XRAI-Ethics: Towards a Robust Ethical Analysis Framework for Extended Artificial Intelligence

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Abstract

Extended Reality (XR) integrates real and virtual environments through spatial computing technologies, playing a crucial role in the development of the Metaverse. The synergy of XR with Artificial Intelligence (AI), referred to as Extended Artificial Intelligence (XRAI), enhances immersive experiences and operational efficiencies across various domains and human activities. However, ethical considerations for XRAI remain underexplored, particularly considering fairness, privacy, bias, and responsibility. This paper introduces the XRAI-Ethics framework, which aims at defining a novel approach for analyzing and extract ethical risks and principles for XRAI. The XRAI-Ethics framework seeks to promote responsible development and implementation of XRAI technologies, offering guidelines for both public and private sectors to ensure ethical practices in emerging XR applications.

Index Terms: Extended Reality, Artificial Intelligence, Ethics.

1 Introduction

Extended reality (XR) has become an increasingly popular technology in several fields, including entertainment, industry, education, and healthcare [48, 55, 14, 58, 26]. XR paradigms are foundational for the Metaverse, defined as a convergence of physical, and extended realities providing immersive experiences to naturally visualize and interact with digital information within real and virtual worlds [45, 14, 68, 58, 53]. However, the Metaverse implementation requires the orchestration of additional technological paradigms to inject logical, social, and economic systems, which are key components of our societies [63, 42, 8, 37, 23, 6]. To this date, the Metaverse development is driven by several paradigms, including Artificial Intelligence (AI), Web technologies, the Internet of Things (IoT), Blockchains, and Non-Fungible Tokens (NFTs) [14, 58, 40].

Despite the general attention to the joint usage of all these technologies, the composition of AI and XR was one of the most studied and defined a new body of research, named "Extended Artificial Intelligence" (XRAI) [69, 24, 40]. This is because AI plays a fundamental role: defining an intelligent stratum that supports users in automatizing and augmenting experiences in the Metaverse [57, 74, 14, 58, 40, 53]. For example, XR researchers employed AI methods to solve problems like object tracking and virtual agent communications; AI, and situated predictions. Conversely, AI researchers adopted XR technologies to address issues such as understandability and explainability [69, 56, 59, 14, 58, 1, 27, 24]. In such a context, an increasing body of research is orchestrating, composing, and pipelining XR and AI paradigms for the benefit of several fields of study, from consumer, academic, and industrial perspective [56, 69, 64, 24]. With such premises, and considering that the ergonomics of consumer XR devices are increasing while the performance of integrated AI models is improving, it is predictable that a higher market quota for these devices will occur (e.g., Apple Vision Pro [1]) impacting different sectors of our everyday lives [46, 2]. It is worth observing that, the software systems built on top of this technology are continuously fed with real-time data coming from critical sources such as humans, industrial sensors, and autonomous machines. Such data defined concerns regarding user privacy and security, raising concerns for malevolent usages in different contexts of usage (e.g., Medical, and Industry).

Considering risks like this, a recent debate was started to define the ethical principles and values guiding its development and use. For example, the IEEE Standards Association initiated a global initiative for the Ethics in XR and related technologies [2]. This initiative highlighted ethical challenges and possible guidelines in some of the contexts of the application of XR. At the same time, a few public governance entities discussed about politics of XR and the Metaverse (i.e., European Parlament [3]). However, to the best of our knowledge, no explicit and well-defined regulations currently exist that address ethical guidelines for XR, particularly those that incorporate the complexities arising from the use of AI paradigms. Considering this scarcity, we could resort to a literature review process, to have a comprehensive understanding of the ethical issues to be considered for XR, including AI, supporting such a transition. There is indeed a growing trend in the area of XR ethics and AI ethics considered separately. For example, various studies have explored the potential for both XR and AI to be manipulated by ma-

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[1] https://www.statista.com/statistics/1398458/apple-vision-pro-shipments/

[2] https://standards.ieee.org/industry-connections/ethics-extended-reality/

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023SC0250

licious entities, avoid accountability, and propagate bias and unfairness, primarily detailing specific ethical concerns and challenges without offering a general perspective on analysis and mitigation strategies [38, 15, 53]. However, those two disciplines should be ethically analyzed together, since XR often follows technological research outputs of AI (and vice-versa), which creates the urgency for joint ethical guidelines [24, 53].

