WORLD ECONOMIC FORUM

Metaverse Cybersecurity: Building Resilience in the Future Internet

BRIEFING PAPER

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Foreword

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The ongoing history of the internet can be described as a series of innovative disruptions, continuously shifting the habits of consumers, industries, regulators and observers alike. Since its broader release to the public in 1993, the World Wide Web has facilitated the advent of novel innovations such as social media and online payment systems, resulting in profound departures from traditional means of information sharing, human interaction and commerce. These, and other, innovations have catalysed many new avenues for global economic opportunity and improved communication.

Yet, innovation is not without risk. In addition to the opportunities developed throughout internet ecosystems, there are ever-evolving pathways for harm and exploitation rooted in systemic and user vulnerabilities, often inadvertently aided by lagging or ineffective governance mechanisms. To build trust in current and future iterations of the internet, care must be taken to safeguard users, minimize and mitigate harms, and increase the availability of beneficial opportunities.

The governance track of the World Economic Forum's Defining and Building the Metaverse Initiative is pleased to contribute to this global conversation on the governance principles needed to foster responsible and ethical cybersecurity mechanisms for a resilient, safe and trustworthy future internet.

Introduction

The integration of augmented reality (AR), virtual reality (VR) and extended reality (XR) throughout centralized and decentralized platforms is facilitating immersive experiences that offer boundless consumer and industry value across multiple sectors. As these frontiers continue to offer enhanced communication and connectivity, the future of the internet presents new avenues for global interaction and innovation. Therefore, ensuring resilient digital ecosystems that support secure environments for diverse global usership is imperative to realizing the potential of the metaverse and its place as one of the drivers for the internet's unfolding future.

Protecting the next phase of the internet requires a preventative, forward-looking approach that involves the whole of society and prioritizes building trust, promoting agency and safeguarding user experiences. While systems are not impenetrable and platforms are not impervious, stakeholders can mitigate long-term risk by approaching cybersecurity through a focus on resilience, the ability for systems to operate under attack and recover efficiently.[1]

As part of the ongoing work of the governance track of the World Economic Forum's Defining and Building the Metaverse Initiative, this briefing paper outlines the unique cybersecurity challenges associated with the metaverse and the next phase of the internet. It seeks to guide the attention of decision-makers and developers with the ethical, resilient cybersecurity considerations from a global governance perspective, with the purpose of tackling these cyber risks while they are still in their nascent stages – to prepare metaverse ecosystems to stand against harms posed by threat actors and sustain through undesired behaviours by users or systems themselves.

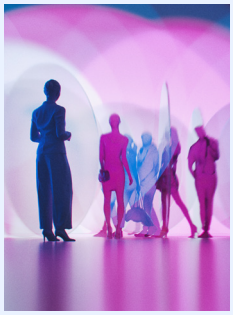
1 Unlocking value and mitigating risk

The next phase of the internet offers a paradigm shift for social and economic value creation predicated upon immersive experiences and further integration of financial infrastructure,[2] spanning multiple jurisdictions.

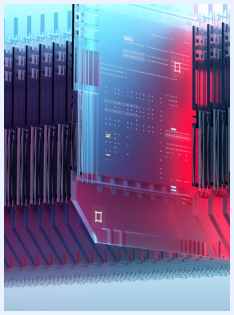
These developments, without proper governance measures, may produce a set of unmitigated security risks, targeting different facets of user safety and experiences that can be evaluated through four thematic areas.

Privacy

Virtual assets



Safety



Political systems

Evaluation of threats to immersive environments through these four thematic camps allows for pragmatic and action-oriented governance recommendations that are, reliable, lasting and sustainable. These recommendations support the security dimension of the World Economic Forum's Digital Trust Framework to ensure metaverse technologies are being deployed to "protect all stakeholders' interests and uphold societal expectations and values."[3]

1.1 Privacy

Risks to data and identity

The metaverse is widening the user's data exhaust – the trail of data generated by a system from a user's activity, behaviour and transactions. In addition to all forms of data previously generated by internet use and online activity, metaverse technologies broadly expand the landscape of generated data types, potentially exposing users to more frequent, varied and consequential security risks due to data breaches, identity theft and surveillance.

