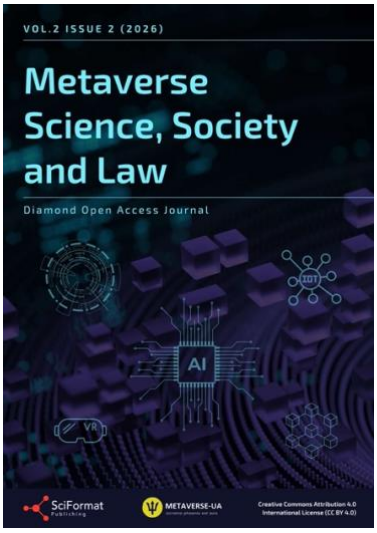


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ETHICAL GOVERNANCE AND HUMAN-CENTRIC DESIGN IN THE MULTISENSORY METAVERSE: THE CASE OF DIGITAL OLFACTION

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ABSTRACT

This work explores the complex landscape of ethical governance and the regulatory framework governing the metaverse, with a specific focus on the integration of multisensory experiences and digital olfaction. It analyzes the role of the metaverse as a catalyst for digital transformation and examines key international and European legislative initiatives, highlighting the current regulatory void surrounding sensory data and "cognitive biometrics." The research addresses the critical risks associated with emotional manipulation and the emergence of the "Darkverse," where immersive environments can be exploited for subconscious psychological influence. As a strategic response, the study proposes an Ethical UX Design Framework tailored for digital olfaction, emphasizing user autonomy, explicit consent, and accessibility for individuals with olfactory dysfunctions. By bridging technological innovation with ethical mediation and participatory design, this research contributes to the development of a more secure, inclusive, and ethically governed multisensory metaverse.

KEYWORDS

Metaverse, Metavethics, Multisensory Experiences, Digital Olfaction

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1. Introduction

The development of multisensory technologies, which combine data and stimuli from multiple senses (e.g., vision, hearing, touch, smell), creates new perspectives across various sectors. Simultaneously, however, questions arise regarding their regulatory, ethical, and legal implications, as their use intersects with fundamental rights such as privacy and personal data protection. While research and innovation advance, the regulatory framework appears unable to keep pace with the complexity of these technologies. Specifically, there is no specialized regulatory framework governing multisensory technologies as a distinct category.

Instead, the majority of regulatory attention focuses on broader technologies, such as Artificial Intelligence (AI), the Internet of Things (IoT), and biosensors, which can serve as constituent components of multisensory systems (Hadzovic et al., 2023; De Almeida et al., 2021; Li et al., 2023; Bouderhem, 2024). The European Union's AI Act, for instance, will constitute the first significant regulatory framework for AI and may indirectly affect multisensory technologies that utilize such components, such as AI-based biosensors (Bouderhem, 2024).

Generally, the rapid evolution of these emerging technologies has mobilized policymaking with the primary goal of safeguarding human rights from the design and development stages (Yilma, 2023). However, new technological fields, such as neurotechnology, raise intensifying challenges. They bring to the forefront not only the fundamental principles of human rights but also the need to recognize new ones, such as cognitive liberty, mental privacy, mental integrity, and psychological continuity (Ienca and Andorno, 2017). At the same time, international human rights law is shifting due to its interaction with digital rights, a fact that creates opportunities for their promotion in the digital age but also raises concerns regarding its broader political acceptance (Shany, 2023).

Within this dynamic yet fragmented regulatory environment, multisensory technologies emerge as a distinct category of innovation with significant application potential, but also with clear regulatory gaps. The absence of a unified framework renders them a field of particular uncertainty, where challenges transcend technical integration and touch upon critical political, legal, and ethical consequences. In fact, digital scent technology is increasingly recognized as a foundational pillar for the Internet of Senses (IoS), facilitating profound immersion within the metaverse by enabling the precise digitization, transmission, and synthesis of olfactory stimuli (Panagiotakopoulos et al., 2022).

