presence and embodiment that immersive experiences give the user. Indeed, studies have shown that users identify their avatars, or virtual representations of themselves in VR, as a part of themselves.[10] Unfortunately VR's ability to replicate the physical world in virtual space also means that it can realistically and convincingly replicate physical abuse. This means that not only is verbal harassment a concern in immersive spaces, but so is physical abuse and sexual harassment.[11] These forms of harassment and abuse can have severe psychological impacts, particularly on individuals who have experienced or are at acute risk of similar actions in their physical reality. "There is a world here that can be very triggering for people who have dealt with this kind of abuse in the real world," noted Carlos Gutierrez, deputy director of nonprofit LGBT Technology Partnership and Institute.[12]

Indeed, many social VR users have experienced harassment. In one survey of 600 social VR users, nearly half of all female respondents and over one-third of male respondents said they had experienced sexual harassment in VR.[13] Respondents also reported verbal and sometimes physical harassment against their avatar targeting their gender, race, or sexuality.[14] In another study of women who were first-time social VR users, many of the participants brought awareness of sexism and gender-based harassment into the experience and took defensive or preemptive actions, such as avoiding large crowds or not engaging in conversations with strangers.[15] As one participant noted, "I have a few real-world experiences that I don't want to experience necessarily virtually." [16]

VR platforms can address some of these risks. For example, within social VR experiences, best practices such as safety bubbles (an invisible perimeter around an avatar that prevents other avatars from violating a user's personal space within a virtual environment) and other user safety

controls have become standard.[17] Likewise, particular VR applications, especially those offering social VR experiences, will need to develop their own user safety policies and enforcement mechanisms, similar to how other online platforms address harassment and abuse today. For example, a social entertainment platform might ban a user who engages in inappropriate behavior. Finally, when employers or organizations such as schools implement multi-user VR applications, they will be responsible for addressing inappropriate behavior that occurs in virtual spaces. For example, a business that uses AR/VR devices for collaboration might establish policies that apply disciplinary measures for inappropriate behavior in virtual workspaces. By creating clear and appropriate accountability mechanisms for virtual harassment and abuse in different contexts, developers and implementing organizations can better protect their users.

As platforms and implementing organizations consider these types of safety measures in VR applications, it is important that they seek input from those often targeted by online harassment and abuse.[18] Even well-intentioned platforms may inadvertently harm those who they mean to help if they are developed without input from those users. This is already a phenomenon in two-dimensional digital media. For example, in an attempt to address online bullying, the social video-sharing platform TikTok in 2019 limited the reach of videos created by certain users, such as those with physical or cognitive disabilities. However, disability advocates rightly criticized this policy, arguing that it was made without sufficient input and removed creators' ability to make their own decisions about their personal safety.[19] Better engagement at the outset can prevent these types of missteps.

Building for Physical Safety, Health, and Comfort

Although immersive experiences are virtual, they can have tangible impacts on a user's physical reality. AR/VR devices and applications should take into consideration the potential health and safety impacts for a diverse set of users, particularly those who are most vulnerable to harm. Merging or fully replacing the physical world with virtual elements alters situational and spatial awareness, which increases the potential for accidents due to distractions or sensory obstructions. While this is true for all users, the danger is greatest for those who may already rely on assistive technologies to gain an awareness of their surroundings that others may take for granted. For example, while many users rely on sound to maintain some awareness of their physical surroundings even when fully immersed in a VR headset, deaf and hard of hearing users do not have this same sensory connection to their physical space. This puts them in greater danger if there is an emergency signal, such as a smoke alarm going off. And efforts to address these types of issues often has spillover benefits, such as also protecting the safety of hearing users who wear noise-cancelling headphones. Many VR devices already include safety features that quickly return users to their physical environment, such as external cameras that will display physical surroundings when users step outside of predetermined boundaries, or the ability to display virtual replicas of furniture within an immersive environment. Further developing features to improve users' situational awareness will significantly mitigate safety risks both in personal and professional uses.

