THE FUTURE OF XR

Advisory Council

CHARTING THE FUTURE OF IMMERSIVE TECHNOLOGY:

TRANSFORMING WORK, EDUCATION, HEALTH, AND ENTERTAINMENT

2024

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LETTER FROM OUR PRESIDENT & CEO

In the 1990s as the World Wide Web and personal computing took off, the conversation revolved around its possibilities—advancing democratic values, improving quality of life, connecting the world. Then, in the early 2000s, the same pattern emerged with mobile technology. In both instances, so many of us were enamored by the benefits and possibilities of these exciting new platforms that we did not reflect enough on the potential impacts of such revolutionary technology.

As we stand now on the cusp of the next computing platform – immersive computing – we should learn from the lessons of the past, ensuring that all stakeholders -- industry, government, civil society, and academia -- take a candid and comprehensive approach to ensuring that the many opportunities this technology has to positively impact so many aspects of our lives, including entertainment, health care, education and job training, are realized. This paper reflects this goal. We are very optimistic about immersive technology, but we know that there is work to be done and challenges to meet. Our goal is to identify the challenges and chart a path forward to secure the future of immersive technology.

No single actor will be able to solve every issue we address. But we can address some issues within the scope of our organization's mission, support other organizations who are also tackling these challenges, and spur others to contribute as well.

Elizabeth Hyman
XRA President and
Chief Executive Officer

– Elizabeth Hyman, XRA President and Chief Executive Officer

II. EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

XR is an umbrella term for immersive and spatial computing that encompasses hardware, software, and services enabling virtual, augmented, and mixed reality. As an integral part of the next generation of computing platforms, XR technology is increasingly being adopted for entertainment, gaming, and across industries as an enterprise solution to improve efficiency, learning outcomes, and hybrid work and school environments. This is even more so as we see artificial intelligence and machine learning, location intelligence tools, and software applications converge with XR.

If XR is to realize its promise, all stakeholders must both learn from the challenges and missed opportunities of previous technological innovations as well as chart a clear-eyed vision of the future – a future in which XR creates inclusive, welcoming, immersive spaces while enhancing the overall efficiency, utility, and experience of navigating digital worlds.

With that vision in mind, the XR Association (XRA) has committed to several initiatives based on a series of discussion sessions with experts from industry, academia, and civil society. Through the creation of the Future of XR Advisory Council, XRA gathered this diverse set of thought leaders together to identify the critical issues that will impact the evolution of XR -- virtual, augmented, and mixed reality technology -- over the next decade. The resultant working groups addressed the following topics:

» Norms and Behavior in Immersive Spaces
» Safety and Well-Being for Youth
» Privacy as an Element of Trust
» Respect and Diversity in the Workplace
» Interoperability

Based on the output of these working groups, XRA has committed to launching nine initiatives that represent what we believe is a forward-looking, proactive, and meaningful agenda that will contribute materially to the evolution, growth, and positive impact of XR technology development and adoption.

INITIATIVE 1: A workshop to develop additional online safety tools for young people in immersive environments.

INITIATIVE 2: A literature review of the benefits and impacts of XR on young people.

INITIATIVE 3: A new chapter of the XRA Developers Guide focused on the safety and well-being of young users.

INITIATIVE 4: A common taxonomy of key terms impacting consumer privacy in immersive technology.

INITIATIVE 5: A dedicated privacy track as part of the annual AR/VR Policy Conference that XRA hosts with the Information Technology and Innovation Foundation (ITIF).

INITIATIVE 6: XRA will create a Resource Hub to provide examples and best practices to encourage adoption of XR tools and programs in a way that fosters greater respect, inclusion, diversity, and accessibility.

INITIATIVE 7: A resource exchange for developers to share ideas and tools that address norms and behaviors.

INITIATIVE 8: An easy-to-understand guide on how to address harassment, bullying, or other bad behavior in immersive environments.

INITIATIVE 9: A working group to explore ways to highlight innovative strategies for creating safe, inclusive, and respectful user experiences in immersive environments.

XRA's commitment to these initiatives, which are explained in more detail in the white paper, is intended to augment the significant amount of work taking place throughout the immersive technology community, including at XRA, that directly relates to the many issues and challenges that the Future of XR Advisory Council process surfaced. While the white paper highlights many of these efforts, there is still work to be done.

Importantly, this project started from the belief that XR technology can and will fundamentally and positively change the way people work, play, learn, engage, and live. Achieving this vision depends not just on pure technological advances but a broader suite of issues focused on how they are implemented, managed, accessed, and regulated. And we found that, among our working groups, there was unanimous agreement that industry, government, civil society, academia, and even users themselves will need to play a role to realize the collective benefits of XR technology for all.

III. INTRODUCTION

XR is an umbrella term for immersive and spatial computing that encompasses hardware, software, and services enabling virtual, augmented, and mixed reality. XR technology is widely considered a candidate to be the next major computing platform[1][2] XR technology, perhaps best known for entertainment and gaming (both solo and multiplayer), is increasingly being adopted across industries as an enterprise solution by companies, educational institutions, and governments looking to XR technology to improve efficiency, learning outcomes, and hybrid work and school environments. This is even more so as we see artificial intelligence (AI) and machine learning, location intelligence tools, and software applications converge with XR.

Indeed, the use cases for XR continue to grow as this emerging technology evolves. The XR gaming industry and its potential for entertainment, storytelling, live performance, and sporting events is beginning to be unlocked in exciting ways. XR's use in healthcare is also on the rise, with the technology helping surgeons visualize organs, tumors, X-rays, and ultrasounds in real time and from multiple angles[3]; it's being used to treat patients with dementia[4] and PTSD[5] and is being explored as an alternative to pain-relieving prescriptions, including opioids[6].

In manufacturing, XR technology is allowing engineers and manufacturers to test for flaws and optimize designs at an early stage without having to develop countless costly prototypes, and technicians can use immersive technology to guide the assembly of complex hardware by digitally overlaying instructions and information about various parts onto the workspace. XR is being used for job training and education in various industries, including auto manufacturing, the energy sector, and aerospace. Schools, universities, and museums have been exploring XR as a tool to deepen learning experiences and provide students with transformative 3D perspectives on the subjects they are being taught.

As consumer options become more compelling and enterprise and industrial applications continue to multiply, these uses will merge over time, making XR a part of daily life for users across the globe. But, if XR is to realize its promise, lessons learned from prior generations of technology should be combined with a clear-eyed vision of the future. The industry can learn from the pitfalls, challenges, and missed opportunities that previous technological innovations have encountered. A future in which XR is able to create inclusive, welcoming immersive spaces will require not just learning from the past but also the development of completely new solutions to address the unique policy issues that immersive environments create. Responsibility for creating this future necessitates a shared, holistic approach involving all stakeholders' efforts.

With that vision in mind, the XR Association (XRA) created the Future of XR Advisory Council to bring together experts from numerous fields, including industry, academia, and civil society for a series of working group sessions, to identify the critical issues that will impact the evolution of virtual, augmented, and mixed reality technology over the next decade. While there was not always consensus in the working groups on each issue or recommendation, there was unanimous agreement that industry, government, civil society, academia, and even users themselves will need to play a role to realize the collective benefits of XR technology for all.