In this context, while this paper recognizes the multidimensional nature of multisensory experiences, it chooses to focus on digital olfaction technology as a primary case study. This choice is not accidental; on one hand, digital olfaction is perhaps the most regulatorily neglected sense in human-computer interfaces, and on the other, this focus is supported by the author's specialized doctoral research in this specific field. By drawing upon early technological insights (Panagiotakopoulos et al., 2022), this discussion attempts to highlight the broader regulatory gap governing the metaverse, offering a concrete example of how ethical governance can be applied to emerging, non-traditional sensory technologies.

2. Background

2.1. The Metaverse as a Catalyst for Digital Transformation

The metaverse can be compared to the digital transformation wave of the early twenty-first century, offering immense opportunities alongside implementation challenges across diverse organizational settings. To adapt successfully, institutional frameworks must address digital space regulation, technological integration, strategic collaborations, privacy, and systemic security. Since organizational needs vary significantly—such as between the media and gaming sectors—a generalized yet adaptive framework is essential to guide the integration of key technologies like Augmented Reality (AR), Virtual Reality (VR), and AI into specific service architectures (Dwivedi et al., 2022).

Beyond functioning as a mere virtual environment, the metaverse serves as a globally accessible 3D computational infrastructure that bridges emerging technological trends with practical societal and business applications. In the public sector, this transformative ecosystem redefines accessibility and civic engagement. By leveraging interconnected virtual spaces, governments and public organizations can deploy virtual service hubs, host inclusive assemblies, and provide immersive educational resources, thereby expanding global access to public and cultural assets (Deliyannis et al., 2024).

Furthermore, the metaverse unifies multiple layers of advanced technology and human knowledge, positioning users within interactive workspaces through immersive tools and avatars. This paradigm shift toward real-time 3D environments enables advanced content co-creation and fosters innovation across multiple domains (Agarwal and Alathur, 2023). Specifically, it introduces novel revenue streams in commerce via

virtual storefronts, personalized interactive environments in education, and hybrid collaboration tools in the workplace (Agarwal and Alathur, 2023). Ultimately, the metaverse enhances both public digital experiences and broader corporate structures, driving the overarching digital transformation of society and business (Rehm, Goel and Crespi, 2015).

Despite this profound potential, the sustainable development of the metaverse requires addressing critical multi-layered challenges. These encompass technical limitations (such as scalability and interoperability), psychosocial risks (including addiction and social isolation), and profound ethical, legal, and environmental concerns (Agarwal and Alathur, 2023). Effectively mitigating these hurdles is paramount for the metaverse to contribute constructively to global digital transformation and the broader paradigms of Industry 5.0.

2.2. Governance of the Metaverse

Governing the metaverse presents complex challenges due to its borderless nature and the diversity of its virtual worlds. Establishing interoperability and standardization across these distinct environments requires a multi-layered governance model to address jurisdictional overlaps, cybersecurity threats, and software architecture maintenance. Furthermore, the metaverse raises significant legal and ethical questions (particularly regarding digital asset ownership, digital sovereignty, and law enforcement). Bridging real-world regulations with virtual policies remains inherently difficult, leaving the optimal regulatory framework currently undefined (Dwivedi et al., 2022).

As the metaverse evolves into a complex ecosystem spanning social, commercial, and entertainment domains, establishing a robust framework of adaptable rules becomes critical to ensure security, ethical conduct, and interoperability. The "Seven Rules of the Metaverse" (Parisi, 2021) address this regulatory need, outlining fundamental principles for safe and equitable user interaction. According to these principles, the metaverse is a singular, unified entity (much like the internet) precluding the creation of multiple, isolated "metaverses". It must be inherently inclusive, supporting diverse use cases and affordable content creation, while promoting real-world accessibility, diversity, and equality by mitigating physical and geographical barriers. Furthermore, its governance must remain decentralized; no single corporation can control the metaverse, though individual virtual spheres may be independently managed. It relies heavily on open technologies and globally agreed-upon communication standards to foster scalability and avoid proprietary lock-ins. Finally, the metaverse must be hardware-agnostic (accessible across any device regardless of its display capabilities) functioning as a vast, interconnected network that seamlessly integrates real-time 3D content, digital identity, and global commerce.