To this date, we here define the XRAI-Ethics, a novel framework for exploring and addressing concerns related to fairness, privacy, bias, accountability, transparency, and the responsible use of XRAI technology in the Metaverse (in all the XR spectrum). With XRAI-Ethics, we want to dig into ethical implications and promote the development of ethical guidelines and best practices to ensure AI's responsible and beneficial integration in XR and vice-versa [53]. In particular, we first highlight areas of everyday application where the XRAI technologies could create ethical pitfalls. Then, we preliminary adapt these ethical principles in the XRAI context, starting from the notorious ethical principles of AI [4] [29, 53] to provide a basis for extracting guidelines to regulate both public authorities and private high-tech sector development and management activities for XR contexts.

2 Related Works

Despite the increasing interest and adoption of XR and XRAI paradigms and their ethical concerns, only a few works focused on providing a general ethical analysis for their application domains and different use cases [11, 49, 65, 6, 53].

Authors of [11] introduced a multi-dimensional framework that incorporates a comprehensive ethical dimension to organize user experiences with AR devices in educational settings. This framework was designed to cope with the ethical concerns raised by AR in learning contexts, including user safety, privacy violations, information overload, and harmful social effects. A similar approach was followed in [65]. Authors of [49] examined the ethical dimensions of VR development and research, highlighting the current exclusionary practices that prevalent included developers and researchers from a minority demographic individuals, lowering XR accessibility and applicability. To cope with this, the authors defined a framework for a development cycle contributing to and benefiting from VR advancements to promote the inclusion of a broader population. A similar phenomenon was previously observed in [50] where authors analyzed the representation of female participants in VR publications while performing a meta-analysis to evaluate potential biases arising from gender diversity (or the lack thereof) among participants. Results outlined how the under-representation of female participants in VR studies may result in biased findings, thus increasing the attention for future research to address similar questions regarding other demographic characteristics to ensure broader inclusivity.

The white paper introduced in [6] explores the ethical and social risks associated with the emerging concept of the Metaverse, offering guidance on how organizations can prepare for them. While legal, tax, crime, and intellectual property risks are acknowledged, they are beyond the scope of this discussion, except where they significantly impact societal aspects. The outcome of their analysis advocates for a proactive approach to anticipate and mitigate potential issues, outlining how To open the public debate of what those values and ethical principles should be defined starting from the values identified in UNESCO's recommendation on the ethics of AI. Finally, a very recent work [53], investigates the ethical and security challenges of XRAI technologies in the Metaverse. It underscores the transformative potential of the Metaverse across different sectors such highlighting significant concerns related to privacy, security, and the alignment of commercial interests with societal values. The main novelty of such contribution amounts to a systematic identification of vulnerabilities in XRAI applications, proposing a taxonomy for securing these technologies, and presenting a case study to illustrate real-world threats. The paper calls for a proactive approach to address these issues, ensuring that Metaverse development is both secure and ethically sound.

Being inspired by these related works, we propose a novel framework that aims at integrating not only scientific literature but also white and gray literature along with existing public documents, to define more robust and sound ethical guidelines within the XRAI context.

3 XRAI-Ethics Framework

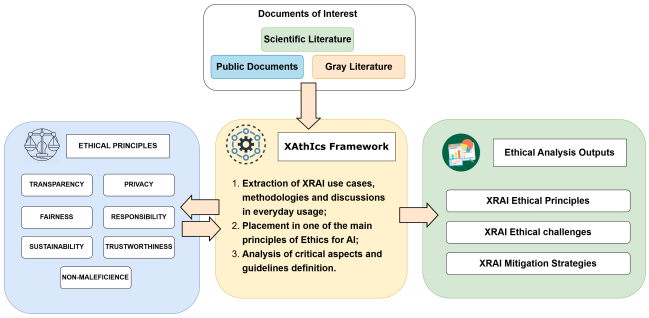

Figure 1: XRAI-Ethics framework.

In this section, we introduce the XRAI-Ethics Framework, which amounts to a novel approach designed to extract, analyze, and define ethical principles and guidelines from diverse literary sources in the context of XRAI. XRAI-Ethics is visually depicted in Figure 1.