While some potential solutions were identified, the working groups also acknowledged that addressing those critical issues will likely be an iterative process as XR technology continues to evolve, and solutions will involve an array of stakeholders, including and beyond the industry itself. These conversations started from the belief that XR technology can and will fundamentally and positively change the way people work, play, learn, engage, and live. But that expectation was tempered by the recognition that achieving this vision depends not just on pure technological advances, but a broader suite of issues focused on how they are implemented, managed, accessed, and regulated.

As part of the Future of XR Advisory Council process, XRA established five different working groups and, based on the work of each group, distilled these into what we believe is a forward-looking, proactive, and meaningful agenda that materially moves the ball forward.

The groups convened to cover the following topics:

NORMS AND BEHAVIOR IN IMMERSIVE SPACES: This working group focused on how best to foster and enforce respectful, safe, and inclusive XR environments. Immersive environments can only thrive if participants have a firm sense of security and trust.

PRIVACY AS AN ELEMENT OF TRUST: The working group focused on the key privacy issues that are raised by immersive technology and how the XR industry can ensure the potential of XR is maximized with the minimum adverse impacts on personal privacy.

SAFETY AND WELL-BEING FOR YOUTH: This group focused on issues associated with the safety and well-being of XR users, especially young people. The future holds tremendous promise for XR applications for youth – for educational, entertainment, healthcare, and other uses – but before the industry can fully realize that promise, some questions about the use and impact of XR technology on youth may need to be addressed.

XR AND RESPECT AND DIVERSITY IN THE WORKPLACE: This working group discussed how the use of XR in enterprise settings creates both opportunities and challenges for fostering respect, inclusion, diversity and accessibility[7] in the workforce.

INTEROPERABILITY: While many other efforts are looking at the technical aspects of interoperability, the working group explored how the industry and other stakeholders should address the intersection between interoperability, policy, law (e.g. intellectual property, antitrust), and economics/business models.

IV. XRA's COMMITMENT TO THE PATH FORWARD

This white paper relies on the discussion of our five working group sessions to highlight the issues, challenges, and potential solutions viewed as important for the continued development and adoption of XR technology.

In considering the initiatives described below, it is important to note the significant amount of work taking place throughout the immersive technology community, including XRA, that directly relates to the many issues and challenges that XRA's process surfaced. Throughout this paper, we will highlight many of these efforts. But there is still work to be done. While not all the suggestions and recommendations that were raised by the working groups are within the bandwidth and remit of this organization, XRA is committed to moving the process forward by undertaking several important initiatives that arose during our discussions.

INITIATIVE 1: XRA will convene a workshop or conference that includes diverse communities of parents, youth, and civil society to help identify and inform how the industry continues to develop additional parental controls and other tools that maximize online safety for young people in immersive environments.

INITIATIVE 2: XRA will conduct a literature review that captures the most up-to-date understanding of the impacts of XR on young people. XRA recognizes that one challenge to realizing XR technology's benefits to youth for education, health, entertainment, and other uses is the need for more research on its potential effects. A literature review of existing research will help academics identify the gaps in our understanding of XR's impacts on youth.

INITIATIVE 3: Following initiatives one and two, XRA will launch a process to author a chapter of its Developers Guide focused on the safety and well-being of young people XRA's Developers Guide is a comprehensive set of guidelines and best practices aimed at helping developers create immersive and engaging experiences. The guides address various aspects of XR development, such as hardware and software best practices and design principles, and they serve as primers for XR development across the industry.

INITIATIVE 4: To address the lack of clarity that exists surrounding critical privacy terms associated with immersive technologies, XRA will develop a process, with input from stakeholders, including regulators, industry, academia, civil society, and others, to create a common taxonomy of key terms impacting consumer privacy, e.g., raw data, inferred data, emotional data, etc.

INITIATIVE 5: XRA will establish a dedicated privacy track as part of the annual ARVR Policy Conference that XRA hosts with the Information Technology and Innovation Foundation (ITIF). This track of the conference will focus on the latest research and best practices developing in the tech industry, and XR in particular, around privacy.

INITIATIVE 6: XRA will create a Resource Hub to provide examples and best practices to encourage adoption of XR tools and programs in a way that fosters greater respect, inclusion, diversity and accessibility. This initiative is intended to establish a one-stop-shop for employers, workers, community groups, and other stakeholders to access information on such tools and programs in XR.

INITIATIVE 7: XRA, working with relevant stakeholders, will develop a resource exchange similar to a GitHub repository, where developers can share existing norms and behaviors tools and plug-ins and/or swap ideas about new tools that need to be developed or are being developed in the XR space. XRA will also explore updating its Developers Guide, particularly Chapter Two: Creating Safe, Inclusive, and Respectful Immersive Experiences, on the most recent tools and best practices for norms and behaviors that are embedded along the XR tech stack.

INITIATIVE 8: XRA will develop an easy-to-understand guide with input from relevant stakeholders to educate users on what tools are available to them in immersive environments that empower users to address harassment, bullying, or other bad behavior, including tools they can use to protect themselves in the moment.

INITIATIVE 9: XRA will create a working group with the objective of creating a platform (a showcase, annual award, etc.) to highlight innovative strategies taken by companies to ensure a safe, inclusive, and respectful user experience in immersive environments. This initiative will build off the XRA Limitless Voices campaign, which seeks to elevate and celebrate diverse and thoughtful innovators in our industry.

In sum, these initiatives are a continuation of the day-to-day work of the XR Association, and at every opportunity, we want to also highlight the phenomenal work that the entirety of the industry and others are undertaking to achieve the full potential of immersive technology.

V. BALANCING THE BENEFITS AND TRADEOFFS

Each working group topic area is interrelated to others and, in some cases, creates conflicting goals. The working groups explored these throughlines and discussed how to balance the benefits and tradeoffs of accomplishing the larger goal of creating immersive environments that are safe for all users and that provide broad benefits to society at large.

Privacy, for example, touches almost every other issue discussed, given that information collection is intrinsic to the functionality of advanced technology, including XR. While data minimization can be employed in XR, XR technology cannot function as designed without collecting some information and data on users' movements and decisions in immersive spaces. Indeed, issues that affect safety, interoperability, and content moderation in XR could impact and create tension with privacy goals. For example, XR technologies use sensors to collect spatial data about a user's surroundings and movements to ensure user safety. But, mapping of users' private physical spaces and/or the capture of bystanders and their attributes must be treated with sensitivity.

Interoperability will likely be important to the vision of a metaverse in which users can move easily between immersive platforms. In doing so, multiple data sets may be collected by each platform. Consumers moving from platform to platform may have an expectation that certain privacy protections and preferences will follow them. Therefore, the pursuit of interoperability also creates a need to address potential conflicts between privacy protections and the smooth movement of users and data across the metaverse. User desire to port their data across worlds, particularly when it comes to the potential for porting social graphs that contain data from other users who may not have consented to have their information transferred, could create additional privacy questions.

While all users' privacy could be impacted by the collection of data in XR, youth[8] privacy has often been treated as a separate category, given their limited ability to provide informed consent. Therefore, privacy will be an important aspect of protecting the safety and well-being of youth who may use XR technology.