AR/VR technologies can also cause discomfort and potentially dangerous physiological responses. It is important for developers to mitigate these effects to the greatest extent possible to increase the potential user base for their devices and applications. These effects often adversely affect users who are underrepresented in the product development process or within a potential user base. One widely cited example of this impact is different users' susceptibility to

"cybersickness," or a sensation of motion sickness within a virtual environment. In one study, researchers believed women were more likely to experience this phenomenon because they had greater difficulty fitting the display to their eyes.[20] In fact, device fit can affect the comfort and usability of AR/VR devices for a broad range of users. Individuals with glasses or other head-worn assistive devices, such as cochlear implants, may have difficulty adjusting a head-mounted or heads-up display to their needs.[21] One researcher using VR headsets as part of a study in Nairobi also discovered the devices did not fit properly for many participants with thick braids or head coverings.[22] Comfort may also depend on contact with the device rather than fit alone, as some individuals who may be hypersensitive to touch or textures may be unable to use wearable AR/VR devices or controllers, particularly for a sustained period of time. By engaging a broad range of potential users from the outset, developers can avoid extensive after-the-fact adjustments to their products.

Access and Inclusion

Industry leaders and policymakers should address the complex and often overlapping barriers to access that could impede AR/VR innovation and adoption. The communities that could benefit most from these technologies often face disproportionate barriers to accessing or using them. As disability rights advocate and general counsel at the Center for Democracy and Technology Lydia X.Z. Brown warned, "immersive experiences can be a way to enable more access to certain types of opportunities and spaces, and also a way to exacerbate, deepen, and worsen existing inequalities and inaccessibility."[23] AR/VR devices and applications, and those who develop and implement them for uses across sectors, should approach access and inclusion holistically, with consideration for the potential physical, technical, and non-technical and intersectional barriers to adoption.

Creating Accessible Devices and Experiences

As Carnegie Mellon University researcher Cynthia Bennett noted, "we tend to innovate inaccessible technology first, and then consider accessibility as an afterthought."[24] When this happens it often results in costly, ad-hoc measures to bring technologies into compliance with baseline accessibility clients and meet the needs of users with disabilities. Many disability advocates are concerned that this trend is continuing in AR/VR. Indeed, because immersive experiences are inherently multisensory, they raise complex accessibility challenges affecting users with mobility, vision, hearing, speech, and cognitive impairments.[25] This makes these technologies challenging or even impossible to use not just for individuals with disabilities, but also anyone who is unable to use certain senses or motor functions even temporarily. For example, a user may be sitting down, or have their arms full, or use the device from a noisy location. Very few users, regardless of ability, will be able to replicate the optimal environment for an experience every time. Therefore, many basic accessibility considerations will also improve overall user-friendliness for many AR/VR solutions.

First and foremost, AR/VR devices themselves must be accessible. From smartphones to smart glasses, controllers to head-mounted displays, users need to be able to setup and use the physical hardware that delivers immersive experiences. "Making sure that the hardware, and the fundamental platforms that these applications are on … are accessible is definitely fundamental to making everything accessible," said Larry Goldberg, one of the leaders of the XR Access Initiative, "otherwise, you may have accessible applications, but there's no way to reach them."[26]

Many consumer devices currently on the market do not meet the basic accessibility needs of users with disabilities.[27]

The platforms, applications, and immersive experiences based on these devices come with their own accessibility considerations.[28] For one, most AR/VR applications require some range of motion, making it cumbersome or even impossible for individuals with mobility limitations to perform actions required to navigate or interact with virtual elements. The audiovisual elements that establish fully or partially virtual spaces also present accessibility issues for deaf and hard of hearing, blind and low-vision, and deaf-blind users, as these multi-sensory experiences offer limited alternatives. And finally, users who are sensitive to cognitive or sensory overload, including those with photosensitive epilepsy or cognitive disabilities, may find fully immersive experiences or significantly augmented physical spaces difficult or dangerous to navigate.[29]