Data breaches

Cyberattacks resulting in data breaches compromise invaluable information such as institutional financial records, sensitive employee information and privileged client data. This can result in the suspension of operations, significant financial loss and severe reputational damage. High-profile cases of data breaches in recent years involving the targeting of US government agencies through contractors[4] highlight the severity of such an attack on metaverse platforms, especially as nation-states have begun building metaverse ecosystems to train government employees or provide remote services to citizens and stakeholders.[5]

Identity theft

The most likely outcome of a data breach on an individual level is identity theft.[6] In metaverse ecosystems, identity theft can have far-reaching consequences, including impersonation and fraud, loss of credentials, and access to virtual assets or accounts.

The theft of metaverse credentials can be used to access stored personal information, including highly valuable and non-duplicative forms of data such as iris scans or fingerprints. These can then be sold for profit to nefarious actors who may use the data to commit crimes in both virtual and physical settings.

In large corporate settings, compromising the metaverse identity or credentials of only a single employee can endanger entire organizations.

A unique identity-related risk in the metaverse pertains to the creation and storage of avatar data. As the representation of digital identity in immersive spaces, avatars[7] are a means of access to communal virtual spaces. The theft of an avatar can therefore be understood as the theft of digital identity, and this may lead to impersonations and enable a threat actor to engender unearned trust, access private spaces and communications, defame the impersonated user, hijack their likeness to spread disinformation, and conduct harassing or abusive behaviours with impunity.[8]

The personal and reputational impact of all these harms is amplified by the visceral connection the metaverse provides users to their digital environments and the peers they engage with via avatars within those spaces.

Identification and surveillance

The metaverse requires access points for users to enter immersive, simulative, or layered reality experiences that will rely on the physical body to control virtual and digital activity. That digital activity leaves a more tangible and pervasive trail linking digital behaviour to a physical user. A UC Berkeley study found that when a machine learning algorithm was trained on public use data of head and hand motion from a rhythm-based VR game, the algorithm was able to identify users from a pool of 50,000 with 94% accuracy using only 100 seconds of use data.[9]

> Without responsible data stewardship, user data could be subject to undue monitoring, manipulation, monetization and surveillance.

While data is a net-neutral byproduct of engagement in immersive technology, it is difficult to understand the extent to which bodily data is being collected, stored and processed. Without responsible data stewardship, user data could be subject to undue monitoring, manipulation, monetization and surveillance.

Governance outlook

Protecting metaverse privacy requires modernizing data conceptions and stewardship practices to account for new and more voluminous data collection and risk vectors associated with XR technologies.

There are many avenues to progress this modernization, including, but not limited, to:

- Augmenting consent protocols to ensure users fundamentally understand the breadth of data collection and use to which they are agreeing.
- Robustly categorizing captured data and attributing rigorous standards to net-new data types, such as treating body-based use data as health data.
- Developing multi-factor authentication and account compromise detection protocols consistent with the state of metaverse technologies.
- Developing ethical industry standards for third-party data and information sharing across jurisdictions.

1.2 Virtual assets

$20 billion

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Digital assets are broadly defined by the Financial Action Task Force (FATF) as "any digital representation of value that can be digitally traded, transferred or used for payment".[10] This can include cryptocurrencies such as bitcoin, non-fungible tokens (NFTs), and gaming tokens available to consumers in Web3 and immersive spaces. While gaming tokens may be valuable only within virtual localities, cryptocurrencies and NFTs may present tangible value more broadly. Bitcoin, for example, reached an all-time high value exceeding $70,000 in early March of 2024[11] and NFTs can link ownership of assets between the physical and digital worlds.[12] In the past, tokens and virtual currencies were only valuable within the confines of a host platform, but as an interoperable, metaverse-driven internet develops, virtual currencies and assets are foundational to building and deriving value in blended reality.

Security risks of blockchain

Most of the trading of digital currencies is conducted on blockchains,[13] which will continue to propel peer-to-peer transactions and promote transparency and seamless record-keeping. As users navigate Web3, blockchain is poised to be the natural means to facilitate transactional interoperability and the safe transfer of assets, including virtual currencies and virtual goods. It is important to note that blockchain integration is not, by itself, a comprehensive security measure. Blockchain processes can be hacked, leading to significant loss of value.