Some policymakers around the world have made age assurance a priority, and places, such as the United Kingdom and California, have passed laws requiring tech companies to include age assurance tools to prevent youth from accessing inappropriate online content. And new laws, such as those being considered in jurisdictions such as Utah, Louisiana, and elsewhere, contemplate requiring youth to verify their ages. However, some consumer privacy advocates have raised concerns about how these new laws might impact data collection and privacy issues[9].

Additionally, interoperability and the establishment of norms and behaviors may present some conflicts, depending on how that interoperability develops and the kinds of worlds and platforms that have interoperable features. For example, interoperability may encourage open worlds where users can move between platforms. However, the more open a world is, the more difficult it may be to moderate content, dispel disinformation, or protect data security and intellectual property. On the other hand, platforms that are not interoperable could create barriers to competition, limit consumer choice, and/or hinder innovation in XR.

In other instances, the success of achieving one goal – such as fostering and enforcing respectful, safe, and inclusive XR environments through the establishment of norms and behaviors – can assist in the success of other goals – such as ensuring youth safety and inclusivity in immersive spaces.

The tensions and challenges inherent in each subject area may be daunting, but each working group considered the balance that should be struck between competing priorities. And some of the work to strike that balance and address the

complicated policy issues associated with XR as an emerging technology is already underway.

FRAMEWORKS FOR COMMON ETHICS AND TAXONOMY IN XR

The Consumer Technology Association (CTA) has released a standard set of definitions through its standards R12 WG1.

Institute of Electrical and Electronics Engineers' (IEEE) P7030 Working Group aims to establish a uniform set of definitions, and a methodology to assess the socio-technical considerations and practices regarding XR where this methodology shapes the positive design of XR systems.

IEEE's Global Initiative on the Ethics of XR aims to proliferate the existing efforts of The IEEE Standards Association focused on the ethical issues related to XR. The main output of this group has been a series of white papers on ethical issues around XR such as accessibility, healthcare, education, online safety, privacy and more.

*This list represents a sampling of resources (or tools).

For example, developing a common taxonomy of terms and definitions for XR was viewed by most of the working groups as an essential element in moving forward with thoughtful policies and goals to guide the transition from 2D to 3D experiences. As noted previously, XRA will launch a process, with input from stakeholders, to develop such a taxonomy of key terms impacting consumer privacy to help focus the industry's efforts in protecting sensitive data. This effort will complement other efforts presently being undertaken by other multistakeholder organizations.

VI. INCLUSIVE DESIGN, TRUST, AND SAFETY

Approaches to privacy, conduct, and content in immersive and multi-user spaces are still being defined and calibrated to weigh competing interests, but ensuring that XR technology fosters trust, as well as safe, positive experiences, is in everyone's interests. After all, the benefits of immersive experiences are well-established. Published studies have suggested positive outcomes from social immersive interactions, such as people feeling less lonely and more connected[10] and/or more socially supported[11]. That sense of connection can come, in part, from user adherence to established norms and behaviors in immersive spaces and from inclusive features that allow users to represent their virtual selves as they wish.

The other side of the coin is concern regarding loss of personal privacy and abusive or discomforting behavior that runs counter to the shared vision of community in any given immersive experience. These concerns are particularly acute when it comes to our youngest members of society. How the XR industry and society at large confront these concerns will determine the adoption of immersive technologies.

A. NORMS & BEHAVIORS IN IMMERSIVE SPACES

Online and immersive spaces are often mirrors of the real world, and because of that, bad behavior cannot be completely eradicated in digital spaces, particularly in those that support user-generated content and interactions. The goal of the XR industry should be to continue its current path of creating incentives to mitigate such bad behavior, building education tools, and developing mechanisms to enforce codes of conduct and community guidelines when they are violated. To achieve that goal, the XR community must look to both the currently accepted modes of regulating social and gaming spaces online, which includes a mix of tools/features, content moderation, codes of conduct, and rating systems, as well as how to ensure that new tools are developed and deployed to address the unique issues specific to immersive spaces. This can be a complex process. For example, a game engine might create a tool that allows users to shield themselves from virtual bullies, but software developers will still need to embed it in their games for users to access it. Additionally, platforms may be able to address violations of their community guidelines in common areas, but they may not know about or be able to regulate bad actors whose behavior is happening within specific third-party apps or games on the platform.

Users may encounter different rules and tools depending on the plug-ins and middleware they use. For example, a third-party chat plug-in may employ different moderation tools than in-app tools, and users should be educated on which tools are available and may work best for them in any given immersive environment. Indeed, the types of norms and behavior tools offered by various stakeholders could act as market differentiators in immersive tech, and trying to force one-size-fits-all types of moderation, enforcement, etc. tools on all XR industry players would likely be counterproductive to innovation and diversity in the industry.

EXISTING SAFETY TOOLS ON XR PLATFORMS

Meta's Family Center

Sony Playstation Privacy and Safety Tools

VR Chat Safety and Trust System

Engage Platform Trust & Safety Tools

RecRoom's Comfort and Safety Tools

HTC's VIVE Guardian

*This list represents a sampling of resources (or tools). It is not intended to be a comprehensive list.

Still, a better understanding of the tools that are already available and in use is needed. That is why XRA, as outlined in Initiative 8, will work to create a repository to better facilitate the sharing and exchange of information about the tools and best practices that are in use to address norms and behaviors.

The XR Association has already developed some best practices for XR software development as part of its Developers Guide. All four current chapters of the guide – Chapter One: Fundamental Design Principles for Immersive Experiences[12], Chapter Two: Creating Safe, Inclusive, and Respectful Immersive Experiences[13], Chapter Three: Accessibility & Inclusive Design in Immersive Experiences[14], and Chapter Four: Designing Immersive Learning for Secondary Education[15] – address the need to create immersive experiences that promote safe and inclusive environments for users of all ages. XRA will continue to update as appropriate and is already committed through Initiative 3 to authoring a chapter of its Developers Guide focused on the safety and well-being of young people.

Learning from Social Media, Gaming, and Others

Given that social media and online gaming platforms have been attempting to address norms and behaviors online for both adults and youth for many years, the lessons learned from those industries might help the XR industry avoid some of the negative behaviors, content, and controversies that have challenged its predecessors. It may also help to illuminate some effective ways to protect youth from harmful content and inappropriate behaviors.

A recent Atlantic Council report titled "Trustworthy Future Web"[16] noted that gaming companies may be in the vanguard of creating rules for content and conduct in XR because they have already begun to explore ways to "leverage player dynamics and safety by design in the conception and construction of virtual worlds and experiences." Some of the tools gaming companies have developed or are developing for AR, VR, and MR games include features that allow "users to control who can interact with them in any particular gaming space" and "stronger tooling to support real-time monitoring in dynamic-video and audio-based user environments." The report notes that "Efforts to improve the ability to provide real-time monitoring in privacy-respecting and less data-intensive ways will have applications for numerous industries." Social media and gaming companies also have extensive experience developing parental controls and content filters to protect youth in online spaces.