Fortunately, it is possible to address many of these accessibility needs as a part of, rather than supplementary to, the overall user experience of AR/VR devices and applications. Ultimately, it is simply a matter of the extent to which users are able to customize their virtual environments to their needs. Accessible user preferences are already a part of other digital platforms, such as automated captioning for video calls or the ability to enlarge text by default on mobile devices. When it comes to VR, some enthusiasts with disabilities have come up with both software-based and low-tech "hacks" in order to use these devices and participate in VR experiences. One survey of VR users with disabilities found that many relied on adaptations such as modifying open-source code, moving within the play area to "walk up" closer to virtual menus or other objects, or augmenting device controls with more accessible hardware.[30] But it is unlikely (and unreasonable to expect) that more casual users would elect—or even be able—to dedicate the time and resources necessary to adapt these technologies to their needs. Instead, developers should consider accessibility for a broad user base for both the inputs (how a user controls and interacts with virtual elements) and outputs (how the virtual environment is presented to the user) when developing AR/VR solutions.[31]

Despite the evident need for standards and best practices for accessible AR/VR technologies, there is not a well-established baseline for accessible design of devices or applications. Although web accessibility guidelines could inform some elements, these were designed for two-dimensional digital media and come up short for immersive three-dimensional experiences.[32] For example, digital video captioning places text from a single audio source in a fixed position on a screen, but immersive spaces require captioning from multiple audio sources in a three-dimensional environment. Similarly, optimizing two-dimensional web pages for screen readers is much more straightforward than it would be in an environment where all or most elements are digitally rendered in three-dimensional space. The current dearth of established standards or widely-adopted best practices for accessible AR/VR means that developers often design and incorporate accessibility features from the ground-up—a costly and time-consuming process that could discourage them from pursuing accessible design from the outset.

Considering Barriers to Access Beyond Design

The ability to use AR/VR devices and navigate virtual experiences is a necessary baseline, but accessible design alone is not enough to overcome the barriers to adoption that disproportionately impact vulnerable, marginalized and underserved users. The "digital divide" is a well-documented concern: As technological innovation proceeds, marginalized and underserved

communities are often left behind, especially initially. This leads to lower overall adoption rates among potential users who could benefit from these technologies, including rural and low-income communities, older adults, and people of all ages with disabilities. The divisions that persist for basic Internet and digital communications could have spillover effects for equity in AR/VR adoption: As Larry Goldberg pointed out, "now that we're talking about technology that demands high-speed broadband [and] fancy hardware, that divide can get even wider."[33]

Robust wireless or high-speed Internet connections are necessary for widespread access and adoption of both stationary and mobile AR/VR solutions. Although some basic immersive experiences (such as 360-degree videos stored on a device and other single-user applications) do not require Internet connectivity, most advanced functions—particularly those that use AR/VR technologies to enhance collaboration and communication—require a reliable, high-speed connection. Indeed, growing optimism about the future of AR/VR is tied to advancements in 5G, which would allow small wearable technologies such as smart glasses to offload processing power to cloud servers without minimizing the user experience or relying on standalone Internet connections.[34] Yet among many potential users, disproportionately those in rural and low-income communities, adoption of high-speed Internet remains low.[35] In order to realize the full potential of AR/VR to overcome barriers from physical distance, policymakers should ensure that broadband sufficient for applications such as remote work, telehealth, and assistive technology is available to the vast majority of the population and affordable for all, regardless of income.[36] This is one reason why including well-designed subsidies to support broadband deployment and adoption should be a core component of potential legislation aimed at improving U.S. infrastructure.

Although innovation is accelerating toward more affordable and user-friendly AR/VR technologies, the cost of the devices themselves remain prohibitively high for many. The lowest-cost options for users in both AR and VR are mobile or web-based applications. But even these require a smartphone or other compatible mobile device or personal computer, and the capabilities of mobile-tethered applications are often limited.[37] As of 2019, VR headsets that did not rely on a mobile device ranged from about $250 to as much as $1,000 per unit.[38] Costs for wearable heads-up displays, including smart glasses and mixed reality headsets, remain even higher.[39] For many individual users, as well as smaller organizations that may consider adopting VR solutions, this cost is simply prohibitive, and could create further gaps in digital adoption for those who would otherwise benefit from the technology. While there is no need for all individuals to have access to AR/VR devices at this time, it could be beneficial to support access for organizations serving certain communities, such as schools serving principally low-income students.