Beyond theoretical principles, the governance of the metaverse is increasingly shaped by global economic and geopolitical strategies. Initial estimates project the metaverse economy to reach three trillion dollars by 2031, prompting aggressive investments and policy formulations worldwide (Meta, 2022). National and international entities are adopting divergent approaches, particularly regarding the regulation of foundational technologies like blockchain, AI, and cloud computing.

In the United States, legislative committees and regulatory bodies are actively integrating blockchain and digital assets into existing financial and healthcare frameworks, while major tech conglomerates (including Meta, Microsoft, and Nvidia) are independently building the required infrastructure. Conversely, China approaches the metaverse as a strategic avenue for global technological dominance. Under the state supervision of the China Mobile Communications Association, the country inaugurated its first industrial group, the "Metaverse Industry Committee." This state-led initiative operates in close collaboration with domestic technology giants such as Tencent, NetEase, and Baidu, all of which are accelerating the deployment of blockchain and 5G technologies to secure a leading position in the global metaverse race (Council of the European Union, 2022a).

Similar proactive strategies are evident across Asia and the Middle East. South Korea is heavily subsidizing digital transformation, aiming to complete the "Metaverse Seoul" municipal project by 2026, while Japan has formalized its blockchain and cryptocurrency regulatory environments. The United Arab Emirates and Saudi Arabia are actively investing in blockchain-based financial systems and digital twins of major urban centers, such as Dubai and Mecca. Highlighting the shift in international relations, Barbados announced plans to establish a digital embassy within Decentraland (IEEE 2022). Finally, recognizing the critical need for technical harmonization, international standards organizations (including the ITU, IEEE, and W3C) are accelerating efforts to publish global data and interoperability protocols for blockchain systems (Wang et al., 2023).

2.3. Legal and Ethical Dimensions of the Metaverse

The emergence of the metaverse necessitates a paradigm shift in how we perceive the intersection of law and ethics within digital environments. Rather than treating legal frameworks and ethical principles as distinct entities, the metaverse requires an integrated system of "Metavethics", a field dedicated to studying the moral and socio-technical implications of human behavior in immersive spaces (Zallio and Clarkson, 2023). This approach demands a human-centric foundation, moving away from the exploitative tendencies of early Information and Communication Technology (ICT) platforms toward a model of "smart regulation." Such a model relies on independent empirical data and interdisciplinary expertise (spanning computer science, philosophy, sociology, and economics) to ensure that public policy remains as dynamic and adaptable as the technology it aims to govern.

A central challenge in this landscape is the erosion of the boundary between physical and digital identity. The legal status of avatars remains a subject of intense debate, as the anonymity afforded by virtual representation often facilitates malicious behavior, ranging from identity theft to sophisticated impersonation attacks (Cheong, 2022; Dwivedi et al., 2022). The capture of biometric identifiers (the digital conversion of unique physical traits such as facial patterns and vocal signatures) raises profound concerns regarding human dignity and autonomy. As these identifiers are intrinsic to the individual's physical self, their digitization and potential misuse within the metaverse constitute a direct threat to personal integrity (European Parliament, 2023). This vulnerability is further exacerbated by the rise of AI-driven "Deepfakes," which can manipulate reputation, disseminate misinformation, or even facilitate sexual harassment, placing both individuals and organizations at significant risk (Awadallah et al., 2023, Tariq et al., 2023).

These systemic risks have led to the conceptualization of the "Darkverse," a term describing the manifestation of organized crime and harmful activities within virtual ecosystems (Dwivedi et al., 2023). Addressing these systemic vulnerabilities requires moving beyond traditional frameworks. Recent scholarship emphasizes the necessity of an "electronic jurisdiction" to regulate public relations in the meta-universe and establish new branches of digital law (Kostenko et al., 2022).