In fact, there are several existing models and resources from social media, gaming, and some immersive spaces that may prove useful guides. Existing non-governmental organizations can play a vital role in moderating content and collecting incident reports on XR platforms, to educate the public, and/or to share information across XR platforms. The Anti-Defamation League, for example, has a Cyber Safety Action Guide[17] that instructs people on how to report hate incidents on various online platforms. Additionally, the Global Internet Forum to Counter Terrorism (GIFCT) develops ways to "prevent terrorists and violent extremists from exploiting digital platforms," such as through its hash-sharing database and content incident protocol[18].

CONTENT MODERATION MODELS

Among XR platforms, VRChat is a relatively mature social, online immersive world with an estimated millions of registered users. Developers in the XR space may be able to learn from VRChat's successes and failures in establishing norms and behaviors, moderating content, developing rules, and otherwise fostering positive social interactions.

Social media site Reddit includes both Reddit employee moderators, known as "admins," and user moderators, known as "mods," both of whom help to regulate the content and conduct of users on Reddit.

ConnectSafely, a nonprofit that educates people about online safety, has specific resources for XR and offers a wide array of research-based safety tips, parents' guidebooks, advice, news and commentary on all aspects of tech use and policy.

As described in the CommonSense Media report, Parents Ultimate Guide to Parental Controls, major operating systems – such as Microsoft Windows, Apple's MacOS and iOS, Amazon's Fire, and others – provide optional settings that parents can use to prevent their children from accessing inappropriate websites or content online, and there are an array of third-party apps that parents can download to track a child's device usage, set time limits, and block content.

The Fair Play Alliance, a coalition of gaming companies and professionals, teamed up with the Anti-Defamation League's Center for Technology and Society to develop the Disruption and Harms in Online Gaming Framework which catalogs "problematic in-game conduct" with the aim of giving game developers insight into how to create safer spaces for players.

In December 2021, the IEEE published a report, Social and Multi-User Spaces in VR: Trolling, Harassment, and Online Safety, with the aim of giving developers and consumers resources to address harmful behavior in VR settings.

*This list represents a sampling of resources (or tools). It is not intended to be a comprehensive list.

Tools to Address Norms & Behavior in Immersive Spaces

While the XR industry can learn from social media, gaming, and other entities, interpersonal interactions in XR are largely transitory and fleeting and may be challenging to moderate.

Positive reinforcement of good behaviors and prevention of bad behaviors is ideal for creating safe and welcoming immersive environments. To that end, studies have examined what is known as the online disinhibition effect, which is defined as "the lack of restraint one feels when communicating online in comparison to communicating in person." Such disinhibition can manifest in both positive and negative ways. One study[19] outlined how users on the internet might exhibit benign disinhibition (revealing "secret emotions, fears, wishes" or showing "unusual acts of kindness and generosity)" or demonstrate toxic disinhibition ("rude language, harsh criticisms, anger, hatred, even threats").

Again, the gaming industry provides excellent examples of multiplayer spaces that help users learn and understand community behavioral expectations and then reinforce them in unique ways. For example, there are several video game titles that gamify good behavior by awarding points, special rewards for positive interactions, and/or allowing other users to rate each other. Such an approach might help foster adherence to a platform's stated norms and behaviors and/or the user-generated conduct codes for more private spaces.

REINFORCING RESPECTFUL BEHAVIOR ONLINE

» Square Enix's Final Fantasy XIV allows players to give each other commendations based on how they've contributed to shared activities, such as dungeons and raids. When players have amassed enough commendations, they also receive exclusive in-game rewards.

» Sea of Thieves' achievement system awards players after certain requirements are fulfilled. The list of commendations for each faction can be viewed within a player's reputation page.

» Apex Legends users have asked the game maker to add an honor system to reward good behavior.

*This list represents a sampling of resources (or tools). It is not intended to be a comprehensive list.

In XR, environmental cues also might help encourage adherence to stated community guidelines or codes of conduct. For example, a calming beach, a socially interactive coffee shop, a dark, loud dance club, or a reverent church environment might all signify different user expectations based on real-world experiences with those spaces. Nintendo's Animal Crossing: New Horizons, for example, was cited by users as a psychologically soothing experience[20][21] during the darkest days of the COVID-19 pandemic.

The XR industry is optimistic that artificial intelligence (AI) can be helpful in addressing challenges related to norms and behaviors in immersive spaces, as other tech platforms do.[22] Human moderators, however, will also play an important role in identifying the wide variety of bad behavior, such as hate speech and harassment, that could present itself on XR platforms. The European Union's Digital Services Act requires online platforms to be more transparent about their content moderation decisions, and in September 2023, the EU released a summary report of its public consultation period for how online platforms will have to report their content moderation efforts.[23] An added benefit of such

transparency efforts is that it may foster a greater understanding of the effects of encouraging good online behavior.

Of course, XR platforms and apps must still guard against bad and harmful behavior that is not discouraged by positive reinforcement efforts. As noted in the 2019 paper "Harassment in Virtual Social Reality" by Blackwell et al., "In immersive virtual reality (VR) environments, experiences of harassment can be exacerbated by features such as synchronous voice chat, heightened feelings of presence and embodiment, and avatar movements that can feel like violations of personal space (such as simulated touching or grabbing)." But, the paper also noted some challenges to addressing behavioral issues: "We find that users' definitions of what constitutes online harassment are subjective and highly personal, which poses significant challenges for the enforcement of platform- or application-level policies."[24]

Because of the ephemeral nature of interactions in immersive settings, as well as the subjective nature of some online behavior, users need tools they can access proactively or immediately to protect themselves from bad behavior. For example, if an XR user is subjected to a virtual assault in VR, the victim's emotional and mental harm may be very real, even though they may not be physically harmed in the real world.

Already, many XR platforms allow users to create a virtual bubble around their avatar to guard against any inadvertent or intentional intrusion into their personal space while in immersive environments. There are additional tools commonly found in XR, such as muting, flagging and reporting, content removal, and more. Standardization of placement might make it even easier for users of multiple platforms to report issues and protect themselves from harmful behavior in real time.

A 2023 report from the Information Technology Innovation Foundation (ITIF) does a thorough job of identifying some of the safety concerns raised by XR, the various technical approaches hardware

manufacturers, game engines, and software developers can and are incorporating into their products to address such concerns, and some of the federal and state regulations that relate to safety issues.[25]

XRA has published two graphically illustrated guides entitled "Into the Digital World" that help explain how XR technology works and what tools are available to the user. XRA is also committed – through Initiative 9 -- to developing an event, award, or other incentive to highlight and celebrate innovative strategies taken to ensure a safe, inclusive, and respectful user experience in immersive environments.

B. PRIVACY AS AN ELEMENT OF TRUST

Information collection is intrinsic to the functionality of advanced technology today. Such collection is often necessary to ensure that technology fulfills its intended purpose, and the types of data collected are often specific to each technology's use case. The tech industry has been grappling with privacy issues over the years, particularly as technology becomes more sophisticated and the information potentially gleaned about users becomes more detailed. While all the above applies to XR tech-nology, XR creates realistic, interactive, immersive experiences that rely on the collection of spatial, biometric[26], and bodily data[27]."

Many existing privacy protections (both those required by law or voluntarily adopted by the tech industry) already apply to XR, but the ways in which data may be aggregated and the inferences[28] that may be drawn about a user based on that aggregation could be unique to XR technology and raise novel privacy questions.