These challenges can lead to less tangible but equally impactful knowledge barriers. When technology adoption lags, so too does technical literacy and confidence in new innovations. Some of these knowledge gaps are generational: A 2015 Pew Research Center survey found that U.S. adults over age 65 were more likely to feel "only a little" or "not at all" confident using digital tools, and many needed assistance when setting up new devices.[40] However, digital literacy gaps exist for many of the vulnerable and marginalized communities that could use AR/VR technologies. For example, another Pew Research Center survey of digital readiness for online learning found that about half of U.S. adults were "relatively hesitant" to adopt these technologies, with women, individuals with lower levels of formal education, members of lower-income households, and individuals ages 50 and over more likely to fall within this category.[41]

Although AR/VR devices and applications have elements that will be new and unique for most users, the fundamentals of these technologies draw from existing digital tools. Persistent digital knowledge gaps put already underrepresented users at a disadvantage from the offset, potentially discouraging use overall or leaving them more vulnerable to potential harms from incorrect use. Because of this, user education and digital literacy will be an important component of any AR/VR-driven equity and inclusion efforts.

Finally, it is important to note that these barriers to adoption coexist for many potential users, acting as multipliers that can further exacerbate disparities in access. For example, as Lydia X.Z. Brown of the Center for Democracy and Technology noted, "disabled people are disproportionately more likely to be unemployed and under-employed, disproportionately more likely to be poor. And so we're less likely to have reliable broadband access, we're less likely to have access to such devices."[42] Similarly, a significant portion of Americans with disabilities are also older adults, so low levels of digital literacy could exacerbate the challenges that inaccessible design present.[43] Because of this, efforts that consider only select barriers to access will still leave many communities behind.

Designing with Representation, Inclusion, and Belonging in Mind

Inclusive AR/VR should consider not only equitable access, but also inclusive immersive experiences. AR/VR experiences that rely on a single (often white, male, and able-bodied) default could discourage potential users who do not identify with or share the experiences of this default from fully participating in immersive experiences. As one participant in the previously mentioned study on women in social VR said, "the only real discomfort is, when you start out, your avatar is a balding white male. I am not a balding white male."[44] Designing with the needs and preferences of diverse users in mind is critical to ensure that AR/VR solutions are, at a minimum, just as inclusive as real-world alternatives. As these technologies have gained more widespread consumer adoption, AR/VR platforms and services have developed more inclusive approaches to avatar selection, ranging from photorealistic representations to highly customizable options.

In the "real world," individuals will adjust how they dress and behave based on the context of their activities, such as acting differently at a professional conference versus a casual meet-up with friends. In order for AR/VR technologies to both replicate and enhance physical spaces, giving users the ability to control from the outset how they interact and represent themselves within immersive experiences is critical. "You own who you are, but you want to have the option to change that, or present yourself however you want to," said April Boyd-Noronha, a diversity, equity, and inclusion expert who leads the Cyber XR Coalition, an organization advocating for inclusive AR/VR.[45] This is particularly true for marginalized and underrepresented users—both those who want to translate visual cues about their identity into their virtual and environment, and those who want to obscure these features to protect their privacy and safety.[46] For example, "for people with disabilities, choosing whether or not to present as having a disability is [important]," said XR Access Initiative advisor Dylan Fox. "In some contexts, they might want an avatar with a wheelchair, in others they may not."[47]

Diverse representation within immersive experiences will inevitably come with trade-offs. Users may choose to represent themselves with a different race, gender, or disability than they have in the real world—and some may do so for specifically disruptive purposes, such as mocking people with disabilities or playing out racial stereotypes. However, the alternative is to require self-

disclosure of marginalized identities or erase those identities entirely within virtual spaces.[48] While this would certainly diminish the experience and discourage adoption of AR/VR for personal or social use, such a lack of representation or mandatory disclosure raises particular concerns for other use cases such as workplace or educational uses. Instead, developers building multi-user immersive experiences should ensure their codes of conduct and monitoring and enforcement mechanisms discourage malicious misrepresentation.