The XRAI (Explainable AI) Ethics Framework operates as a comprehensive system to integrate ethical considerations into XRAI by systematically reviewing diverse sources and organizing insights into actionable outputs. As depicted in the top part of Figure 1, the first stage of XRAI-Ethics systematically reviews scientific and gray literature along with public documents to gather a wide range of perspectives on XRAI ethics. Scientific literature provides theoretical foundations and empirical findings, public documents offer insights into societal expectations and regulatory frameworks, and gray literature, composed of unpublished or non-commercially published works by relevant societies (e.g., IEEE), contributes additional valuable perspectives on actual and future society implications. Following the collection of documents, the second stage of XRAI-Ethics amounts to a structured process including extraction, categorization, and analysis of the ethical concerns and risks outlined in the selected documents. In particular, during the extraction phase, the framework identifies use cases, methodologies, and discussions related to XRAI, focusing on real-world applications and theoretical debates to ensure relevance. The extracted information is then categorized according to robust ethical principles (i.e., transparency, privacy, fairness, responsibility, sustainability, trustworthiness, and non-maleficence). These principles align with globally recognized ethical standards for AI, thereby enhancing the robustness of the framework's outputs [29]. After these categorizations, a detailed analysis of these principles identifies critical ethical challenges and develops corresponding mitigation strategies, resulting in comprehensive guidelines for ethical XRAI development. The XRAI-Ethics Framework thus provides a holistic approach to integrating ethical considerations into XRAI.

This methodology aims at advancing the field of ethical XRAI, offering valuable insights and guidelines that address evolving ethical challenges for these technologies. In the next Section, we will

[4] https://www.unesco.org/en/artificial-intelligence/recommendation-ethics

detail how we adopted XRAI-Ethics to analyze ethical challenges for different principles.

4 Applying XRAI-Ethics: Ethical Implications and Principles for XRAI

Considering AI ethics guidelines from UNESCO [4] and the principles detailed in [61, 29], we here model an adaption of them for XRAI (following an approach similar to [6]). These aim to support the general development of such systems and limit the pitfalls that could lead to ethical problems, as the one highlighted in the previous Section. We will here propose a preliminary analysis of the following ethical principles and linked challenges within different use cases: **Transparency**, **Non-Maleficience**, **Privacy**, **Responsibility and Accountability**, **Sustainability**, and **Fairness**. A summary of our discussions, integrated with some examples, is detailed in Table 1.

4.1 Transparency

Transparency refers to the principle that decisions and processes of XRAI systems should be clear, understandable, and accessible to those interacting with this technology. This principle was declined in several sub-keywords for AI within [29], and we selected some of those principles in the context of XRAI. It is worth highlighting that Transparency can help build trust, facilitate communication, explain decision-making processes, promote human agency, identify algorithmic biases, and align with human-centered considerations [16, 73, 53]. Considering this, *explainability* is crucial to ensure users understand how the system works and how it makes decisions. This will be crucial in applications such as healthcare and finance, where users need to trust the system's decision-making processes [52, 28, 66]. Moreover, effective *communication* is vital to address user concerns or questions about the system's decision-making processes, also supporting financial and economical systems [44, 7, 6]. Finally, *interpretability* should be taken into account [16, 73, 28, 53] since it will be crucial for XRAI systems applied in medical, social or education use cases, where users must be able to understand how the XRAI system arrived to particular recommendations or decisions [15].

4.2 Non-Maleficience

XRAI system should be reliable in its usage, allowing the user to not *harm* her/himself or others and shielded against vulnerability attacks (from malevolent users). In practice, these systems should not pose unreasonable *safety* risks like physical security in conditions of normal or foreseeable use or misuse throughout their lifecycle [29, 39]. Considering *physical safety*, it is worth highlighting that spatial computing paradigms, mostly based on AI, are never 100% correct. This leads to concerns including health issues such as dizziness, falling, or tripping over equipment while immersed in a scenario [65, 12, 22]. On such a context [22] highlighted how mechanisms such as immersive attacks and perceptual manipulations in XR, could be used to define new ways to *harm* people, like adversarial attacks [13]: hackers could fool the XR masking rendering system to confuse a user and drive her/him to dangerous situations [60, 9]. On a similar line, Psychological concerns could include post-traumatic stress disorder, desensitization to violence, and decreased empathy [62, 37, 22]. This should be caused, for example, by the infringement of privacy and mental liberty: XRAI systems may monitor and modify mental states and behaviors without consent, compromising privacy and autonomy [37, 22]. To address these concerns, a user-centered approach to developing XR technology is essential. This approach should prioritize autonomy, identity, and integrity, ensuring interventions respect dignity and self-determination. Development should follow a precautionary principle, favoring gradual innovation grounded in empirical evidence and responsible research [37, 22].