Successfully anticipating and addressing the privacy-related questions raised by XR technology to ensure the highest level of trust among those engaging in immersive spaces will be essential to realizing the full potential of the technology. It will also require carefully balancing the cultivation of XR's promising benefits and the judicious use of

the data XR technology may collect. For example, biometric and bodily data may facilitate groundbreaking uses such as assistive technology for people with disabilities or aiding first responders to react quickly in crisis situations to save lives. But, XR's ability to collect such data may also raise issues around personal and bystander privacy.

Data Collection, Storage, and Minimization

There are a host of current privacy practices – both those enshrined in laws/regulations and those voluntarily practiced by XRA members and the tech industry broadly – that address the need to protect user privacy in digital spaces. Several governments internationally (European Union and United Kingdom, for example) and domestically (California) have enacted privacy laws to address social media and digital technology, and many of those laws already apply to aspects of XR technology. Additionally, the U.S. has privacy laws and regulations aimed at specific types of sensitive personal data or vulnerable populations, such as personal health information under the Health Insurance Portability and Accountability Act (HIPAA)[29], educational records under the Family Educational Rights and Privacy Act (FERPA)[30], and data collected from a "known child" under the Children's Online Privacy Protection Act (COPPA)[31], that largely apply to XR.

However, the patchwork approach of states and regulators has, in some cases, created uncertainty and conflicts for the tech industry and consumers. Because of that, the tech industry generally and the XR industry specifically support a U.S. federal data privacy law to help the industry and consumer advocates ensure basic protections for user data across technology platforms, including XR.

There is also a need to better define what is meant when stakeholders use terms like "biometric," "bodily," and "inferred" data. Creating a common understanding of terms that could affect user privacy will assist the government, the industry, and consumers in identifying any inconsistencies in

existing privacy protections and allow them to proactively address such inconsistencies through the pursuit of government regulation, self-regulation, and/or consumer education. That is why XRA is committed to developing a process through Initiative 4 that is designed to bring together stakeholders up and down the tech stack, as well as consumer advocates, around a common taxonomy of terms impacting consumer privacy. XRA's goal is not to duplicate the efforts of others but to help augment and inform existing attempts to develop definitional clarity in the privacy space. These efforts have been undertaken by governments (e.g., the interagency process at the Federal Privacy Council[32] and at the Office of the Privacy Commission of Canada[33]), by academics (e.g., the Privacy and Information Technology Chapter of the Stanford Encyclopedia of Philosophy[34] and Daniel J. Solove's" A Taxonomy of Privacy."[35]), and multistakeholder groups (e.g., XRSI Standard Taxonomies for Emerging Tech Ecosystem[36]).

An important part of addressing privacy in XR includes the potential use and storage of biometric and bodily data that might be gathered and used to infer a user's emotional or mental state and/or physical health status. While not presently used for this purpose in immersive environments, facial expressions, eye movements, and other physical reactions to stimuli (often unconscious or autonomic) are potentially subject to tracking, collection, and processing that might provide deeper insights into an individual's personal habits, preferences, and feelings than most current online experiences. This is relevant as photorealistic or lifelike avatars remain an industry pursuit and may only become more so as AI is increasingly used to process such data.

Data minimization[37] and limitations on data sharing[38] may be effective strategies to address the kinds of inferred data that could be generated from bodily data. But reaching consensus on the taxonomy of data and what constitutes sensitive data is a predicate to such a strategy.

There must continue to be a candid and open dialogue when it comes to advancing the principle of "privacy by design" for XR. The XR Association is not alone in fostering multistakeholder dialogues and greater understanding around the meaning and protection of privacy in immersive spaces.

MULTISTAKEHOLDER DIALOGUES ON PRIVACY IN IMMERSIVE SPACES

Future of Privacy Forum's "Risk Framework for Body-Related Data in Immersive Technologies" is intended for organizations that collect, use, and/or share body-based data, particularly in the context of immersive technologies. The framework is intended to help organizations evaluate the privacy risks and benefits associated with body-based data and to adopt best practices suitable to their data practices.

The **XRSI** Privacy and Safety Framework sets a baseline set of standards, guidelines, and best, regulation-agnostic, practices for data protection and safety in XR.

Metaverse Standards Forum's Privacy, Cybersecurity, & Identity Working Group was created "to deliver recommendations for responsible innovation that mitigates human and societal harm from objective and subjective privacy risks – including privacy, cybersecurity, and identity risk management at the global level."

*This list represents a sampling of resources (or tools). It is not intended to be a comprehensive list.

Such forums and collaborations almost certainly could help generate a more thorough understanding of current privacy practices and how current law impacts the development of privacy protections in XR.

Meaningful Consent

Consumers also need to understand how XR tracks and uses biometric and bodily data. Such understanding will be key to ensuring consumers can provide meaningful consent on the use of their data.

To be clear, mere "disclosure" of data collection and/or use may not constitute meaningful informed consent, and the tech industry has encountered criticisms in the past in reconciling informed consent with data privacy protections. After all, consumers likely do not understand and/or do not read the sometimes-complicated legalese in the privacy agreements they are asked to consent to when they sign up for products and services on the internet. Concerns about the collection of biometric data are often really about foundational issues such as how the data is stored, used, and potentially shared. The XR industry has an opportunity to chart a more effective path.

Any meaningful consent model should rely on educational tools that give consumers an adequate understanding of how XR tracks and retains data, including whether data is stored locally on a headset (or other local device) or stored remotely, such as in the cloud; how long such data would be stored; for what purposes the data would be stored; and whether any data would be shared with third parties and for what purposes. The Future of Privacy Forum's "Understanding Extended Reality Technology & Data Flows" infographic is an excellent resource helping to educate users on how XR data flows work, and it explores several use cases that XR technologies may support. The infographic highlights the kinds of sensors, data types, data processing, and transfers that can enable these use cases.[39]

There may also be instances in which consent may be difficult or even impossible to obtain, such as from bystanders or persons who inadvertently come into an XR user's space. There is a growing trend among AR glasses manufacturers to incorporate indicator lights to warn bystanders

that a forward-facing camera is on.[40] Still, immersive experiences create new challenges for the need for bystander awareness and in attempting to prevent the involuntary collection of data on bystanders. And at times, privacy law inadvertently acts counter to such efforts. For example, an Illinois law that bars the collection of biometric data, such as face scans, also could bar face blurring because the technology used to blur faces must first scan them, even if only briefly, to ensure the person's features are obscured.[41]

Advertising in Immersive Spaces

Rather than a static ad popping up next to a news story on a webpage or a sponsored video appearing among other content, AR and VR may provide new avenues for native advertising, which could make it harder for users to distinguish between paid promotions and organic experiences.

Many current tech platforms rely on advertising to provide free or low-cost services to their users, and advertising will likely have a role in immersive environments as well. Some users may want their data to be employed to both enhance their experience and generate relevant advertisements, and as a result, there should not necessarily be a blanket prohibition on the use of inferred data for advertising. Instead, limitations should be based on avoiding specific harms, such as identity theft or predictive manipulations intended to affect a user's behavior. The Federal Trade Commission already prohibits native advertising from using "deceptive or unfair practices,"[42] and that will presumably extend to native advertising in XR spaces.