The immersive nature of the metaverse, which integrates multisensory stimuli and records emotional responses, introduces unprecedented opportunities for psychological manipulation. Regulatory bodies, including the Council of the European Union (2022a), have expressed concern that existing frameworks are currently ill-equipped to handle such immersive threats, particularly regarding the influence of violent extremism and the sensory-emotional exploitation of users. To mitigate these dangers, a coordinated international effort is required to establish non-discriminatory standards that respect fundamental human rights while ensuring a secure and inclusive digital environment.

Finally, the governance of the metaverse must address the profound complexities of digital ownership and intellectual property. The current legal uncertainty surrounding cryptographic assets and Non-Fungible Tokens (NFTs) presents significant vulnerabilities. In many cases, NFT ownership confers only a fractional right to claim a digital asset, lacking the traditional protections associated with physical property. Moreover, the artificial scarcity required to maintain the value of digital goods, coupled with the susceptibility of blockchain platforms to cyberattacks, underscores the inadequacy of current intellectual property laws. Addressing these gaps requires a legal evolution—one that harmonizes the principles of secure asset management with the unique demands of a decentralized, real-time 3D economy (Belk et al., 2022; Dwivedi et al., 2022).

While issues of digital identity and intellectual property present significant legal hurdles, perhaps the most profound ethical disruption in the metaverse stems from its multisensory integration. As virtual environments increasingly engage senses that directly trigger emotional and subconscious responses (most notably olfaction) the need to reevaluate existing ethical guidelines becomes critical. This specific intersection of immersive sensory technology and emotional manipulation exposes a significant blind spot in current governance frameworks, setting the stage for a targeted examination of digital olfaction.

2.4. Biometric and Sensory Data: Regulatory Gaps and Conceptual Intersections

The metaverse, as the next evolutionary step of the Internet, is designed to facilitate real-time 3D content and immersive experiences. However, the integration of digital olfaction introduces a novel category of information: olfactory data, which currently exists within a significant regulatory vacuum. At present, there is no direct, comprehensive legal framework specifically targeting multisensory data. Nevertheless, general data protection and privacy regulations, such as those in China, the European Union's General Data Protection Regulation (GDPR), and the United States, influence the collection, processing, and utilization of multisensory information, particularly when it involves personal or sensitive data. These legal regimes mandate transparency and explicit consent, thereby shaping industries that leverage multisensory data for personalized services (Sun et al., 2023).

In industrial and manufacturing contexts, multisensory data governance relies primarily on internal policies and best practices rather than explicit external mandates (Wei and Ye, 2023; Huang et al., 2020). In specialized fields, such as pharmaceuticals, research indicates a lack of unified standards for sensory data derived from human evaluation studies (Clapham et al., 2023). Similarly, in food science, best practices are emerging based on the FAIR principles (Findable, Accessible, Interoperable, Reusable), though these have yet to be codified into formal regulations (Visalli et al., 2023). Furthermore, the deployment of sensory technologies in workplaces and IoT devices raises substantial privacy concerns; while privacy policies serve as the primary disclosure mechanism, their clarity remains inconsistent (Moore and Piwek, 2017).

While subsequent sections focus extensively on biometric data, reflecting its status as a primary subject of institutional and regulatory debate, it is essential to note that existing regulatory mechanisms can be extended to encompass sensory data. Although international literature and legislation refer less explicitly to data generated by sensory interfaces (e.g., olfaction, haptics, or multisensory integration), the prevailing frameworks are structurally analogous, allowing for a direct transfer of knowledge and practices. Consequently, the core principles of biometric protection (transparency, consent, data minimization, purpose limitation, and accountability), should serve as the normative foundation for the institutional management of data produced by multisensory technologies.