If users do not feel they can represent their authentic selves, they may be less inclined to use an experience, which in turn could discourage others from engaging in immersive experiences because they do not see others who look like them in virtual spaces. "The accessibility factor is also a mindset: Do we belong here?" said April Boyd-Noronha, "because that message has been shouted loud and clear, that certain communities do not. And so just shifting that mindset is monumental."[49] Designing with inclusion in mind will be an important component in driving this shift and opening immersive experiences up to a broad and diverse set of users.

Bias and Discrimination

The greatest promise of AR/VR is its ability to render the physical world in partially or fully virtual space. However, this also means that the biases that exist in reality could also manifest in these virtual worlds. "Racism, sexism—the 'isms'—don't stop at the door once you enter a virtual reality," said April Boyd-Noronha; "what is happening in the real world is, for sure, happening to some degree in [AR/VR]."[50] While these technologies do offer potential to serve as tools in reducing instances of bias, it is important to consider the ways in which AR/VR devices could replicate or even exacerbate harmful discrimination within virtual experiences. If developers and implementing organizations understand these risks from the outset, they can develop the necessary policies, practices, and technical mechanisms to reduce the potential for real-world bias and discrimination to undermine the potential of multi-user immersive experiences.

Some of these concerns come specifically from social experiences: As VR researcher Jessica Outlaw has argued, social VR spaces are constructed around unique norms and behavior, or elements of culture, just like any other social group: heroes, archetypes, mascots; stories, myths, origin stories; ceremonies, rituals, symbolic acts, rites of passage; symbols, language, artifacts' taboos, and jokes.[51] Because individuals who are already more likely to face bias and discrimination are largely underrepresented within virtual spaces, many of these key elements are often built around a specific (generally white male) user base. This can lead to discrimination, even if unintentional, within these spaces: "If you're trying to build an inclusive space, but all of your heroes only represent one demographic," said Jessica Outlaw, "that goes to 'who is this space for' and 'who is welcome in this space?'"[52]

Explicit and implicit biases based on visual appearance will undoubtedly persist in virtual spaces, including those used for education, work, and healthcare or other services. Here, users may prefer—or indeed be required—to use photorealistic (or otherwise closely representative) avatars, making it more difficult to obscure parts of their identity such as race and gender. In addition to navigating the biases of coworkers, providers, and peers, users may also bring their own internalized biases into these spaces. For example, studies show that individuals internalize stereotypes about their expected performance based on their race.[53] It remains to be seen whether this self-stereotyping is reinforced, mitigated, or unaffected when users embody an avatar that has these same characteristics.[54]

In addition to transferring existing biases into virtual spaces, AR/VR can also further entrench bias and discrimination in the "real world." The potential for AR/VR to lead to further discrimination in individuals' daily lives is inextricably linked to the concerns of safety, accessibility, and inclusive design discussed in this report. For example, information gathered and inferred about a user in AR/VR could reveal personal information that puts them at greater risk of discrimination, including race, gender, disability, age, or sexuality.[55] Further, AR/VR evaluations used in hiring could discriminate against candidates who underperform due to accessibility challenges, discomfort, lack of understanding of the technology, or simply because they approach the experience from a perspective that was not accounted for when building it.[56]

De facto discrimination can also arise within workplaces, classrooms, and other spaces that may adopt AR/VR solutions if those who are unable to use these devices for any reason are precluded from participating in valuable experiences such as trainings or meetings.[57] This unequal access could impact opportunities for advancement, professional development, and educational enrichment. "I do have concerns that education, public access museums, might take up these technologies and then they won't be accessible," said Cynthia Bennett of Carnegie Mellon University, "So then you're creating gaps in access to public spaces, or business spaces, and creating gaps in education as well."[58] Because of this, it is equally important to maintain "real-world" alternatives to virtual spaces that are accessible and engaging.