C. YOUTH SAFETY AND WELL-BEING

Youth safety and well-being have been a focus for the XR industry, and the industry's future is likely to include more intentional development of products for youth. As this trend proceeds, such products and experiences should include immersive worlds that are designed from a child development-first perspective, where young people can have iterative, socially interactive experiences in XR that align with how youth interact with the physical world and how their brains learn. This means that XR hardware and software should be designed with youth in mind; have inclusive, accessible, and equitable designs that ensure all youth can participate and be represented; provide rich, interactive learning experiences; and give youth the ability to create their own unique experiences.

There is already a growing body of federal and state statutes in the U.S., as well as regulations in the EU and elsewhere, addressing youth privacy. Most primarily focus on data collection and data use, but many of these policies and laws do bleed into areas relevant to safety and well-being beyond pure privacy and data management. Nevertheless, the XR industry has not been waiting for governments to impose regulations on how to address safety and well-being of youth who may use XR. Most major manufacturers of XR equipment and software developers have safety guides, parental control features, and other recommendations for the safe use of XR technology. Additionally, civil society organizations have developed their own guides and tip sheets for parents and kids on the use of XR.

PARENTAL CONTROLS AND PROTECTING YOUTH IN IMMERSIVE SPACES

General Resources:
ConnectSafely Parent's Guide to Meta Quest Pro, Horizon Worlds, Parental Supervision Tools

Common Sense Media Report, "Virtual Reality 101: What You Need to Know About Kids and VR"

XRSI Safety Tips

Company Recommendations and Tools:
» Meta Quest Parent Education Hub
» Parental controls (US) (playstation.com)
» HTC's VIVE Guardian (vive.com)
» Microsoft Family Safety Tools

*This list represents a sampling of resources (or tools). It is not intended to be a comprehensive list.

While youth-centered safety tools already exist, the XR industry is continuing to improve on tools and parental controls that can help parents make decisions about what kinds of technology and content their children can or should be exposed to. For example, because households may only have a single headset and parents may not always be able to participate with their children in XR experiences, screencasting and mirroring are becoming more readily available features for parents whose children might use XR equipment and apps. Most VR devices also allow a parent or guardian to establish accounts with different permissions. To configure controls and permissions for a minor, a guardian can establish their own account online, even if they don't have their own VR device. The separate accounts can be locked using passwords or pins to ensure security. As noted earlier in this paper, blocking, personal bubbles, human moderators, reporting and evidence capture of bad conduct, and enforcement levels for bad behavior (takedowns/suspensions/bans) are all tools in the immersive technology arsenal that are presently being used.

Still, while parents are ultimately responsible for how much supervision they provide over any given

XR hardware or software, many parents need help to understand and use the tools that are available, as well as how to read and understand age/content ratings. To that end and as noted previously, the second edition of XRA's "Into the Digital World" is an easy-to-understand guide that helps people of all ages, and particularly parents, to understand what tools are available to them to protect privacy and to protect against online bad behavior. It is also notable that several civil society organizations have developed their own guides and tip sheets for parents and kids on the use of XR. More of these types of guides (whether in print or through immersive experiences themselves) will be needed.

Finally, digital citizenship and teaching youth how to self-police online spaces, including how to report bad conduct, will continue to be important to keeping young people safe online. For example, Roblox already has a course on digital citizenship that teachers can use to educate students on "how to stay safe online and create positive relationships."[43] Similarly, Boston Children's Hospital has a Digital Wellness Lab that provides helpful tips as part of its Parent's Guide to Digital Citizenship,[44] while CommonSense Media has a webpage dedicated to helping teachers develop a K–12 Digital Citizenship Curriculum.[45]

Research on Youth XR Use

To realize the bright future and strong potential benefits of XR for young people, the XR industry needs to recognize the potential questions that remain about XR use by youth. A significant challenge to expanding XR technology to young people for education, health, entertainment, and other uses is the lack of research on the technology's potential effects on the physical, social, and emotional well-being of youth.

While there has been extensive research about youth and the positive and negative effects of everything from television, movies, and video games to social media and the Internet, there appears to have been less direct research on XR and young people. A cursory review reveals that there are journal articles, papers, and news stories touching on VR. However, most are several years old. A first step that will be undertaken by XRA through Initiative 2 is to do a literature review that captures the most up-to-date understanding of the impacts of XR on young people. There is a need to accelerate the pace of research by independent funders like government- and academic science agencies and foundations. Still, it will likely take some time for the academic literature on XR's impact on youth to catch up to the technology.

There are many institutions such as museums, hospitals, libraries, and educational institutions, to name a few -- that are already investing in hardware and content (including stand-alone AR content) that is designed to educate and inform. Furthermore, healthcare institutions are using XR as an innovative therapeutic tool for pain management, brain injury, and post-traumatic stress disorder, among other things. Gathering results and insights from these institutions could be fruitful.

Whether institutions prove to be the conduit through which XR and youth can be explored for research purposes, there are still a number of research subjects that need further exploration. Those research ideas include:

» The potential physical and emotional/social impacts of VR and AR hardware on youth.

» How immersive experiences in XR impact learning (cognitive skills, learning skills, socioemotional skills, creativity, etc.) across ages and neurodiversity.

» What criteria should be considered when developing age-appropriate experiences that are immersive in nature.

Fostering Fair and Inclusive Experiences for Youth

Ensuring and cultivating an environment that respects diversity should be a high priority for XR spaces that may be used by youth. Research has shown that representation has a profound impact

on a young person's education. A 2021 analysis by Common Sense Media of the available research on the effects of representation in media on youth found that "Media representation is important to how kids build their perspectives on their own ethnic-racial group, as well as that of others."[46] XR industry leaders are working to ensure that products designed for youth and K-12 educational settings promote diversity, equity, inclusion, and accessibility goals and allow for inclusion and representation of youth from various backgrounds, identities, cultures, religions, and communities.

Of course, as noted previously, the push to help young people achieve representation will need to be balanced in a way that respects young people's privacy, as well. Chapter Four: Designing Immersive Learning for Secondary Education[47] of XRA's Developers Guide touches on the needs classrooms require, along with considerations schools must take into account around student privacy.

The many ways in which XR technology can be made usable and accessible to users of all ages with disabilities can be found in detail in Chapter Three of XRA's Developers Guide: Accessibility and Inclusive Design in Immersive Technology.[48] In addition to those suggestions, public schools must comply with the federal Individuals with Disabilities in Education Act (IDEA), which generally requires schools to provide comparable educational opportunities for infants, toddlers, children, and youth with disabilities up to age 21.

D. XR AND RESPECT AND DIVERSITY IN THE WORKPLACE

It must be acknowledged that harassment and abuse in digital spaces has often been targeted at communities of color, the LGBTQ community, religious minorities, people with disabilities, and other underserved communities and cultures. Unfortunately, youth have also been targeted by online predators. Therefore, creating norms and behaviors and effective enforcement mechanisms

in XR environments is an important part of promoting safety for all users.