More broadly, biometric data refers to measurable biological and behavioral characteristics used for identification or authentication, such as fingerprints, facial features, heart rate, gait, and EEG signals (Khan et al., 2020; Tatar 2023). Conversely, sensory data encompasses information collected via sensors, including physiological signals (e.g., body temperature, heart rate) and behavioral responses (Fuentes et al., 2018; Persiani et al., 2021). The broader field of sensory digitization recognizes the potential of utilizing olfactory, visual, and haptic signals for biometric and cybernetic applications (Zhao et al., 2024). However, a critical distinction remains: sensory data does not inherently constitute biometric data. It is classified as such only when utilized for the unique identification or verification of individuals based on their physiological or behavioral traits (Chaki et al., 2019; Persiani et al., 2021).

Beyond national frameworks, UN agencies like the UNHCR and WFP utilize biometric data for refugee registration and humanitarian aid, creating complex legal environments where national security objectives frequently intersect with privacy and civil liberties (Açıkyıldız, 2024a; Wilson et al., 2022). To prevent arbitrary or disproportionate privacy infringements, the UN Special Rapporteur on human rights and counter-terrorism has repeatedly stressed the necessity of embedding the rule of law within these systems (Huszti-Orbán and Ní Aoláin, 2020), particularly because biometric data represent unique, irreversible traits highly vulnerable to cyber breaches (Hardyanthi, 2024). In parallel, the Council of Europe's Convention 108 (modernized in 2018) establishes a globally inclusive binding framework that explicitly treats biometric and genetic data as sensitive categories requiring heightened safeguards, effectively bridging universal UN human rights principles with specialized regional tools (Council of Europe, 2018a).

The digitization of unique physical traits leads to an unprecedented "datafication" of the human body, directly impacting bodily and digital integrity (Wendehorst and Duller, 2021). The regulatory landscape struggles to keep pace with these advancements. While the GDPR strictly regulates traditional biometrics, a significant ambiguity exists regarding sensory data that reveal emotional states—termed "cognitive biometrics"—which may not directly identify an individual but can expose profound psychological profiles (Magee, Ienca and Farahany, 2024; UNESCO, 2024). The UNESCO draft recommendation explicitly recognizes cognitive biometrics as capable of revealing volitional and emotional states, demanding strict adherence to mental privacy as a fundamental human right. Furthermore, in the United States, the Federal Trade Commission (FTC) has explicitly warned that the misuse of biometric and sensory data poses severe risks of manipulation (Federal Trade Commission, 2023).

2.5. The European Union Regulatory Landscape

The advent of the metaverse introduces new definitions of citizenship, such as "algorithmic" citizenship, linking social roles to digital proficiency (Şahin, 2023). To ensure an inclusive society, the European Commission has proposed a set of digital rights and principles supplementing the EU Charter of Fundamental Rights. Through initiatives like the "European Citizens' Panel on Virtual Worlds," the EU has established guiding principles emphasizing human-centric design, health, sustainability, and transparency (European Commission, 2023).

The GDPR (Regulation (EU) 2016/679) remains the cornerstone of the EU's legal framework. While it does not explicitly reference digital olfaction, its scope encompasses any technological means used to collect personal data. Under the GDPR, "biometric data" is strictly defined as data resulting from specific technical processing of physical or behavioral traits that confirm unique identification. In this context, data generated by sensory interfaces—such as scent profiles linked to a user's biochemical or psycho-emotional state—can be classified under these sensitive categories. Central to this framework is Article 9, which generally prohibits the processing of special categories of data unless explicit consent is obtained. Given the high psychophysiological risks associated with immersive technologies, Article 35 mandates a Data Protection Impact Assessment (DPIA) prior to processing (Regulation 2016/679, p. 54). This framework is structurally reinforced by core principles including transparency and data minimization (Article 5), information obligations (Article 13), the right to erasure (Article 17), and the right to object (Article 21).