4.3 Privacy

The ethical considerations related to **Privacy** in XRAI are multifaceted [21, 35, 39, 42, 15, 16, 32, 18, 70, 6]. Privacy concerns arise from the collection and use of personal data, particularly sensitive information such as biometric and psychometric data, which requires stringent safeguards to prevent misuse. Additionally, there is uncertainty about how existing laws and regulations will apply to XR, raising questions about legal protections and regulatory compliance [42, 15, 16, 32, 18, 35]. This is also true for the use of these technologies in public spaces, including by government and law enforcement, which introduces potential privacy risks, including surveillance and unauthorized data collection [32]. This results in the need for *data protection* frameworks. To access XR experiences, devices should incorporate hardware usage protection mechanisms (e.g., LiDAR, camera arrays, microphones, and IMU devices, which are essential for driving key functionalities) [3, 42, 16]. Moreover, such a control mechanism must be extended to data fed to AI models that could implicitly model users' actions, attitudes, and emotions [42, 31]. This data could also be used to model human-like avatars with the same identity as the user (visual aspects, behavior, intentions, emotions, and taste), which could be used to define malevolent users to act as others [42, 70].

4.4 Responsibility and Accountability

XRAI systems should be auditable and traceable and there should be oversight, impact assessment, audit, and due diligence mechanisms to avoid conflicts with human rights norms and threats to environmental well-being [42, 4, 72, 28, 5, 25, 47, 41]. As also highlighted by AI principles [29], the community should be concerned about *integrity* and legal liability regarding underlying processes leading to harm, promoting diversity. Considering these, XRAI and Metaverse designers, institutions, and industry are named as accountable for AI actions, with debates over whether XRAI itself should be held accountable or if humans should always bear ultimate responsibility [42, 25]. This was also outlined by [41], where authors' analysis revealed how Metaverse creators approach accountability of XRAI as a mechanism while operating companies primarily address accountability within the virtual-physical domain, focusing on developing the necessary internal and external infrastructure to ensure the proper functioning of their Metaverse while details are often sparse and not well-cleared. This means that stakeholders should uphold transparency, avoid biases, and ensure that their technologies are designed and implemented ethically, committing to ethical principles and societal values [42, 5, 47].

4.5 Sustainability

Advancing *sustainable* XRAI requires addressing not only environmental dimensions but also social and economic ones [43, 4, 51, 10, 30]. In particular, XRAI technologies should be designed to minimize consumption and, therefore, reduce their carbon footprint [4, 51, 10, 30]. At the same time, their environmental and social impacts should be measured during and after their useful life, along with their interoperability with other existing systems and technologies, reducing the need to create new systems and minimizing duplication of efforts. Authors of [6] highlighted how a fundamental analysis amounts to measure the carbon footprint of XRAI systems. A more recent challenge that has been identified for AI is related to the *energy* consumption of large models, which consume millions of dollars in electricity and therefore have a significant carbon footprint and will have a core role within XRAI systems [67]. At the same time, a careful analysis of remote rendering mechanisms for XR devices must be carried out, considering the massive computation needed for their execution [36, 75]. On a similar line, NFTs, based on blockchains that use consensus algorithms for adding new blocks to the chain must be taken into account, considering their energy consumption [54]. Those will be used to val-