For the purposes of this white paper, XRA wanted to examine how immersive technologies may help achieve greater opportunity and inclusion in the workplace and what barriers must be addressed to achieve such an outcome. AR, VR, and MR can be powerful tools to help expand economic opportunity and employment among underserved communities. Immersive training can create inclusive environments that simulate real-world situations, provide opportunities to practice skills in a safe and supportive environment, and create experiences where all trainees can learn and develop skills without fear of judgment or discrimination.

Access to Training & Upskilling

XR is already being used in various enterprise settings. This includes immersive training simulations, remote real-time assistance, and interactive learning, all of which have the potential to expand access to job training and upskilling to underserved, neurodiverse, or geographically isolated populations.

XR's promise as a workforce training and upskilling technology tool and a mechanism to foster greater respect, inclusion, diversity, and accessibility may prove to be even more impactful as AI could be utilized for precision learning, in which educational and training modules are personalized to an individual's learning style and needs. Personalizing a learning experience could be helpful to people with disabilities and those from different cultural backgrounds.

Of course, multiple stakeholders have a role in increasing adoption of XR in enterprise settings and achieving any potential goals around inclusion and diversity. The buyers of XR enterprise technology, i.e., the employers, have the ability, consistent with federal and state law[49], to build into their contracts with technology vendors accessibility and other features. And corporate leaders have resources

available to educate themselves on the value of XR in the workplace and the way in which it can be adopted to promote diversity, equity, and inclusion.

RESOURCES FOR XR-FACILITATED EQUITY IN WORK

The IEEE Global Initiative On Ethics Of Extended Reality (XR) Report: Extended Reality (XR) Ethics And Diversity, Inclusion, And Accessibility

XR Access Resources page

"Inclusive XR in the Workplace: How Accessible Immersive Technologies Can Help Employers Upskill and Enable an Increasingly Diverse Workforce" (from the Partnership on Employment & Accessible Technology (PEAT) and XRA)

XRA's Developers Guide, Chapter Three: Accessibility & Inclusive Design in Immersive Experiences

Current and Potential Uses of AR/VR for Equity and Inclusion (from the Information Technology and Innovation Foundation)

*This list represents a sampling of resources (or tools). It is not intended to be a comprehensive list.

More tech companies are emphasizing DEIA features as they launch new products to market. This is particularly the case with accessibility tools. Adjustable lenses, closed captioning, color and light contrast, voice command, and voice recognition to allow for hands-free use, as well as other input modalities, are now available. The XR industry is constantly striving to improve many of these features and add more. As is evident from the growing list of accessibility features in immersive technology, XR companies increasingly recognize that inclusive design is good for business and have made advances in accessibility features in their products in recent years.

There is also an important role for government and public institutions in helping to ensure that the move toward immersive computing platforms is safe, inclusive, and accessible to a wide variety of the public. Diversity and accessibility issues in the workplace exist, in part, within the context of laws in the U.S. and around the world. Those laws broadly prohibit employment discrimination based on race, ethnicity, and sex. The Americans with Disabilities Act (ADA) requires most employers to provide reasonable accommodations for people with disabilities. Section 508 of the Rehabilitation Act requires federal public sector buyers and adopters of emerging immersive technologies to procure accessible technology that meets their business needs and aims to work towards full compliance with accessibility goals.

XRA and the XR industry are already working with members of Congress and Cabinet agencies on policy concepts that would promote the use of XR for workforce training and development. One such initiative, a bill introduced by Representatives Lisa Blunt Rochester (D-DE) and Tim Walberg (R-MI), would establish a grant program to support community colleges and career and technical education centers to develop programs for workforce development using immersive technology.

Publicly funded universities, community colleges, and libraries are also important players in helping to bridge the "digital divide" and improve access to immersive technologies. The Brookings Institution has undertaken important work to look at institutions of higher learning and ensure equitable access to XR.[50] States such as Nevada are also investing in exposure to VR education for job and career paths as a part of its public library system.[51]

XR ACCESSIBILITY FEATURES

» [HTC Vive Elite](#)
» [Apple Vision Pro](#)
» [Meta Quest 3](#)
» [Magic Leap 2](#)
» [Sony PSVR](#)

*This list represents a sampling of resources (or tools).
It is not intended to be a comprehensive list.

Through Initiative 6, the XR Association is also committed to creating an online resource hub where employers, workers, community groups, and other stakeholders can access information on tools and programs in XR that promote respect, inclusion, diversity, and accessibility. The goal is to help increase the development of XR in a way that bakes in those principles and actions.

VII. XR AND INTEROPERABILITY

A wide variety of think tanks, academics, policy organizations, industry, and civil society groups are attempting to coalesce around what interoperability means in the burgeoning metaverse and how it can be achieved. XRA is optimistic about the process underway at the Metaverse Standards Forum, which is providing a venue for cooperation between standards organizations and companies to support the development of interoperability standards for an open and inclusive metaverse. Other notable efforts in this regard include the World Economic Forum's Metaverse Governance Working Group, which produced a briefing paper, "Interoperability in the Metaverse,"[52] and the Web3D Consortium, which hosted the workshop "Building 3D Web Interoperability for the Metaverse" in October 2023 with the goal of discussing how best to make the metaverse fully interoperable with the World Wide Web in order to enable new metaverse capabilities.

To add to these efforts, XRA's Interoperability Working Group contributed ideas on how the industry and other stakeholders might address the intersection between data portability, interoperability, policy, law (e.g., intellectual property, antitrust), and economics/business models. It is XRA's hope that our sister forums and organizations will use the robust discussion we fostered as additional considerations for the scope and ambition of their work.

What Is Interoperability?

Setting aside engineering concerns, XRA and the interoperability working group focused on the functionalities that may be needed for interoperability in the metaverse. Two essential functions of an interoperable immersive ecosystem will be technical interoperability,[53] which enables cross-platform integration, and data interoperability,[54] which involves the use of interoperable, standardized data formats such that content and/or digital assets can be understood across platforms.

Technical interoperability and data interoperability must be considered in the context of whether a platform, engine, or service has a business model that supports interoperability. The notion of what might constitute maximum interoperability is difficult to define, particularly because the topography of the metaverse has yet to be mapped, and many features have not yet been built or conceived of. There is a popular view of the metaverse in which maximum interoperability is represented as an openness of worlds in which the movement of people and data is unrestricted. However, there is not yet a consensus on how open immersive worlds should operate. While open-world interoperability is seen as ideal in many sectors, there will likely be many instances in which a platform, engine, or service may need, want, or be expected to have total control over access to data on its platform, such as for healthcare, financial services, or other sensitive sectors.

Indeed, most immersive platforms are unlikely to operate on the extremes of open and closed. Instead, there will likely be a spectrum of openness and interoperability – from full horizontal inter-platform interoperability to in-platform vertical interoperability – that platforms, engines, and services will rely on. The working group posited that various levels of technical interoperability and data interoperability are likely to evolve depending on the stakeholder, business model, regulations governing specific market sectors, and market demands. In other words, interoperability could potentially be sector-specific. Interoperability will also depend on how it is defined going forward, given the emerging nature of XR technology in general.