However, the immersive nature of the metaverse introduces complexities that transcend traditional data protection. Crucially, the Council of the European Union's document ST 9292/2022 explicitly addresses multisensory immersion, warning that: *"In the coming years, technological developments will enhance this immersive experience, in particular through the integration of additional sensory mechanisms, such as an olfactory sensor"* (Council of the European Union, 2022c, p. 3). The Council warns that real-time tracking of emotions via headsets or sensory 'captors' could allow malicious actors to manipulate individuals, exposing severe gaps in current frameworks like the Digital Services Act (DSA) and Digital Markets Act (DMA).

This regulatory void is further acknowledged by the European Parliament's January 2024 Resolution, which notes that *"VR sensor data are as uniquely identifiable as a fingerprint and can be used to extract information about users' personality... mental state and emotions"* (European Parliament, 2024). Contemporary academic research supports this institutional concern. Tu and de Castro e Silva (2025) argue that specialized safeguards are required for the unique behavioral data generated within the metaverse, while Hine et al. (2024) conclude that significant legislative gaps remain in immersive governance. Consequently, until formal legislation catches up with the IoS, embedding stringent ethical design principles directly into metaverse interfaces remains imperative.

3. Multisensory Experiences

3.1. Designing Multisensory Experiences

Multisensory experiences undergo a profound transformation through XR technologies as they traverse the Reality-Virtuality Continuum. Within this spectrum, sensory elements may be purely physical (fully real), digital (fully virtual), or a hybrid of both (Mixed Reality - MR). Despite technological progress, several critical questions in multisensory design remain open. These include the engineering of task-specific devices, the correlation between stimulation mechanisms and resulting user reactions, the seamless integration of stimuli into the narrative, and the personalization of experiences based on individual and cultural differences (Velasco and Obrist, 2021).

Multisensory experiences can be positioned anywhere along the reality-virtuality axis. In some immersive scenarios, technology operates discretely in the background, while in others, it remains overt (Velasco and Obrist, 2020). Unlike spontaneous everyday occurrences, multisensory experiences are characterized by intentionality, implying a rigorous underlying design process. However, the senses constitute a "messy," heterogeneous, and complex assembly of multi-level interactions. Depending on the design objectives, it is necessary to isolate patterns of sensory unity and coherence. This requires a nuanced understanding of "sensory measure", the interactions between different senses (cross-modal correspondences) and the unique attributes that make individual senses significant. For example, replicating a walk in a forest requires a landscape architect to carefully integrate diverse sensory inputs to reconstruct the holistic essence of the event (Obrist, 2021).

While the AI Act indirectly addresses sensory components, a more targeted ethical approach is required for multisensory interactions. Recognizing these challenges, Velasco and Obrist (2021) formulated the Three Laws of Multisensory Experiences, drawing inspiration from Asimov's laws of robotics to provide a foundational ethical framework:

- The Law of Beneficence (Do No Harm): Multisensory experiences must be designed for the greater good and must not inflict harm. Designers bear an ethical responsibility to ensure that sensory inputs are not weaponized for subconscious exploitation or behavioral manipulation.
- The Law of Justice and Agency: Users must be treated fairly, and experiences should be inclusive, catering to diverse groups (e.g., the elderly, children, and different cultural backgrounds). Furthermore, the user must not be a passive recipient but must maintain agency (the ability to influence and control their own experience).
- The Law of Transparency: Both the creator of the experience and the specific sensory elements employed must be disclosed to the user. Especially in VR/AR environments, users must be aware of who controls the environment and which specific stimuli (visual, auditory, olfactory) they are receiving, upholding the principle of informed transparency.

Building upon the comprehensive theoretical framework of multisensory integration developed earlier, it becomes clear that the senses in the metaverse do not operate in isolation but as a unified, interconnected system. Consequently, the "Three Laws of Multisensory Experiences" by Velasco and Obrist (2021) align directly with the conclusions of this study, confirming that design intentionality must treat the IoS not as a mere summation of stimuli, but as a cohesive landscape of perceptual interactions (Fulkerson, 2013).