Ethical Principle	Challenges	Example	References
Transparency	Ensuring that XRAI systems' decisions and processes are clear and understandable to users.	**Medical system**: XRAI medical systems should be designed so that understand the rationale behind AI actions, such as identifying patterns in images or describing how spatial computing render information on a patient. **Social Interactions:** AI algorithms used for social XR interactions and reputation systems should be clear to users. If a user's behavior is rated or monitored, s/her should know explain how these ratings are determined	[29], [16], [73], [53], [52], [28], [66], [44], [7], [6], [15]
Non-Maleficence	Ensuring that XRAI systems are reliable and do not cause harm to users or others. This includes protecting against safety risks and vulnerabilities.	**Safety Risks:** XRAI systems should be designed to avoid physical injuries such as dizziness or tripping, which can occur during normal or foreseeable use. **Psychological Impact:** XRAI systems should avoid negative psychological effects, such as PTSD or decreased empathy, and should not infringe on privacy or mental autonomy.	[39], [65], [12], [22], [13], [60], [9], [62], [37]
Privacy	Protecting personal data collected and used by XRAI systems, including sensitive information such as biometric and psychometric data. Ensuring compliance with laws and preventing misuse, especially in public and regulated environments.	**Data Protection:** XRAI devices should include hardware protection mechanisms to secure sensitive data from unauthorized access. **Surveillance Risks:** Use of XRAI technologies in public spaces by government or law enforcement may lead to privacy concerns such as unauthorized data collection and surveillance.	[21], [35], [39], [42], [15], [16], [32], [18], [70], [6], [3], [31]
Responsibility and Accountability	Ensuring XRAI systems are auditable and traceable, with mechanisms for oversight, impact assessment, and due diligence. Addressing who should bear responsibility for XRAI decisions and actions, and how to uphold integrity and legal liability.	**Oversight Mechanisms:** Implementing systems to track and audit decisions made by XRAI technologies, ensuring they align with human rights and environmental norms. **Accountability Debates:** Determining whether XRAI systems or the human operators are responsible for actions and potential harms caused by these systems.	[42], [4], [72], [28], [5], [25], [47], [41], [29]
Sustainability	Addressing environmental, social, and economic dimensions in XRAI technologies. Minimizing carbon footprint and energy consumption, and evaluating the impacts throughout the lifecycle of the technology.	**Carbon Footprint:** Reducing the environmental impact by designing XRAI systems that consume less energy and have a lower carbon footprint. **Economic and Social Impact:** Considering the impact of blockchain-based technologies, such as NFTs within Metaverse trading systems like Decentraland.	[43], [4], [51], [10], [30], [6], [67], [36], [75], [54], [34], [19]
Fairness	Promoting social justice and non-discrimination within XRAI systems, ensuring that all users have equal access and benefits. Addressing algorithmic biases and ensuring inclusivity.	**Bias Mitigation:** Identifying and reducing algorithmic biases to prevent stereotypes and ensure equitable treatment across different user groups. **Inclusion:** Designing XRAI systems to be inclusive, addressing challenges faced by minority groups and users with disabilities to ensure they are not excluded from the benefits of these technologies.	[17], [49], [33], [6], [20], [76], [71], [65], [38]

Table 1: Ethical Principle: Transparency in XRAI Systems

idate mostly any event performed within Metaverse, including AI actions, and are key to analyzing their impact while making them more sustainable, also from an economical perspective [43, 34, 19].

4.6 Fairness

Within the XRAI domain, all the actors should promote **Fairness** along with principles such as social justice, and non-discrimination while taking an inclusive approach to ensure XRAI's benefits are accessible to all [17, 49, 33, 6, 20, 76, 71]. Considering *Justice*, it is highlighted how this was correlated to the respect for diversity [17] and the need for future research to account for influential factors when comparing XRAI effects on users between different groups [49]. This highlights the importance of fairness while designing XRAI systems. This is linked to bias analysis, as understanding and mitigating algorithmic biases are essential to prevent perpetuating stereotypes in XR environments, also driven by bias already present within AI algorithms [20, 76, 71]. It is worth mentioning that *Equality* is inherently linked to fairness and consistency, as ensuring equal access to XR technologies and AI-powered content is vital for promoting justice and collecting data to create unbiased experiences. Finally, *Inclusion* is one of the most relevant aspects for XRAI and the Metaverse: due to their immersive nature, pose a heightened risk of excluding different populations. For example, [49] found that approximately 95% of the world's XR systems were being primarily designed for male, western, educated, industrial, and democratic populations. This is even more stressed when considering minority populations: as an example, many users with disabilities could be excluded if proper adaptive mechanisms are not implemented. Those pose several challenges that must be mitigated through novel practices to address these issues [17, 49]. On this line, social concerns may include an absence of engagement with others in real-time and difficulty establishing relationships with others [65]. This was highlighted by SocialVR's reported safety issues: harassment and trolling are not unusual within this platform, making the environments feel less safe and inclusive than is ideal for users [38]. Despite being a limited study, this highlighted a need for further research on the safety of minorities' experiences and the reluctance of individuals with similar experiences.

5 Conclusions and Future works

We here introduced the XRAI-Ethics framework, which provides a structured approach to analyze ethical discussions in scientific and gray literature, including public documents, to define ethical challenges, principles, and possible mitigations within the XRAI arena. We then applied our framework to analyze different challenges within such context, under the lens of different and robust ethical principles, including **Transparency**, **Non-Maleficience**, **Privacy**, **Responsibility and Accountability**, **Sustainability**, and **Fairness** defining a novel schema to promote and support ethical research in this field. Future research will focus on refining the XRAI-Ethics framework, including a more structured literature review while focusing on defining mitigation strategies per each use case and highlighting ethical risks.

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