Because gaming platforms are already incorporating both immersive worlds and cross-platform game options into their systems, the video game industry provides a useful case study. For example, the massive success of the video game Fortnite prompted gaming platforms to more aggressively consider their proprietary approach to gaming systems and platforms, and now all major gaming platforms allow cross-platform play of some third-party games.[55] Examples of previous case studies on interoperability include John Palfrey and Urs Gasser's 2012 book "Interop: The Promise and Perils of Highly Interconnected Systems,"[56] and Adam Thierer's 2020 paper on "Soft Law in U.S. ICT Sectors: Four Case Studies." [57] Furthermore, it will be important to follow the emerging policies in Europe that already require dominant tech platforms to create certain interoperable features, such as messaging.[58]

Mapping the Immersive Ecosystem

Existing disagreements among XR stakeholders in the metaverse over what precisely is meant by the term "interoperability" appear to be a hindrance to creating consensus on what must be done to foster it. A consensus has not emerged, in part, because the technology landscape is constantly evolving, and definitions of interoperability and related concepts tend to shift depending on who is doing the defining.

Like the dearth of definitional clarity surrounding interoperability, classifying key aspects of immersive ecosystems has not been done. Understanding who the various stakeholders in the metaverse will be (users, social platforms, gaming platforms, hardware manufacturers, software developers, etc.) and what their business models and responsibilities are toward users are important components of understanding how to

move forward with interoperability. Already, some work in this regard has taken place among academics exploring the taxonomy, components, and applications necessary for the metaverse.[59]

In mapping the metaverse, the provision of horizontal interoperability, in which products and services on competing platforms can interconnect with little to no friction, may differ depending on the scope of each platform or service's business model. In some cases, open worlds may present security risks where sensitive medical or personal information is concerned. In other cases, platforms may find economic benefits from such openness. In general, horizontal interoperability may foster more competition by making it easier for new entrants to arise. However, participants in our working group noted that depending on business models and other economic incentives, some platforms may decide that supporting technical and data interoperability dilutes the value of their services, intellectual property, and functions of their platforms.

Vertical interoperability may include both within-platform interoperability, where third parties can augment or supplement the larger platform, and cross-platform interoperability, where third parties can offer their extensions across multiple competing, but interoperable, platforms.

The Role of Intellectual Property Rights

Interoperability will necessarily be informed by the important role intellectual property rights are likely to play in how much openness platforms, engines, and services may offer or will be necessary.

Immersive worlds may have layers of creator rights that are embedded in the immersive environment, governed by real-world intellectual property laws, or both. For example, an immersive game community may have both content and digital assets generated by users, as well as established real-world brand assets, available for purchase in the community. Depending on the creator and/or the rules established by the hosting platform, accessing or transferring such objects to other

immersive environments may be prohibited, restricted to certain geographies, circumstances or platforms, or fully allowed.

Questions may arise about how digital assets and data should be treated, what rights consumers might have, and what consumers should expect when they "buy" virtual assets. Merchants and brands that own trademarks and copyrights will likely want to control situations in which their brands are applied and/or visible to others accessing immersive environments. Conversely, consumers may have an expectation or desire to take their digital assets, such as costumes, expensive designer sneakers, etc., with them as they traverse the metaverse. It will, therefore, be important to clarify what permissions and rights users acquire when users "buy" digital assets and that those permissions are easily understandable.

While innovation and robust competition are vital, there are many reasons why products and services might or might not be interoperable. These reasons can include product usability, user needs, intellectual property law, privacy, security, and building sustainable business models. Additionally, many platforms may have or need access to personal identifiable information (PII) on users in order to operate, which could argue for less interoperability.[60]
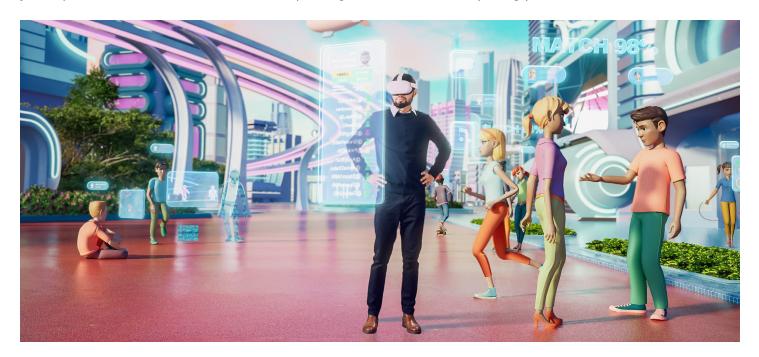
VIII. CONCLUSION

It is instructive to realize that in 1995 there were only 33.8 million wireless subscribers in the United States, representing about 12.4% of the population.[61] In 2023, almost 30 years later, it is estimated that over 310 million people in the United States – more than 90 percent -- use mobile technology.[62] We are fully in the midst of the mobile computing era.

By contrast, we are still in the early days of the immersive computing era. Admittedly, numbers are hard to come by, but it is estimated that there are 66 million VR users and 110 million AR users in the U.S.[63] These numbers are encouraging and demonstrate that immersive technologies are at a stage of growth that resembles 1995 for mobile phones.

Importantly, as exemplified by the topics in this report, the conversations around the impact of immersive technology and the approaches needed to ensure users have trust in the technology are as mature as the conversations that take place today around mobile technology and the World Wide Web. That is how it should be.

A few years ago, business advisory services firm Price Waterhouse Coopers (PwC) forecast that immersive technologies could add as much as $1.5 trillion to the global economy by 2030.[64] Since then, exciting new AR and VR devices have come to market, and there are already examples of the convergence of these two modalities. AI is revolutionizing the ability to easily build three dimensional worlds, and brilliant engineers are working to bring sensory experiences like touch and smell to XR. All of this technological ingenuity is driving the creation of innovative solutions for education, healthcare, manufacturing, retail, entertainment, and so much more.

Immersive technology has been rapidly growing and becoming mainstream, but the industry and its proponents must be full and active participants in the effort to address the relationship between technology and society. Without trust in the technology, it cannot succeed. This paper and the process that went into drafting it is a down payment on meeting that trust. There are many actors from industry, academia, civil society, and more that participated in this process who are equally committed to a robust discussion that yields positive and constructive results impacting the immersive computing platform of tomorrow.

IX. ACKNOWLEDGEMENTS

THE FUTURE OF XR ADVISORY COUNCIL

The XR Association expresses our heartfelt gratitude to those who have become integral members of The Future of XR Advisory Council (XRAC). XRAC, an independent advisory council, is dedicated to defining the XR ecosystem and providing invaluable insights that shape the ongoing initiatives of the XR Association.

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In addition, we would like to acknowledge the rich and diverse conversations that we had with our working group members. To learn more about the working group members, please go to https://xra.org/xrac/

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28. For purposes of this paper, "inferred data" was used to refer to the output of data that has been processed, as opposed to discrete data that is provided (knowingly or otherwise) directly by a person. In other words, "inferred data" is the conclusion reached about an individual based on the analysis of other discrete pieces of information. For example, based on data describing heartrate, pupil dilation, length of gaze, and facial expression, it may be inferred that an individual is drawn to a particular object. Inferred data often describes a predilection or emotional state. Notably, the individual about whom the inference is made may not themselves be aware of the result, i.e. the individual may not know they had an emotional response to a particular image.

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