At this juncture, participatory and inclusive design emerges as a primary tool for ethical governance. As documented by Panagiotakopoulos, Cheirchanteri, and Tzortzi (2025), the active involvement of users in the co-creation of multisensory environments ensures that emerging technologies are developed with a focus on inclusion, transparency, and respect for human autonomy, thus preventing passive exposure to unchecked sensory channels.

3.2. Design Framework: Core Principles for Digital Olfaction

While the three laws proposed by Velasco and Obrist (2021) establish a broad philosophical and ethical foundation, their practical application in Graphical User Interface (GUI) construction requires a specialized design model, particularly due to the unique challenges of digital olfaction. As Kaye (2004) pointed out, olfaction is an exceptionally complex sense that is technologically difficult to control due to five inherent factors: categorization issues, intensity control, rapid olfactory fatigue, chemical complexity, and intense subjectivity in perception.

To address these specific practical barriers and drawing upon earlier empirical research, this study proposes an Ethical UX Design Framework. Unlike general governance rules, the proposed framework directly translates ethical considerations into User Interface (UI) mechanics:

- **Visualization of Invisible Interaction:** The lack of a visible odor source creates risks of subconscious manipulation. The system's GUI must continuously visualize when an odor is emitted, its origin, and its chemical identity (e.g., via radar charts, as demonstrated in earlier experimental setups), thereby converting invisible chemical information into comprehensible visual data.
- **Explicit Consent Mechanisms and Stop Controls:** Unlike audiovisual content, odor physically enters the user's body. The interface must feature strict opt-in settings for receiving olfactory files, as well as prominent, immediate "kill switch" controls to halt diffusion in cases of allergic reactions or psychological distress.
- **Prevention of Olfactory Overload:** Addressing the rapid olfactory fatigue identified by Kaye (2004), the software must incorporate algorithmic constraints. The system should enforce minimum time intervals between scent bursts and include mechanisms to regulate the intensity of molecular concentration, thus protecting the user from overstimulation.
- **Cross-Cultural Odor Mapping:** The graphical environment for scent selection—such as the "MetaScent Toolkit," a conceptual spatial user interface framework proposed by the author—must enable the categorization of odors based not only on their chemical composition but also on their cultural contexts. Scents associated with sacred or socially sensitive contexts across different cultures must carry specific warning labels.

3.3. International Standardization and Multilevel Governance

One of the most critical observations derived from the design process is the complete absence of a universally recognized visual language for digital olfaction. As highlighted by empirical research and user interface (UI/GUI) usability testing, relying on a simple icon such as a "nose" remains highly ambiguous for users. This ambiguity introduces significant cognitive confusion regarding whether the icon represents an activation command or merely a sensor status indicator.

Consequently, there is an urgent need for international standardization bodies to develop a standardized set of olfactory glyphs—analogous to a "Unicode for scents"—to unify the visual lexicon of multisensory interfaces globally and enhance interaction transparency. Concurrently, traditional regulatory approaches prove insufficient in capturing the complex dynamics of immersive environments, rendering multilevel governance frameworks indispensable (Al-Kfairy et al., 2025). Achieving global regulatory convergence is crucial to striking a sustainable balance between technological innovation and the protection of fundamental human rights on an international scale (Helbing et al., 2024).

3.4. Accessibility and Inclusion

This research also revealed a significant gap in accessibility, as current systems rely almost exclusively on text labels, thereby inadvertently excluding users with anosmia. Future GUIs must align with international Web Content Accessibility Guidelines (WCAG) for inclusive design, offering alternative modalities for perceiving scents. Drawing upon empirical qualitative data and design proposals, this study proposes the use of diagrams to visualize the chemical profile of an odor, utilizing axes that describe characteristics such as "sweet," "woody," or "spicy." This approach enables users to cognitively "see" and comprehend the olfactory stimulus, even if they cannot physically experience it due to anosmia. Concurrently, digital olfaction can serve as a valuable supplementary navigational channel for individuals with visual or auditory impairments, enhancing their overall immersion and autonomy within the digital space. This aligns seamlessly with the core principles of participatory design for an inclusive metaverse (Panagiotakopoulos, Cheirchanteri, and Tzortzi, 2025).