Theft and fraud

Through social engineering tactics and phishing scams, hackers may gain access to a user's digital wallet and then steal stored digital currency and other virtual assets. It may be difficult to provide adequate redress to victims of theft in the metaverse, particularly if the virtual asset stolen is stored within the confinements of a different legal jurisdiction, with incompatible regulation to that of the victim's point of origin.

Illicit financing

The potential misuse of NFTs includes money laundering, market manipulation, tax evasion, intellectual property crime, terrorist financing and other illicit financial activities. Due to fragmented jurisdictions, virtual assets offer terrorist and criminal organizations a means to leverage inconsistent tracing and governance coupled with the anonymity often associated with virtual assets to launder money or finance illicit activities. In this sense, weak and fragmented governance becomes a cybersecurity vulnerability itself.

Governance outlook

The continued progress of Web3 and XR technologies stands to create transformative commercial value through both net-new digital assets and seamless integration of physical/digital value transfer. To deliver and sustain this value, robust and resilient system protections, networks for information sharing and redress mechanisms must be in place.

Some potential avenues to advancing such protections are:

- Modernize legal definitions and redress channels to account for virtual assets, enabling relevant public sector escalation, enforcement, and support in cases of theft, fraud, etc.
- Standardize basic authentication protocols to access digital wallets.
- Ensure developers are conscientious of foundational privacy, safety and security principles when designing network infrastructure.
- Establish cross-border and jurisdictional information-sharing mechanisms to adequately identify, trace and prosecute metaverse financial crimes.

1.3 Safety

As immersive technologies and digital asset integration bolster the relevance and impact of digital experiences in users' lives, safety in immersive spaces will increasingly impact safety in the physical world. The World Economic Forum's Typology of Online Harms, rooted in human rights principles, "harmonizes universal perceptions of online threats".[1] These harms, which are often not criminalized, must be encoded, and adopted by the international community to ensure adequate recourse and safety standards, with special attention to the needs of vulnerable populations engaging with metaverse technologies, such as children and adolescents.

Child and adolescent safety

Online dangers to children such as cyberbullying, sexual exploitation, grooming, harassment and coercion are well documented within Web2 spaces, and extensive research has been conducted on the psychological ramifications of children's exposure to harmful online content. However, the extent to which experiencing harm in immersive environments may impact children's mental and emotional health or their development remains unknown.

Sexual offenses in the metaverse, targeting users' avatars cause "significant psychological and emotional trauma"[1] and have already occurred in immersive environments.[20] These risks are further compounded by the risk of "phantom touch – brain sensory input that causes the body to experience sensations similar to physical touch"[21]; meaning, victims of sexual assault in virtual reality could experience unwanted physical contact, specifically when using a haptic suit.

Children and their devices must be safeguarded from predators seeking to take advantage of gaps in security measures. Child spaces in metaverse environments must have strong security protocols to ensure unauthorized users cannot access these communities, and age-based controls and adequate reporting mechanisms should be made available to children and parents.

Cybersecurity and physical safety

Emotionally vulnerable users are particularly at risk of falling victim to social engineering tactics being expertly deployed in simulative and layered reality environments. Each year, thousands of people are lured to travel by criminals promising employment or other benefits and are then trafficked and forced to work on scam farms[22] Vulnerable people, such as children, may inadvertently reveal sensitive data about themselves and their families, such as location, preferences, routines and financial information, that could be leveraged by nefarious actors for a myriad of illicit purposes including fraud, money laundering, identity theft and targeted physical violence.

Experiencing immersive or augmented environments safely requires cybersecurity measures that ensure endpoints are not compromised by nefarious actors with malicious intent. Hardware, such as headsets, haptic suits and glasses, can be hijacked[23] leaving users vulnerable to manipulation and interference. Should a hacker gain access to a headset, for example, they could manipulate and distort the user's environment and lead them to inadvertently harm themselves or others. This raises significant concerns surrounding national security, as threat actors could launch an attack that exploits weaknesses in VR/AR/XR hardware and software systems such as "man in the room" attacks[24] to spread malware and other forms of disruptive viruses.