CONSIDERATIONS AND IMPLICATIONS FOR INCLUSIVE USE AND ADOPTION OF AR/VR

Inclusive design and implementation of AR/VR will not just make the technology more convenient for some users, but will accelerate innovation and widespread adoption of these technologies by increasing the potential user base and addressing concerns that many businesses, schools, and governments will expect to see resolved before they adopt the technology. Inclusive solutions will allow AR/VR to realize its full potential to expand opportunity and improve lives, while failure to consider and address the risks and challenges that it presents will leave many potential users behind.

AR/VR devices and applications need to comply with existing civil rights and anti-discrimination laws. Not only does a lack of inclusive and accessible solutions put vulnerable users at greater risk of harm and exclusion; it also creates legal challenges for those developing and implementing them. And as Dylan Fox noted, "based on the time it takes for these things to go through the system, if somebody is getting sued for an accessibility issue that probably means it's widespread, it's everywhere already."[59] The first lawsuit for VR captioning was filed in 2020—indicating that this is a much more immediate concern than many realize.[60] Other laws in place to prevent discrimination in employment, housing, public services, and other areas will also apply to AR/VR, although it remains unclear what full compliance would entail for many immersive experiences.

Beyond legal compliance, the organizations developing and implementing AR/VR solutions should not dismiss the privacy, health, and safety concerns of vulnerable and marginalized users. Quite simply, if users feel they are putting themselves at risk, they will be hesitant to adopt or use the technology. Harassment, abuse, and overall lack of representation within immersive experiences can discourage users who may already experience these in their daily lives.[61] Further, physical health, comfort, and safety are a necessary baseline. Instances of physical

discomfort, from difficulties wearing or holding a device to motion sickness or other physiological responses could prevent potential users from accessing AR/VR tools and experiences and exacerbate existing inequalities. This is true for entertainment or socializing purposes, but also for workplace or education settings.

If the equity and inclusion challenges of AR/VR are not addressed, these experiences and services will remain available to only a limited user base. This is particularly concerning for use cases such as healthcare or government services, where the most vulnerable communities already face barriers to access. "I don't think [AR/VR] should be in use until they're accessible, period," argued Cynthia Bennett, "particularly by institutions that are supposed to be meeting our basic needs."[62] To ensure they expand access to services and opportunities, it is equally important to consider AR/VR solutions in tandem with analog solutions. As Carlos Gutierrez of the LGBT Technology Partnership and Institute noted, "as this gets adopted more broadly, policymakers need to ensure that people who don't have access to these devices are having the same access to resources."[63]

CONCLUSION

AR/VR solutions offer many opportunities to create a more inclusive and equitable future. To maximize these opportunities, those developing and implementing AR/VR solutions should integrate feedback from a diverse set of individuals. While past innovations provide a roadmap for many of the types of challenges that these new technologies will raise, it is still necessary to seek feedback directly from those who will be impacted by the technology, including traditionally vulnerable, marginalized, and underserved communities. Many organizations involved in AR/VR development are already doing so, and they should continue and expand upon these efforts.

To build inclusive and accessible immersive experiences, it is necessary to carefully consider potential risks and challenges to different users. If done right, AR/VR technologies could expand opportunities for vulnerable, marginalized, and underserved communities. If those developing and implementing AR/VR solutions don't address these concerns or set them aside for future consideration, fewer individuals will want to use, or be able to use, these technologies.

Developing inclusive AR/VR devices, applications, and uses will require an iterative approach that directly engages the users and communities who face the greatest risks of exclusion and harm. If developers, policymakers, and implementing organizations keep the concerns of these users in mind, they can create practical AR/VR solutions that mitigate many of these issues from the outset. Moreover, finding solutions during the product design phase can circumvent the need for costly regulatory actions that might make it harder to get products in the hands of users. Addressing privacy and safety concerns and reducing barriers to adoption will open up these technologies to new users and applications. Inclusive AR/VR solutions will drive this technology.

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