4. Discussion

The implementation of the aforementioned principles is intended to serve as a shield against a range of emerging ethical and social challenges. A central issue in this context is the emergence of the so-called "Darkverse" and the risk of emotional manipulation. The absence of an adequate regulatory framework for multisensory experiences (including olfaction) leaves room for malicious practices. This process renders the user vulnerable to subconscious psychological influence, while the appearance of "digitally altered odors" enhances the possibility of deception or severe disorientation within the virtual space.

The dimension of health and safety in these environments necessitates the establishment of strict medical protocols. Beyond the common symptoms of nausea or allergies, specific olfactory stimuli may act as "triggers" for episodes of post-traumatic stress disorder (PTSD) or anxiety attacks. Consequently, ethical governance is essential to prevent involuntary exposure to harmful stimuli, particularly in environments with a therapeutic orientation, such as digital aromatherapy.

Alongside physiological risks, critical issues of accountability, cybersecurity, and ownership arise. As olfactory data and corresponding cognitive reactions are susceptible to interception, the need for advanced encryption technologies and the use of specialized protocols becomes imperative. The existing legal vacuum regarding civil liability in cases of harm (e.g., an allergic crisis or the exertion of intense psychological pressure) complicates the situation. The complexity of the interaction between software providers, content creators, and hardware manufacturers mandates the adoption of a "shared responsibility model." Additionally, the digitization of the sense of smell introduces new questions regarding intellectual property: the use of NFTs to secure olfactory profiles creates technical and legal challenges concerning the management of scarcity, authenticity, and fractional ownership of digital assets.

Behind the management of such multisensory data often lie AI systems, whose applications are particularly concerning if not properly regulated. These systems can negatively impact human rights and the rule of law, causing phenomena of discrimination, privacy violations, and extensive surveillance (Nagy, 2024). The use of AI in decision-making processes carries serious risks, as it often masks responsibility and undermines traditional accountability mechanisms (Land and Aronson, 2018). At the same time, human bio-enhancement technologies necessitate a revision of international human rights law to protect individual dignity in new technological environments, maintaining a consistent ethical and deontological stance (Terec-Vlad, 2022).

More broadly, these technological innovations bear a dual nature: on one hand, they enhance the ability to record and report human rights violations by facilitating mass mobilization (Homberg and Möckel, 2022); on the other hand, they can strengthen authoritarian control (Dragu and Lupu, 2021). Consequently, regulators and human rights experts must carefully balance the risks and benefits arising from their utilization (Land and Aronson, 2018).

To overcome these challenges, simple legislative compliance is insufficient. The adoption of Participatory Design (PD) methods is also required as a structural element for the creation of an inclusive metaverse. Within the context of multisensory experiences, the role of the designer is transformed. The designer now assumes the role of an "ethical mediator," tasked with bridging technological capabilities with local cultural narratives and community values. Through this prism, the design of digital olfaction ceases to be merely a technical process driven by corporate monopolies and becomes a democratic, co-creative act that respects cultural pluralism and protects the user's cognitive liberty (Panagiotakopoulos, Cheirchanteri, and Tzortzi, 2025).

Crucially, a human-centric metaverse must not overlook accessibility. Current digital olfaction systems rely heavily on text labels, inadvertently excluding individuals with anosmia. Aligning GUIs with WCAG and utilizing visual diagrams to map chemical profiles (e.g., "sweet," "woody") ensures that users can cognitively comprehend olfactory stimuli even if they cannot physically perceive them. This approach transforms digital olfaction into an inclusive navigational channel for all users.

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