Violence and radicalization

The threat of radicalization is only exacerbated in immersive environments where groups such as terrorist organizations can weaponize the effects of presence and embodiment.[25] These tactics have had historical success as exemplified by the hundreds of thousands of former terrorist fighters and their families remaining in camps across Syria and Iraq following the fall of Da'esh[26] who were either radicalized or scammed online into joining ISIL.

Digital twins

As industrial metaverse use cases advance, the data types available to hackers and scammers will only be widened. Data and information on critical infrastructure vis-à-vis digital twins, as adopted by cities globally to facilitate urban planning and smart development,[27] may incentivize terrorist groups and criminal enterprises to exploit live data of vulnerable targets and assets in metaverse spaces to produce physical harm.

Governance outlook

The critical importance of online safety efforts is well-known, and it will be essential to continue scaling these efforts to meet emerging technological capabilities and risks. Further, it will be essential to supplement safety-by-design with resilience-minded governance efforts aimed at protecting users and systems even after malicious attempts are made.

Examples of resilience-minded efforts include the need to:

- Adopt common conceptions for online harms to enable aligned, cooperative detection and remediation of critical safety threats as and after they appear.
- Develop industry standards for trust and safety, including robust digital literacy and reporting channels with explicit support and response resources dedicated to harms impacting disproportionately vulnerable user groups.
- Apply heightened security standards for stored data pertaining to real-world infrastructure and personally identifiable user information.

"The threat of radicalization is only exacerbated in immersive environments where groups such as terrorist organizations can weaponize the effects of presence and embodiment.

1.4 Political systems

In a report entitled *The Geopolitics of the Metaverse*, the Eurasia Group reports that "incipient metaverses are already breaking down along geopolitical lines".[28] The upshot of this fragmentation is inconsistent regulation and enforcement, leaving greater vulnerability for metaverse exploitation by threat actors. The connection between new avenues of attack and increased incidence of attack is notable; Arkose Labs' 2022 State of Fraud & Account Security report found that metaverse companies experienced 80% more bot attacks and 40% more human attacks than other businesses, as well as being more frequent targets for "master fraudsters".[29]

Fragmented policy

Taking stock of cyberthreats against the metaverse, it becomes increasingly clear that a resilient metaverse will be one that serves a globally distributed consumer and creator base, unbound by the limitations of national borders, supported by global governance and underpinned by interoperability standards. A secure metaverse will not be one developed in a fragmented manner that leaves the future of the internet to be determined by national interest.

Notably, data governance is already differentiating vastly across the European Union, the United States and Chinese jurisdictions,[30] which leads to fragmented data management and inconsistent cybersecurity requirements that make systems susceptible to exploitation. Harmonization across jurisdictions is important to establish minimal cybersecurity and data governance requirements that will prevent governance weaknesses from becoming cybersecurity vulnerabilities themselves. Metaverse hardware and systems must be interoperable so there is a shared metaverse underpinning a safer and resilient future internet.

Governance outlook

As jurisdictions across the globe approach regulation to metaverse technologies and digital assets, intentional and impactful collaboration will be essential for the state of the future internet.

Examples of collaborative governance efforts may be:

- As described in the Safety section, the adoption of a common taxonomy of online harms will be critical to a globally successful technology governance climate.
- Globally collaborative frameworks must facilitate inclusion for and contribution by the global south.
- Governance efforts should support a common understanding of harms by developing and maintaining collaboration and information-sharing policies to ensure a broadly beneficial and rights-preserving metaverse environment.

Conclusion

The future of the internet is being built on the continued development of immersive and Web3 technologies and stands to offer transformative value to users, industries, and society.

To cultivate, advance and protect that value, it will be necessary to approach the cybersecurity and safety risks inherent to communications and financial technologies with cutting-edge expertise and global cooperation.

By focusing on resilience-minded governance efforts, stakeholders can augment traditional safety discussions and go further to ensure metaverse and Web3 advancements are broadly beneficial, equitable and sustainable.

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